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A farmer-led approach to changing practice around antimicrobial use on UK dairy farms

Lisa Morgans[1], Sarah Bolt[2], Maria Paula Escobar[1],Henry Buller[3], David CJ Main[2] and Kristen R Reyher[1]

[1] Bristol Vet School, University of Bristol, Langford, Bristol, BS40 5DU

[2] Kingshay Consultancy Ltd

[3] Royal Agricultural University, Cirencester, Gloucestershire, GL7 6JS

[4] University of Exeter

Supervisor: Dr Kristen R Reyher

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CONTENTS

1. Abstract

Despite increasing pressure to reduce antimicrobial use (AMU), many UK dairy farms still rely on antimicrobials to maintain a healthy herd. This research aimed to assess the potential of peer-to-peer support through Farmer Action Groups (FAGs) to achieve practical, farmer-led changes to reduce AMU and improve herd health and welfare.

FAGs - based on the 'Stable Schools' model used widely in Denmark - harnessed local-level experience and expertise to solve the challenge of reducing AMU. Five FAGs were established across South West England, each made up of 5-8 dairy farms that met approximately every 6 weeks to discuss medicine usage. Thirty diverse dairy farms participated in the study over 2 years. Meetings involved a farm walk and facilitated discussion, all of which were audio recorded for qualitative analysis. Medicine reviews were carried out on each farm at the start and end of the project to assess any change in AMU and to benchmark farms. The outcome of each meeting was a co-produced Action Plan for the host farm of practical measures to achieve the goal of antimicrobial reduction without adverse impacts on herd health and welfare. Each farm and their Action Plan were re-visited at a second meeting 8-12 months later to evaluate any changes.

All farms implemented at least one recommendation from their Action Plan by the second meeting and on the average Action Plan, 54.3% of recommendations were implemented. Many recommendations were still ongoing at the end of the study. The majority of participating farms (n=27) reduced or eliminated use of highest priority critically important antimicrobials (HPCIAs) over the 2 years. Participants spoke highly of the project and benefited from the sharing of knowledge at each meeting. The exchange of knowledge on medicine use and herd health during the farm walks and facilitated discussions empowered farmers to change practices; they gained confidence from the group learning experience. The FAGs developed a sense of solidarity from going through a process of change together. A key component of this was the role of the facilitator in guiding the groups and supporting the knowledge mobilisation. Moreover, knowledge gaps were identified by the participating farmers regarding how their practices around AMU could contribute to AMR, the different types of antimicrobials used and particularly which were HPCIAs. This highlighted a lack of collaboration between veterinarians and farmers at the time of the study. Consequently, the project stimulated an increase in herd health discussions between farmers and veterinarians as a result of the knowledge mobilisation in the FAGs.

In conclusion, a farmer-led approach was successful in supporting and encouraging a change in practice around AMU on all participating dairy farms. The knowledge generated in the

participatory group environment contributed to a shift away from HPCIAs. There is potential for this approach to be scaled-up across the country. Funding for facilitation that can be readily accessed by farmers and training facilitators to support new groups is a primary proposal that has emerged from this research.

2. Introduction

AMR is a momentous global concern with estimates predicting that by 2050, 10 million people a year could be dying from drug-resistant infections such as tuberculosis (World Health Organisation, 2018). AMR is not a new problem and reports from as early as 1969 warned about the impending crisis from the overuse and misuse of antimicrobials (Kirchhelle, 2018). There is much debate about the transmission routes of AMR and the role agriculture plays in perpetuating the problem (Finley et al., 2013, Collignon, 2015, Horigan et al., 2016, Tang et al., 2017). This was the global challenge which acted as the trigger for this research and has prompted many authorities and policy makers to search for novel tools and strategies to avoid an antibiotic apocalypse (O'Neill, 2015).

Reducing the overuse and misuse of antimicrobials is of the utmost importance in the fight to slow the development of antimicrobial resistance (AMR; World Health Organization, 2018). Antimicrobials are commonly used to treat food-producing animals in the UK and there is a risk that their use in farming drives resistance in human health (Heuer et al., 2006, Knetsch et al., 2014, B.A. Wall, 2016, O'Neill, 2015). Consequently, in recent years there has been increasing pressure on the farming industry to demonstrate responsible AMU (O'Neill, 2015). To do this, interventions to change how antimicrobials are used and to reduce the need for their use are becoming increasingly important (Speksnijder et al., 2015b, Collignon, 2015, Scott et al., 2015). This requires considering on-farm interventions which influence and change practices around use of antimicrobials and prevention of disease. Reducing levels of disease and improving animal health can have an indirect impact on reducing AMU and forms the basis of the World Health Organisation's Global AMR Action Plan (Organization, 2015). This thesis proposes an innovative approach to changing farm practices around disease prevention and AMU in the UK dairy sector. The research is funded by the Agriculture and Horticulture Development Board for Dairy who have a direct interest in the approach and its outcome as a knowledge exchange organisation.

There has been extensive work examining farmer behaviour and influencing practices on farms. Many interventions have focussed on a top-down approach, either through regulation, legislation or traditional agricultural extension methods. Although previous and existing interventions have been successful in part at changing farm practices (e.g. outlawing the battery cage in poultry farming and the Dutch reductions in AMU in farming after government involvement), these have also revealed gaps in the ability to encourage long-lasting changes that farmers value and therefore fully embrace (Speksnijder et al., 2015a).

The sustainability of top-down approaches, to include advisor-led initiatives, in creating a change in practice on farm is variable. They can be unpopular (Escobar and Demeritt, 2016), poorly adhered to (Down et al., 2016) or lead to unintended consequences (Barnes et al., 2013). Part of the problem is the movement of expertise and knowledge in a unidirectional way; this passive transfer of knowledge and technical expertise has been called into question in recent years (Chambers and Ghildyal, 1985, Lacy, 2011, Pretty, 1995). It has also been recognised by the World Bank and others that long-lasting sustainable changes in farming are not possible without farmer participation in their development (Conroy, 2005)). Furthermore, the "one size fits all" method of giving advice to elicit behaviour change has been shown to be flawed by many studies (Kristensen and Enevoldsen, 2008, Vaarst et al., 2001, Bradley, 2013) and has a role to play in the poor uptake of veterinarian advice on farm (Jansen et al., 2010). Examples to support this are farmer attitudes towards and outcomes of disease eradication schemes, such as Johnes control (Ritter et al., 2016) and to veterinary herd health planning (Jansen et al., 2010, Derks et al., 2014). A fresh approach to creating change on farm is necessary and there are many disciplines that can contribute knowledge to this area, such as the field of human behaviour. There is increasing literature calling for more participatory, bottom-up approaches to change farm practices (Barnes et al., 2013, Rose et al., 2018) with farmers taking ownership of the problems and solutions. This is in combination with a growing recognition that for complex challenges with multiple factors and interacting stakeholders, innovative solutions and insights from disciplines such as the social sciences are needed (Burton, 2004, Escobar; and Buller;, 2013, Dijk et al., 2017).

An essential element in many participatory approaches is the role of facilitation. There are a number of contemporary examples that have documented the importance of a facilitator (FAO and the Farmer Field Promotion Services, 2013, Fioret et al., 2018, Dijk et al., 2017) and their pivotal part in establishing and supporting groups going through a process of change (Brogue, 2013, van Dijk et al., 2017, Conroy, 2005).This study was helped significantly by the inclusion of an AHDB Dairy facilitator – the facilitator played a key part in supporting knowledge mobilisation, co-ordinating participatory activities to build commonality and guiding farmers through the learning journey, which has contributed to the success of a bottom-up approach to reduce reliance on antimicrobials. Moreover, the AHDB Dairy facilitator had a huge part to play in recruiting farms to the study by acting as a familiar and respected community member (more on this can be found in the author's thesis).

This research supports the principle that farmers have a wealth of experience relevant to the challenges they face on farm and an expertise that should be recognised. Farmers possess valid knowledge related to their farming context, which is vital for generating practical, long-

term solutions (Cornwall and Jewkes, 1995). One example initiative that successfully harnessed farmer knowledge to solve a complex challenge was the Stable School model (Bennedsgaard et al., 2010). This began as a farmer-led project to reduce AMU on organic dairy farms in Denmark (Vaarst et al., 2006). The Stable Schools were inspired by Farmer Field Schools (Vaarst et al., 2007b) and involved small groups of dairy farmers meeting on each other's farms to share common experiences. The meetings would involve a farmer-led farm walk and each attendee would contribute a positive comment and a recommendation for the host farm to work on to achieve a reduction in AMU. The Stable Schools helped participant farmers improve the way they farmed to reduce the use of antimicrobials (Vaarst et al., 2007b). These farmers demonstrated a 50% reduction in treatments with no detriment to animal health and welfare; the approach was consequently adopted into Danish agriculture policy as part of the obligatory animal health planning service (Vaarst and Fisker, 2013). This research explores how a similar approach works in the UK and how it could be scaled-up.

The Stable Schools were adapted specifically for this study and re-named Farmer Action Groups (FAGs). Five FAGs were established for the research and followed over the course of two years. Investigation into how the FAGs helped support farmers and the changes in practice that followed are the focus of this research. This study has revealed three main determinants for the adoptability of such an approach in the UK, which are explored in depth. These were: recruitment ease, degree of participation and level of action through the process of Action Planning. Recruiting and engaging farmers in a bottom-up initiative such as the FAGs benefits from optimising existing networks and pivotal community members. The use of Gate-keepers to access the farming community and improve recruitment outcomes was prioritised for this study. Gate-keepers were firstly, veterinarians due to their close relationship with farmers (Lowe, 2009, Enticott et al., 2011, Atkinson, 2010) and AHDB Dairy due to their extensive existing contacts in the industry. Participation in the study was characterised by the development of a spirit of solidarity between farmers and the mobilisation of knowledge, which was supported by facilitation. Understanding how knowledge is generated in such a project and how it is mobilised helps support changes to practice on farm. Also highlighted were concerns within the veterinary profession about farmer knowledge, which came to light during recruitment. Presentation and discussion of the latter can be found in the author's thesis.

This research builds on our knowledge of participatory interventions. Its aim is to improve our understanding of how to effectively support farmers through a process of change. The findings have implications for others designing and implementing farmer-led initiatives. The focus on knowledge mobilisation and ensuring farmers have relevant knowledge at their finger-tips is a key finding. The importance of fostering a sense of solidarity in a farmer-led project is shown

to have wide-ranging benefits. FAGs demonstrated the power of a bottom-up project in encouraging changes to farm practice (particularly around disease prevention) and the opportunity it gave participants to improve. This project aimed to empower farmers and succeeded in improving their confidence and capacity to change their practices. This research will be of importance to policy makers formulating future agriculture policy on knowledge exchange, farming practice and antimicrobial stewardship (AMS).

2.1. Research Aims

A combination of quantitative and qualitative data - collected via the framework of a Participatory Action Research methodology - has been used in this research to answer the following research questions:

What lessons can be learnt from the experiences of adopting the Stable School model in the UK

1. To encourage changes in practice on farm
2. To reduce the use of and need for antimicrobials
3. To replicate the approach on a wider-scale?

This research aimed to not only enhance our understanding on farmer-led approaches and participatory interventions on farm but to directly influence policy in this area.

Although this research has earnt the label of a participatory intervention in that it aimed to support changes to farm practice, it was not a randomized, controlled intervention trial. This research does not attempt to compare the participatory approach with other types of interventions in an empirical way. Instead, this research seeks to understand how to support changes in practice on farms and how the FAG approach could be applied on a wider scale. The study aimed to triangulate its findings by collecting data in multiple ways, using qualitative and quantitative techniques, and to learn how the approach helped participating farmers reduce the use of and need for antimicrobials. The determinants of this method's adoptability will add to knowledge on evaluating participatory interventions.

3. Methodology and Methods

3.1. Methodology

3.1.1. Conceptual framework

The framework used to conduct this research was Participatory Action Research (PAR); data was generated by an active participatory approach. The results have also been interpreted through the lens of participation and the effect participation has had on a change in practices around responsible AMU in dairy farming. Key elements of a PAR methodology adapted for this research included co-setting agendas, practical goal-orientated action on reducing AMU, mobilising knowledge in innovative ways to help initiate change and facilitating and fostering a sense of solidarity and community when changing practices on farm.

One succinct definition of PAR is given below;

> *"PAR seeks to understand and improve the world by changing it. At its heart is collective, self-reflective inquiry that researchers and participants undertake, so they can understand and improve upon the practices in which they participate and the situations in which they find themselves. The reflective process is directly linked to action, influenced by understanding of history, culture, and local context and embedded in social relationships. The process of PAR should be empowering and lead to people having increased control over their lives" (Baum et al., 2006)*

An important aspect of PAR is empowerment for those going through a process of change. PAR aims to enable a community to decide on its own problems and work together to find solutions to those shared problems. The FAGs were designed with these key principles in mind and aimed to foster a sense of collective action between farmers, so they could share best practice and embolden each other to implement changes on farm. The operationalisation of the FAGs could be seen as a form of community organising and is a necessary step in assisting a community on a process of change (Stoecker, 2012).

Without this process of community organising (which is part of the job of a facilitator), it is argued action can not readily follow. Goal setting (i.e. reducing AMU) and rational planning (systematic visits to farms to enable knowledge exchange) are parts of enabling an environment of participation so that action can occur (Stoecker, 2012). Once this is achieved, participants can have a dominant decision-making role, labelled as 'Delegated Power', which is one of the upper echelons of the participatory ladder (Arnstein, 1969). On the other hand, community organising could be seen as a key criticism of these approaches for not being truly participatory and farmer-led due to the involvement of external actors (in this research, the

facilitators). It is the view of the author that external actors such as facilitators are, in fact, integral members of a multi-actor group, demonstrated in the Hennovation project and many other EIP AGRI programmes (Dijk et al., 2017). External knowledge and experience is part of vernacular expertise, as described in rural development by Lowe and authors (Lowe et al., 2019) . As such, their role enhances and supports any action on farm, which is the result of a PAR methodology.

An example of PAR in action are Farmer Field Schools (FFS), now known as Pastoralist Field Schools (FAO and the Farmer Field Promotion Services, 2013). FFS work on the basis of farmer-led experiential discovery. With the help of a facilitator, farmers/pastoralists collectively improve the way they farm through a bottom-up philosophy. Small groups trial different management practices and husbandry skills and share their learning with each other over a period of time. The changes to practice are owned by the participants and are in response to challenges identified by the participants. Stable Schools, established in Denmark were inspired by the FFS model (Vaarst et al., 2007a, Vaarst et al., 2006) and were the foundation for this research.

3.1.2. Adaption of Stable Schools

Stable Schools were adapted for the UK context because of (1) differences that exist between the dairy sectors in Denmark and the UK, (2) the fact that the Stable Schools were originally focussed on only organic dairy farmers while this research involved all dairy farm systems, and (3) the challenges posed when recruiting UK dairy farms to the study.

The original Stable School design has been augmented here by:

- widening participation beyond one milk pool,
- use of AHDB Dairy contacts as primary recruitment method,
- decreasing frequency of meetings,
- having a veterinary researcher and facilitator present to support Phase One meetings,
- restricting travel time to meetings for farmers within a group by keeping each FAG within a limited geographical area,
- adding in discussion tool activities to maintain engagement, and
- using medicine reviews and benchmarking as a ‘carrot’ for signing-up to the project and measuring progress, compared to collecting herd health parameters using a centralised database like DANMAP (Bennedsgaard et al., 2010).

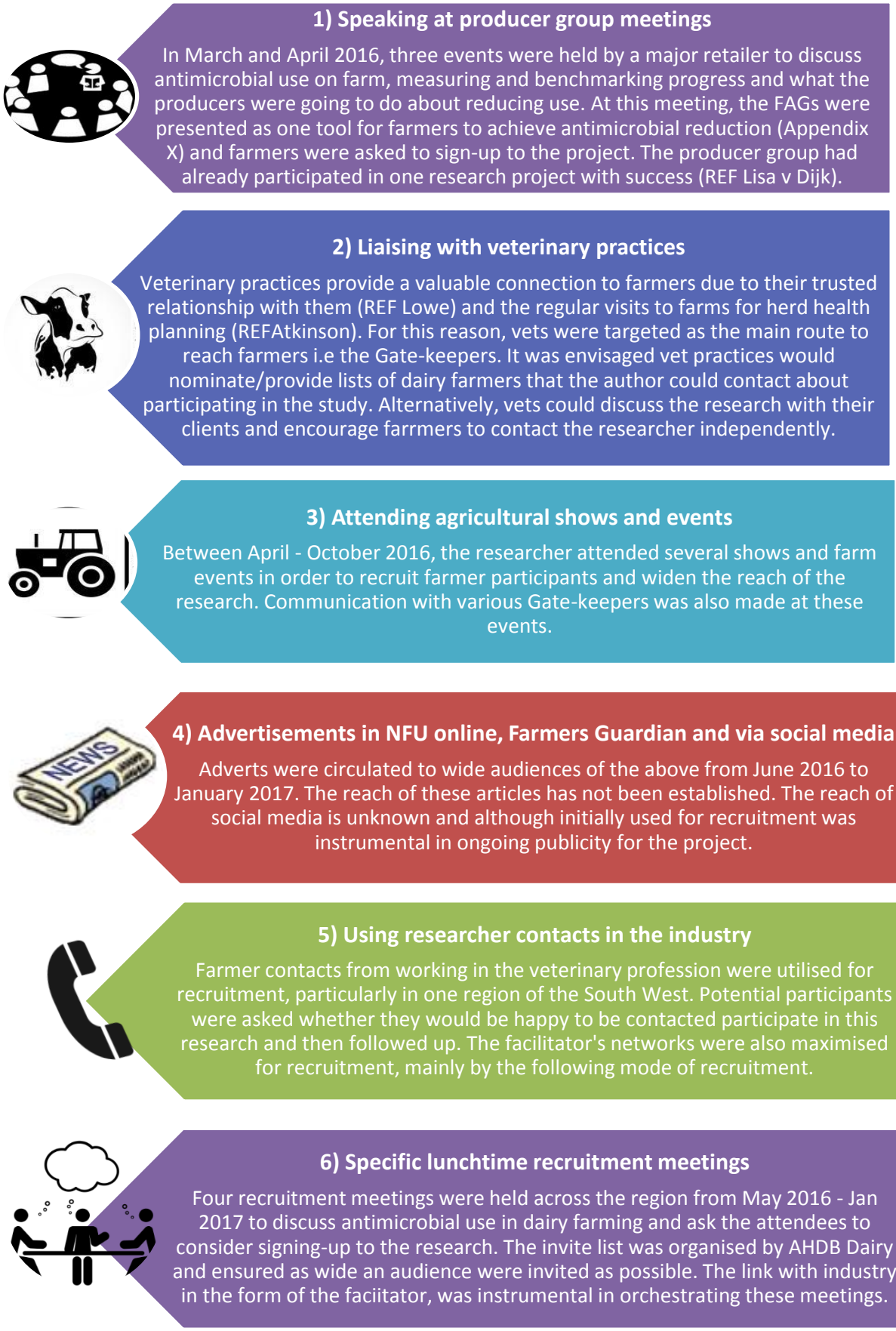
3.1.3. Recruitment

Recruitment was approached in a multi-pronged fashion to maximise the number of potential participants reached and to reduce bias (for approach see Figure one). The use of Gate-keepers was adopted as a method of recruitment for this project because of the realisation that the target group of dairy farmers could be hard-to-access; the researcher was based in an academic institute with little day-to-day contact with the target audience. The Gate-keepers for this project were primarily veterinarians and AHDB Dairy (namely the project facilitator).

Veterinarians specialising in farm work were identified as the Gate-keepers for recruitment of dairy farms to this project, due to their close relationship with farmers and trusted position as farm advisors (Lowe, 2009, Atkinson, 2010). Veterinarians must complete an annual herd health plan for all dairy farmers as part of Red Tractor Farm Assurance standards and they are the only profession that can prescribe Prescription Only Medicines - Veterinary (POM-V; e.g. antimicrobials) to animals under their care, as stipulated by the Royal College of Veterinary Surgeons. Veterinarians are an efficient way to reach as many dairy farms as possible due to their pre-existing networks, especially those regarded as 'hard-to-reach' (Jansen et al., 2010, Ritter et al., 2017), which helps to make the recruitment process more inclusive. Thus, it is logical to assume veterinarians were appropriate Gate-keepers for this project. It was hoped veterinarians would select which farms would benefit or be interested in participating.

The outcomes from recruiting farms to this study are not covered in this report. Please refer to the author's thesis for more detail.

Figure one – The different approaches to recruitment taken as part of the FAG project



3.2. Methods

3.2.1. Operationalisation and format of the FAGs

FAGs were inspired and structured on Stable Schools implemented in Denmark (Vaarst et al., 2007b). Five FAGs were established for this study with an average of six farms in each group (range five to eight). This number was based on the Stable Schools work, which reported the optimum group size to be between five and eight farms (Vaarst et al., 2007b). This number aimed to create enough discussion and idea generation at each meeting but was not too large so as to be difficult to manage (Vaarst et al., 2007b).

The FAGs operated in two phases of meetings. In Phase One, each participant in the group hosted the rest of the group on their farm for the first time. This occurred in sequence until everyone in the group had hosted once. The order was decided upon by the group. In Phase Two, each participant hosted their group again for a second time to evaluate any changes made and reflect on any learning from the first phase. Meetings occurred approximately every four to eight weeks with frequency increasing towards the end of the project to ensure everyone participating had the chance to host their group twice on their farm.

The meetings took place from July 2016 - June 2018. The primary researcher (who is the author of this report) was present at all meetings and an external facilitator from AHDB Dairy was involved in the running of the groups in the first phase of meetings. The external facilitator was working as a Knowledge Exchange manager for the project funders at the time of the study but due to a change in circumstances was unable to facilitate the Phase Two meetings. The primary researcher took on this role in Phase Two.

There were 58 meetings in total; 60 meetings were planned but one farmer moved farms before hosting a second time and another postponed his second meeting indefinitely. Thirty farms took part for the whole period of the project and hence were included in the final analysis. The 30 farm participants were spread over the five different FAGs in different regions of South West England. Each FAG was a separate entity and the only time all 30 farm participants met each other was at a finale meeting at the end of the project (July 2018).

Phase One - Hosting

One key part of the project for each farm participant was hosting the FAG on their farm so they could showcase how they managed their herd and ask for input from a group of likeminded farmers on things they could improve. The first phase of the project involved each FAG member hosting their group for the first time. The host farmer was encouraged to lead a

farm walk and to cover all areas of farm management. They were asked to identify one to two areas they deemed to be their strong points and one to two areas they wanted to improve or saw as a challenge. These issues did not have to relate to AMU necessarily; this was partly the role of the facilitator to ask probing questions into farm practices, which is discussed later.

The key output from hosting in Phase One was the production of a farmer-led Action Plan. This was then re-visited in the Phase Two meetings. In between hosting the first and second time, the farmer participants would attend the rest of the group meetings and share ideas and knowledge on other group members' farms. Attendance at meetings was deemed crucial to the success of the project, and the primary researcher and facilitator took an active role in encouraging attendance at each meeting (such as regular emails and texts reminding participants when and where the next meeting was and inclusion of varied group activities and prizes to maintain interest). The sharing of ideas and experience between farmers, as demonstrated in the Stable Schools, would only work if there was enough 'critical mass' at each meeting (i.e. enough farmers present to share knowledge).

Facilitation

Facilitation has been shown to be a critical element in many farmer-led initiatives, such as Hennovation, Discussion groups (Dijk et al., 2017, Sherson et al., 2002, Vaarst, 2011) and a Soil Association programme called Innovative farmers (https://www.innovativefarmers.org/). Facilitators can act as knowledge brokers and have a role in inspiring confidence in participants, as well as initiating projects from the start (Main et al., 2012, Dijk et al., 2017). In Phase One of the project, an experienced facilitator was involved in the recruitment of the farm participants and the running of the meetings. The facilitator was employed by the project sponsors (AHDB Dairy) and was familiar with the Stable School methodology as she had been using it in practice with UK dairy farmers. Her role at each meeting included but was not limited to starting the meeting, ensuring everyone got to speak and was heard, keeping the group together and on time during the farm walk, asking probing questions of the farmer's practices (see examples below) and distilling the discussions around an Action Plan onto paper for the host farmer. The facilitator held farmers to account and would challenge thinking and practices frequently.

Below are a few examples of facilitator questions that occurred during meetings. These were generated spontaneously by the facilitator but were guided by the agenda that the primary researcher and host farmer co-created before the meeting (see Figure two). These questions were also in response to the discussions on the farm walk and the ideas the farmers contributed.

- Why do you think waste milk is better for calves than milk powder?
- Do you think your lame cows are in pain?
- Why do you give X for treating Y?
- What do you think is the reason for the increase in mastitis cases?
- What does the group think of this shed?
- Does the group have any thoughts on the calf rearing protocols described?

The primary researcher took on the role of facilitator in the Phase Two meetings due to the AHDB-employed facilitator having a change of circumstances. Due to the veterinary experience of the primary researcher, she had an important role to play in knowledge brokering during meetings (filling farmer-identified knowledge gaps based on veterinary knowledge on medicines) as discussed later in the report.

The synergy between the AHDB Dairy-employed facilitator and the primary researcher was an unexpected aspect of the meetings and helped to maintain engagement of farmers. Without the AHDB Dairy facilitator, the study would have failed to recruit enough farms and potentially affected the farmers participatory experience. More on this can be found in the author's thesis.

The pre-visit

As part of the operationalisation of the groups and to assist in building rapport with the farmers, the primary researcher visited each farmer participant on farm prior to them hosting for the first time. This was called the 'pre-visit' and allowed the primary researcher to not only collect relevant data pertinent to the research (i.e. medicine records, herd health parameters) but co-create an agenda with the farmer identifying areas they wanted to discuss. Building an element of trust is described in Livestock Action Research (Conroy, 2005) and Community Research (Kumar, 2002). It is crucial for building relationships for a productive learning environment, as described in Communities of Practice (Wenger, 1998).

Figure two illustrates the process the researcher went through for each farm participant in Phase One of the project. At each pre-visit, a questionnaire was completed to structure the data collection on farm (see thesis). The questionnaire aimed to capture the essential data needed to complete the medicine reviews (described later) and to collect data to track herd health parameters, as in the Stable Schools (Bennedsgaard et al., 2010). However, as discussed earlier in this report, the adaptions to the Stable School method meant that collection of herd health parameters for comparison between Years One and Two was abandoned. The validity of the UK on-farm data was considered to be poor compared to that

of the Stable Schools' DANMAP data and was deemed less valuable to the participants compared to the Medicine Review data.

Co-creation of the agenda

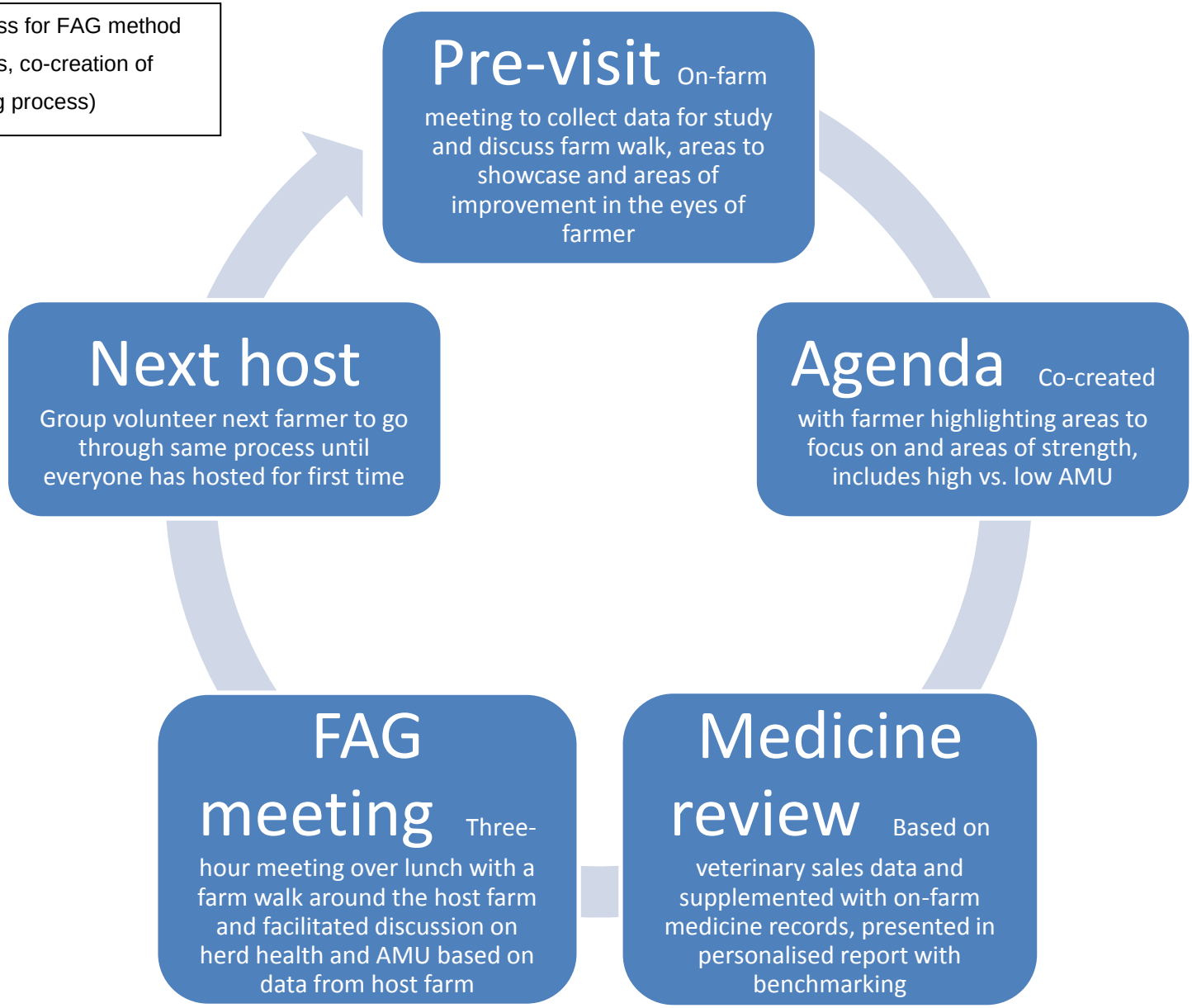
An approximate agenda was agreed with the farmer participant prior to hosting, which highlighted areas the farmer wanted to discuss with the group. The facilitator then used the agenda to help the group keep to time and to ensure she was familiar with the farmer-identified key areas and thus could frame questions accordingly (see thesis for an example agenda). The remit of the discussion was not fixed; farmers were encouraged to explore a variety of topics related to farming and herd health as well as AMU. This was steered by the farmers and quickly became apparent led to more productive discussion than keeping the focus narrowly on AMU.

Meeting format

Each meeting lasted approximately three hours, included a farm walk and ran over lunch time (11am - 2pm). This decision came from the researcher's own experiences of running farmer meetings in the dairy sector. Lunchtime meetings were between morning and afternoon milking, so fitted in with the dairy farmer schedule. The facilitator's experiences of running farmer meetings for several years also indicated this was the most appropriate time and duration. Feedback from farmers during the course of the project confirmed that this was the most convenient time for them as well. Food was provided as routine at each meeting and was a scheduled part of the meeting format; this again came from the author and facilitator's experience of running farmer meetings.

The farm walk was designed to be led by the host farmer with minimal facilitatory input (i.e. keeping the group together and asking questions pertaining to AMU if the discussion strayed off-topic for more than 10 minutes). The meeting format was similar for each farm and remained the same between Phases One and Two. The only difference was there were no 'pre-visits' in Phase Two (Figure two); this was instead replaced with a semi-structured interview to assess any changes to practice and implementation of the Action Plan.

Figure two - Process for FAG method (data collection visits, co-creation of agenda and meeting process)



'Catch-up' session

The meetings began with a group session (either indoors or in a shed) where each farmer participant either introduced themselves (if it was the first meeting) or shared with the group what had been happening on farm since the previous meeting. This was supplemented with questioning from the facilitator and primary researcher regarding any treatments or AMU. This acted as a 'catch-up' session and set the precedent for the subsequent discussion to be interactive and informal. This method of beginning a meeting has been shown to help when fostering dialogue and identifying challenges as described in Hennovation (Dijk et al., 2017) and Livestock Action Research (Kumar, 2002).

Medicine Review session

The 'catch-up' session was followed by a brief discussion (~10-15 minutes) on antimicrobials and measuring usage. This discussion focussed on the Medicine Review for each hosting farm with the data presented to the group, with the consent and prior approval of the host farmer. Benchmarking was also carried out as a tool for the group discussion. Benchmarking has been shown to be a useful tool in driving behaviour change (Snoo et al., 2010, Sumner et al., 2018, Ibrahim and Polk, 2014) and was a technique used by the author previously in veterinary practice. The primary researcher ran this session and used it to demonstrate and discuss how to measure AMU and what the provided Medicine Reviews meant. The researcher also started to introduce the topic of HPCIAs and the impending restriction on the usage of certain products in farming, stemming from the O'Neill report (O'Neill, 2015). The concept of HPCIAs had been introduced at the recruitment meetings as well, which were held prior to the FAGs commencing (see thesis for full details). This part of the meeting was initially to help explain the Medicine Reviews that the primary researcher had produced for each participant (e.g. what the different metrics meant, what was excessive or inappropriate use, what were the different medicine categories described, providing trade name examples etc.). It quickly became apparent however, that knowledge on antimicrobial classification, including HPCIAs, was lacking, and further information about this was requested by the participants. This process of reflection on what the participants wanted and required from the Medicine Review process helped the project to evolve to be as farmer-focussed as possible.

The farm walk

After the Medicine Review session, the host farmer led the group on a farm walk. This lasted approximately 60-90 minutes. In Phase One of the project, the farm walk aimed to cover the whole farm system and demonstrate to the group the environment and confines within which the host farmer was working. It was also an opportunity to showcase areas the farmer participant was proud of and areas they wanted to improve. In Phase Two, the farm walks were shorter in duration and the primary researcher asked the farmer to focus on any changes - either from the Action Plan or in addition to it - that had been implemented on farm. Hence, some areas of the farm were not covered

again in the Phase Two farm walks. It was assumed the group had a good working knowledge of the host farm because of visiting within the last 12 months as part of Phase One.

Farm walks have been shown to be an effective format for knowledge exchange in farming (Brogue, 2013, Dodunski, 2014, Lacy, 2011). The Stable Schools also featured farm walks and used farm data to help the group work together to improve each host farm (Vaarst et al., 2007b). The experience of the primary researcher and facilitator in running farm walks prior to the study also enforced the idea that these were a good basis for farmer learning.

Action Planning

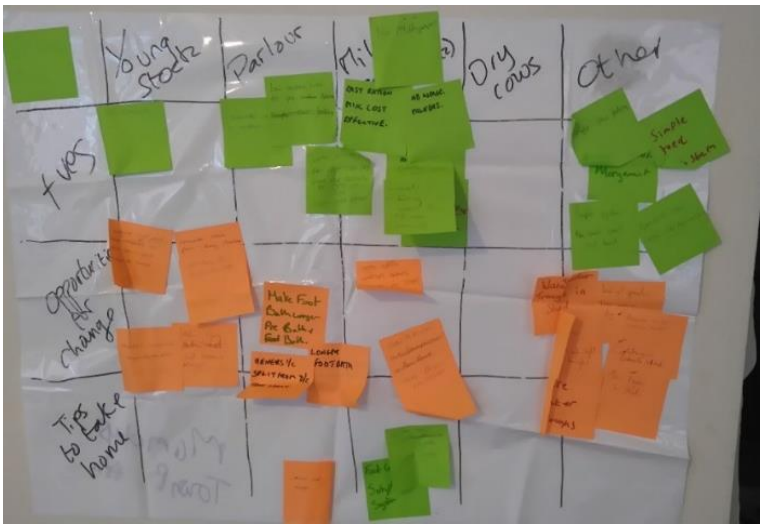
The farm walk ended with lunch and a sit-down discussion on what the group had learnt from the host farmer. This next part of the meeting was a key step of the process; the discussion was facilitated to co-produce a farmer-led Action Plan of practical ways for the host farmer to reduce the need for and use of antimicrobials on their farm. An example Action Plan can be seen the author's thesis alongside the meeting summary report. The Action Plan was the fundamental output from each meeting in Phase One. The host farmer was able to accept or disregard suggestions and, once finalised, the Action Plan was written up as part of the meeting summary report by the primary researcher. The host farm could then work on implementing the actions over the subsequent months.

The meetings ended with a volunteer to host the next meeting and approximate date. Once everyone in the group had hosted for the first time, the second phase of meetings commenced. Phase One lasted approximately one year depending on the group, number of farms in the group and how frequently they met. Phase Two was an opportunity to reflect and evaluate how much of the Action Plan had been actioned and whether there was any benefit seen from implementing any of the farmer-led suggestions to reduce AMU on farm. Phase Two followed a similar meeting format to Phase One with a slightly shorter farm walk and more time spent discussing changes made to farm practice in an attempt to reduce AMU. The post-lunch discussion focussed on the host farm's Action Plan - what had been tackled, what had been disregarded or failed and why. This was discussed as a group and further suggestions/improvements invited. More detail on the facilitated discussion in Phase Two can be found in the author's thesis.

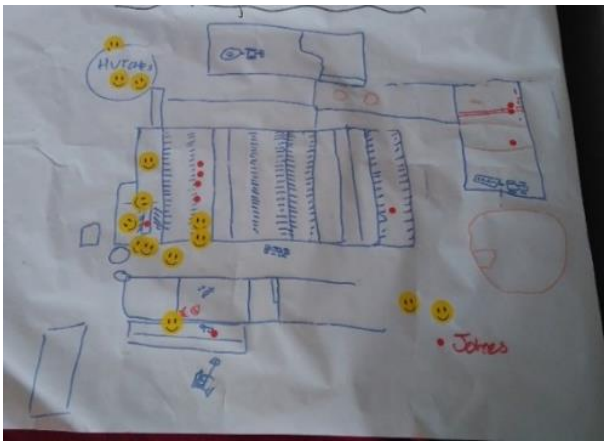
Discussion tools

The discussion after lunch (i.e. Action Planning in Phase One) involved a variety of novel tools and exercises to stimulate discussion and refresh ideas. These types of activities are widely documented in Livestock Action Research and Community-Based Research (Conroy, 2005, Kumar, 2002) and were designed in collaboration with the primary researcher and the facilitator. Examples included:

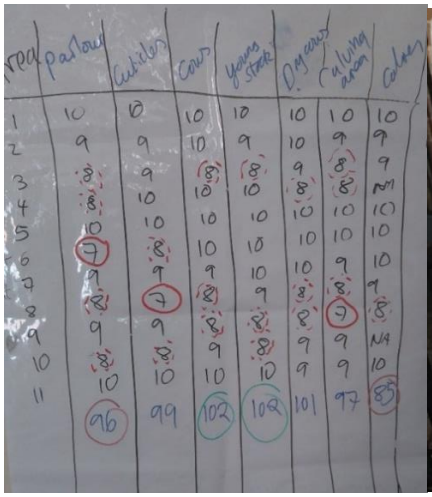
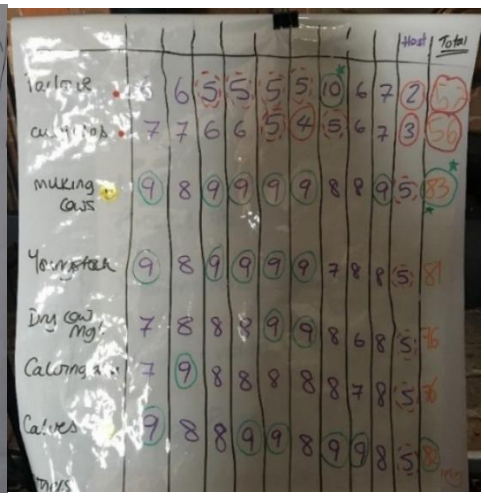
1. **Use of sticky notes on posters-** Farmer participants were encouraged to write ideas on sticky notes and place them on a wall poster (see figure X) categorised as in Table X. The suggestions were then read out and discussed as a group.



2. **Mapping of the farm walk-** A volunteer farmer participant was asked to draw a map of the farm walk they had just been on, directed by the rest of the group. The host could pass comment at the end on the accuracy of the illustration. The group were then asked to place colour-coded stickers on the illustration representing things the host was doing well and areas that could provide opportunity to reduce AMU.



3. **Score chart exercise-** Each farmer participant was given a score chart with areas of the farm walk printed down one side, including a blank section. Participants were then asked to rate the areas of the farm on a scale of 1-10 (1= awful; 10 = absolutely excellent), giving optional reasons beside the score. The score charts were then collected, scores added up on a poster and discussed. All scores were anonymous and the lower scoring areas were focussed on for the Action Plan.

4. **Ping Pong ball ranking exercises-** Several labelled bowls were displayed representing a different area of the farm walk, with an optional 'other'. The farmer participants were then asked to place colour-coded balls into the bowls reflecting things the host farm was doing well and opportunities for change regarding herd health and AMU.


Table one – example of 'sticky notes' discussion tool poster used during discussions

Areas of farm walk	Things going well	Opportunities for change	Tips to take home
Parlour			
Cubicles/sheds			
Calf house			
Pastures			
Calving shed			

3.2.2. Data capture and analysis

Qualitative and quantitative data were collected in order to answer the research questions. The collection and analysis of the qualitative data is described first. The following sections on Medicine Reviews and Action Plans deal with how the quantitative data was collected and analysed. The qualitative data were used to assess how the Stable School methodology, adapted for the UK context, helped foster a change in practices on participating dairy farms. The data collection and analysis also aimed to further learning on how this method could be adopted in a wider context.

The different types of data collected via different techniques was interpreted in tandem to enhance the conclusions drawn - this is called Triangulation. Triangulation refers to the process whereby the veracity of individual findings is improved by two or more different methods reaching the same conclusion (Richards, 2009). This technique is widely used in social sciences and stems from the use of triangulation in navigation to pinpoint a location based on two known points in space.

The data collected during the running of the Farmer Action Groups included:

1. qualitative data from the group discussions at the meetings using an audio-recording device and transcriptions of a select number of meetings
2. qualitative data from semi-structured interviews with each farmer participant using an audio-recording device and verbatim transcriptions
3. quantitative and qualitative data from the co-creation and implementation of the Action Plans, collected at semi-structured interviews with participants
4. quantitative data from Medicine Reviews for each farm in the project as well as farm herd health parameters[1] collected at the start of the study (e.g. lameness rates, mastitis rates, cull rates etc)

[1] This data was not used in the analysis due to its lack of relevance for measuring outcomes and its lack of comparability between farms

Qualitative data from the FAG meetings

An encrypted audio-recording device (Olympus Digital Voice Recorder DS-3500) was used to capture the conversations and ideas shared at each FAG meeting. The 'catch-up' session, Medicine Review session, the farm walk and Action Planning discussions were recorded and listened to by the primary researcher within three weeks of each meeting (this comprised approximately three hours of audio per meeting). The farmer participants provided signed consent at the start of the project for the recording to take place and were aware of the role it played in the researcher's work.

The total amount of audio data collected from the FAG meetings was approximately 174 hours. The primary researcher was present for all 58 FAG meetings and listened back to the audio file for each meeting as part of compiling a meeting summary report for participants. The researcher then transcribed a further ten meetings for formal analysis - a total of 30 hours of FAG meetings were transcribed and formally analysed by the primary researcher using the software package NVIVO version 11 (QSR International, Australia). This number of meetings was chosen for formal analysis as it represented meetings on various participating farms with different hosts/attendees and across the different FAGs. It also captured data from the first meetings where farmers did not know each other and were perhaps more unsure of the approach. There was a substantial wealth of information in each meeting to address the research questions; each meeting provided evidence of knowledge sharing, learning, peer support and community building. Data saturation was evident after analysis of only five meetings by the primary researcher.

Field notes were also taken by the primary researcher during each meeting and variable forms of feedback was collected after each meeting (see Figure three). These were not analysed formally but were used to create the meeting summary reports. These reports were used to inform the analysis further (i.e. a further record of topics discussed, ideas implemented on farms) and provided extra quotes from meetings not transcribed formally. All these data sources informed the author's understanding of the process and influenced the reflective nature of the facilitation in the project

Figure three – One form of meeting feedback used in the study

Formal data analysis

Thematic Analysis was chosen as the preferred analytical approach due to its common use in other related studies in the agricultural sciences (Vaarst et al., 2001, Vaarst et al., 2002, Kristensen and Enevoldsen, 2008, Lowe et al., 2019) as well as relevance to the data collected. Thematic analysis works on the principle of organising rich data sets by identifying sub-topics, then examining these organised data sets for patterns, relationships and common ideas, referred to as themes (Richards, 2009). Using the research questions as a framework and adopting deductive analysis specifically, ten meetings across different farms and groups were transcribed and used for the formal analysis. A deductive approach was then used to ask qualitative data-specific questions for targeted interrogation (Richards, 2009), such as: 'What practices did farmers change as a result of learning from their peers in a FAG?', 'What examples are there of knowledge exchange and sharing?', 'How have farmers supported each other?', 'How has the facilitation helped?', 'What was the role of the different aspects of the FAGs?' 'What barriers existed to changing practice?'. The overall research questions formed the framework used for this first stage of coding - the data was organised into 'nodes' in NVIVO answering the specific areas of interest.

A deductive approach was chosen over an inductive approach because of the wealth of subject matter covered in the discussions at each meeting, much of which was not strictly related or pertinent to the study aims. This study wanted to understand how this approach supported farmers and how it could be applied on a wider scale.

By following the principles of Thematic Analysis, the coding of transcripts was performed in a two-step process. Firstly, 'topic coding' where content answering the research questions was identified and organised, as described using a deductive approach above. This was followed by analytical 'coding on' (Richards, 2009). This second step takes a more analytical stance and links the coded text by a commonality, relationship or theme. It is sometimes referred to as axial coding (Fielding, 2001) and involved interrogating the first set of codes, asking questions like: 'Can they be grouped?', 'What relates them?', 'How do they differ?', 'What causes these comments/topics?' and 'What is the consequence of these topics?'. All coding was done in NVIVO version 11 (QSR International, Australia).

3.2.3. Semi-structured interviews

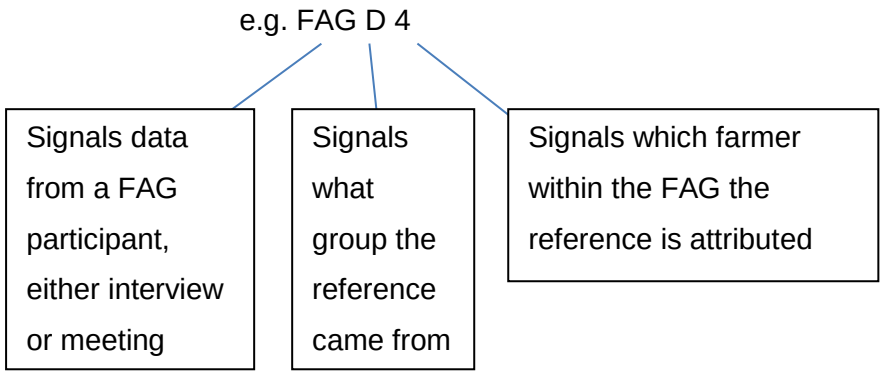
Interviews were carried out in order to understand the farmer participants' views on the project from a more personal angle (not in a group context) and to capture why they had joined the project in the first place and what made them carry on participating.

Semi-structured interviews were performed with 27 farmer participants during the project after they had hosted for the first time in Phase One (June 2017 - June 2018). All interviews were audio-

recorded and 16 were transcribed verbatim by an external company (Bristol Transcription Services). These 16 interviews were formally analysed using Thematic Analysis between February 2018 – October 2018. This number was chosen since data saturation was reached by interview 16 regarding rationales for participation. Data saturation was met as deemed by the interviewer before formal analysis was complete due to the re-occurrence of similar comments, view points and the lack of novel data emerging. Interviews continued despite this in order to assess each farm's Action Plan within the scheduled interview visit but were not transcribed verbatim for Thematic Analysis.

Interviews lasted between 30 minutes and two hours. They were done on farm by the primary researcher and involved either the main farm manager or one or two extra team members (herdsmen or family members). The interviewer followed a topic guide that was designed based on the research questions and the progress of the FAGs (see thesis appendix). The 16 interviews involved 15 farmers from 12 different participating farms. These interviews are referred to from herein as participant interviews.

Referencing of the qualitative data from the meeting transcripts or interview transcripts in the text will be described herein as:



The same approach to interview data analysis as described for the FAG meeting transcripts was followed and the results assessed and reflected on in parallel in an integrative approach (Fielding, 2001, Richards, 2009). Findings from the interviews and FAG meetings were integrated to inform the final analysis and findings from the study in tandem. This is in line with the principles of Triangulation whereby different methods and aproaches to the same questions are performed and re-inforce the findings. Findings from qualitiative research techniques, such as interviews are not desgined to be representative or generalisable. The idea is to explore in-depth the realities and perspectives of a select sample of people to further our understanding on human practice and behaviour. For these reasons these techniques and the resultant findings should be viewed not as a general rule for all farmers but the realities of those interviewed.

Thirty five further interviews were conducted with non-participants and auxilliary industries as part of the wider research. For more on the results of these interviews please refer to the author's thesis.

3.2.4. Medicine Reviews

The Medicine Reviews consisted of quantitative data. Designed to measure a change in AMU, the Reviews became far more applicable as tools to foster discussion at the FAG meetings. Thirty Medicine Reviews were conducted, one for each participant farm. Each Review covered two consecutive 12-month periods - from the start of the project through to the end - in order to measure and assess any changes or reduction in AMU. Twelve months was chosen as an adequate time period for the Reviews due to covering all four seasons, allowing for differing disease prevalence and thus differing AMU patterns (Mills et al., 2018). Due to the time constraints of the project, only two years' worth of medicine data was able to be collected and processed.

Veterinary prescription data was the basis for the reviews, with the exception of three farmer participants where it was impossible to obtain veterinary prescription records for reasons the veterinarians were unwilling to disclose. These Medicine Reviews were therefore based on farm medicine records only. Using veterinary prescription data for 27 of the reviews reflected the amount of antimicrobial *sold* to farm rather than what was actually used (Mills et al., 2018). Nevertheless, veterinary prescription data is a fair proxy of AMU (Hyde et al., 2017) and was the most reliable data for the majority of farm participants at the time of starting the project. On-farm medicine records were also obtained for each farm participant so as to increase the level of detail and accuracy of the review (Mills et al., 2018). These data were useful for collecting modal course lengths, daily doses and allocation of certain medicines to certain categories of stock (e.g. to determine injectable antibiotics that were used for calves versus adult cows, compared to assuming all farms followed the product data sheet recommendations) (Mills et al., 2018). These data were collected and interpreted in collaboration with the farmer participant at the start of the project at the pre-visit (see Figure two).

The veterinary prescription data for the 27 farmer participants was provided by 15 veterinary practices from across South West England. This data was provided in various formats such as Microsoft Excel for Office 365 MSO spreadsheets, PDF documents and scanned images, and also included expenditure for each product sold. All raw data was kept confidential and not shared more widely than the research group. Signed consent was provided by the farmer participants for the primary researcher to collect the data and veterinary practices were encouraged to liaise with the farmers participating in the project. Data were then processed and inputted into Microsoft Excel for Office 365 as a count of the number of each antimicrobial sold to the farm (number of bottles and therefore millilitres, number of tubes and/or units) and the total expenditure on each group of medicines.

Costings were done as part of the Medicine Review process, which tallied percentage expenditure on different types of medicines per year, pence per litre (PPL), percentage expenditure on HPCIAs versus non-HPCIAs and percentage expenditure on different forms of antimicrobials (i.e. intra-mammary, injectable, oral, etc.). The presentation of this type of data was becoming more commonplace in the industry at the time of the study (https://www.kingshay.com/wp-content/uploads/Example-Dairy-Antimicrobial-Report-SMALL.pdf) and helped stimulate discussion amongst farmers.

Data from the initial questionnaire carried out with each farmer participant in the pre-visit included details about stock numbers (total number of calves in the year and average number of adult stock in the year) and annual milk production (as sold). This was recorded in Microsoft Excel for Office 365 along with the Medicine Review data compiled from the veterinary sales data. Categories of stock were chosen based on the Danish categories (Jensen et al., 2004), which were deemed the most similar to the UK dairy sector in 2016 and were the most feasible for data collection.

- Calves= <12 months old
- Youngstock= >12 months old and not yet milking
- Adults= milking stock (dry and lactating)

A medicine audit template was created using Microsoft Excel for Office 365 by the primary researcher, which listed all licensed antimicrobial products for cattle in the UK from the VMD database. Data from Summary of Product Characteristics (SPCs) was used to input active ingredients, routes of administration, concentrations, dosages, course lengths and pack sizes/volumes. Where a range of values was given on the SPC, for instance for dosing, the median figure was taken. Additional products that were used off-license were added on an ad-hoc basis as veterinary sales data was collected and the Medicine Reviews were formulated. At the time of starting this study, no such spreadsheet or template with all the necessary SPC data was available in the UK, thus it had to be created for the study. This medicine audit template was the basis of the information used to calculate the different metrics for each farm's Medicine Review.

The data from the total amount or number of antimicrobials used on each participant farm was then transferred to a separate sheet in the Medicine Review workbook for calculation into AMU metrics. This sheet presented each farm's AMU in the following metrics:

1. Cow Calculated Courses (CCC)
2. Animal Daily Doses (ADD)
3. Milligrams of antimicrobial per 1000 litres of milk (mg/1000L)
4. Milligrams of antimicrobial per kilogram biomass (mg/kg)
5. Grams of antibiotics from intramammary tubes per cow per year (g of AB/cow/yr)

These metrics were chosen because they were already in wide use in the industry (Mills et al., 2018) and/or were being used to measure national AMU in the UK (VMD, 2018) as well as other countries in Europe (Postma et al., 2015, Ferner et al., 2014, Speksnijder et al., 2015b). Metric 1. was being used by a retailer group and several veterinary practices at the start of the project (van Dijk et al., 2017). The hope had been to recruit from this pool of producers, which was unsuccessful. Metrics 2. and 3. were included at the direct request from participant farmers. Metric 2. was also used for farm AMU reporting in the Netherlands and after a study tour with some of the farmer participants to the Netherlands in October 2016, this was chosen as a preferred metric for the Reviews. Metrics 4. and 5. were used in the VARSS report (VMD, 2018) although some adaptions in calculations were made for this project.

There were three main adaptions made for the Medicine Reviews compared to national reporting:

1) Using different denominators when calculating the metrics compared to national figures (particularly Metric 4.). Research since this decision was taken has shown the weight of UK adult dairy cattle to be fairly similar to below (Schubert et al. *under review*).
    - 100kg= average weight of calves <12 months old
    - 300kg= average weight of young stock >12 months old but not yet calved
    - 600kg= average weight of adult milking stock (Jensen et al., 2004)

2) Due to being able to allocate average weights for three distinct categories of stock on a standard dairy farm, the Medicine Review metrics also included calf numbers in the calculations and, where possible, allocated certain antimicrobials to calves only. This information came from the on-farm medicine records, discussions with farmer participants and SPC data.

3) HPCIAs for this project were initially defined as fluoroquinolones, 3rd and 4th generation cephalosporins and macrolides, as per WHO guidelines (Collignon et al., 2016). It was noted and acknowledged by the author that during the project's evolution, the European Medicines Agency (EMA) - therefore the VMD and the National Office for Animal Health (NOAH) – issued a classification of HPCIAs including only fluoroquinolones and 3rd and 4th generation cephalosporins. In response to this, the primary researcher altered the classification in the reviews to exclude macrolides as HPCIAs in line with the EMA. This happened during Phase One and all Medicine Reviews subsequently stated which antimicrobials were HPCIA or CIA according to the EMA or the WHO.

Once AMU had been calculated, the data were compiled into a farmer-friendly report for discussion at the FAG meeting. After the first 12-month review, AMU for each farm participant was also benchmarked against the other farmers in the same FAG and across the five FAGs. Benchmarking

has been shown to be effective in instigating a change in practice (Sumner et al., 2018) and was used to help recruit farms to the project (see author's thesis for more on recruitment) . Benchmarking of AMU across the first year was used in discussions in Phase One FAG meetings. Once Phase Two commenced, the second 12-month reviews were compiled and presented in a new report that compared Year One with Year Two (see author's thesis for example reports).

3.2.5. Action Planning

The Action Plans were a further indicator of the impact and success of the FAG project. Thirty Action Plans were co-created by the farmer participants (one per host farm). These were a direct outcome from the farm walk and facilitated discussion at the Phase One meetings. The use of the discussion tools (as described earlier) and the skill of a facilitator was maximised to help each farmer group co-create a series of practical steps to help the host farmer reduce the need for and use of antimicrobials. It is important to add that the Action Plans were farmer-led; the researcher and facilitator had minimal impact on the steps recommended and simply acted as guides in the process of Action Plan development. The knowledge and experience of the group of farmer participants was the source of the Action Plan. The facilitator would question the group and raise certain topics that were brought up on the farm walk as a reminder. The researcher would occasionally raise the topic of the host farm's Medicine Review if the group were struggling for suggestions in order to focus minds on the areas of higher AMU. For this reason, it was deemed crucial to have good attendance at each meeting to increase the number, variety and quality of suggestions for the host farm's Action Plan.

Phase Two meetings were focussed on evaluating the host farm's Action Plan and assessing how well it had been implemented. The period between each farm participant hosting for Phase One and then Phase Two varied between eight and twelve months and was the time the farmers had to implement the practical steps from the Action Plan. At each semi-structured interview with the farmer participants, the researcher would ask the farmer/s about their Action Plan and what they had actioned/implemented. They were given a series of 'drop-down' answers to choose from on a spreadsheet: 'fully completed', 'partially completed', 'not yet completed but hope to', 'not at all' and 'don't know'. Participants were also asked if they perceived any benefits from implementing each specific action and were asked to elaborate. These data were captured in Microsoft Excel for Office 365 and each answer was allocated a numerical score.

At the Phase Two meetings, the FAG was asked to rate the benefit observed/envisaged for each practical step on the host farm's Action Plan, as well as discussing what had been implemented, what hadn't and why. The facilitator would then ask for ideas to improve or expand the Action Plan for the host farmer, creating a 'Re-Action Plan' - this was not evaluated or followed in the same way

as the initial Action Plan. The comments and ideas from the groups' discussion were collated into the meeting summary reports in the same way as for Phase One meetings.

To assist the discussion and reflection on the host farm's Action Plan in Phase Two meetings, a card sorting exercise was done based on the individual actions from the Action Plan. Each individual action was described on a card and the cards were shared out amongst the FAG. The participants would then discuss the individual actions based on the host farms explanation of what they had done whilst on the farm walk. The group would then decide which of the following categories the actions fell into: Success, Ongoing, Disregarded, Disaster. These categories were chosen by the primary researcher after the initial interviews with participants discussing their Action Plans.

4. Results and Discussion

Four key results have been selected for presentation in this report – data on the attendance at the meetings, the farmer experience of the FAG project, changes to practice through the process of Action Planning and the outcome of the Medicine Reviews. Results from the recruitment phase and interviews with auxiliary industries and non-participants have not been included here in the interest of keeping the report succinct and relevant but can be found in the author's thesis. Due to the inclusion of qualitative data, the results and discussion have been amalgamated as is normal for qualitative research.

4.1. Degree of participation

The first set of empirical results illustrates the number of meetings and the level of attendance. Although the relationship between attendance and engagement cannot be taken uncritically, attendance is widely used, for example, in the context of education, as a likely indicator of engagement (Grey and Gordon, 2018).

Table two illustrates the mean and median percentage attendance at each FAG meeting as well as across all five FAGs. A participant is defined at the farm level for the attendance figures. A farm is said to have 'attended' if one or more farmers from that farm turned up to a meeting.

Table two - Level of attendance across all FAG meetings in Phases One and Two

Farmer Action Group	**Total number of meetings**	**Mean percentage attendance (%)**	**Median percentage attendance (%)**
Wiltshire	10	82.0	80.0
Devon	16	83.6	90.6
Cornwall	13	69.2	69.2
Somerset	10	74.0	80.0
Dorset	9	73.3	77.8
Totals	58	76.4	80

Mean percentage attendance across all five FAGs was 76.4%. An average farm participant attended just over three-quarters of the meetings for their FAG. Median attendance was 80% across all five FAGs. Considering the meetings were held at all times of year on a variety of different farms, this is a high percentage attendance and indicates a good level of engagement. Some participants had 100% attendance (n=2) and the majority of participants (n=27) had over 60% attendance over the course of the project. The lowest attendance was 38.5% for one participant farm who did not host a

second time in phase two due to time constraints. The project lasted approximately 18 months for each FAG, depending on the size of the group.

Attendance clearly cannot be uncritically and simplistically equated with engagement, which brings with it an array of values, motivations and rationales. Using attendance as a marker of engagement is further complicated by the manner in which each is recorded. The attendance of a farm participant with only one member of staff would be considered the same as a farm participant with several staff members. However, the farm with several staff members was technically more able to attend the meetings as they had more 'personnel' available to go. Generally, the individuals that represented a farm that came to meetings were the same individuals throughout the project. More on how attendance and engagement varied can be found in the author's thesis.

4.2. Experiences of participation

The farmer participants found the project useful, enjoyable and of value to their businesses and their own learning. Feedback was overwhelmingly positive and many were sad when the project came to a close. Figure four is an example of one form of feedback used.

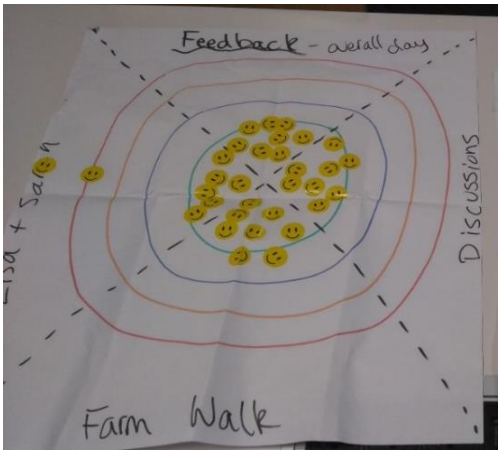


Figure four – One form of meeting feedback

The data drawn from in this section is from the FAG meetings themselves and semi-structured interviews with individual participants. From the analysis of those data sources several key elements of the farmer experience participating in the FAGs have been identified, such as peer-to-peer support, seeing and hearing from other farmers, guidance from facilitators and an informal participatory learning environment. The various elements have been analysed and have been brought together under two overarching themes of Knowledge Mobilisation and building a Spirit of Solidarity, which will now be discussed.

4.2.1. Knowledge Mobilisation

The exchange and sharing of knowledge emerged as a key element in the implementation of actions on farm in FAG project and was something farmer participants all agreed they gained and valued from participation. PAR methodologies aim to empower people through collective knowledge sharing and generation (Cornwall and Jewkes, 1995). The participatory mechanisms built into the study design and implementation (i.e. farm walks, group discussions, sharing of data through the medicine reviews) allowed the farmers' own experiential knowledge to be used to create farm-specific solutions to reducing AMU. In this sense, 'knowledge' was generated, shared and actively mobilised through the two-way flow and sharing of knowledge between participants. The term Knowledge Mobilisation is being used in this study to cover the identified importance of the following processes; the two-way flow and sharing of knowledge between participants; between the author and the participants; the low attributed value of sharing knowledge amongst non-participating farmers and the lack of knowledge sharing on certain subjects by many veterinarians. Knowledge mobilisation is a key process in a farmer-led, bottom-up approach, even more so on a topic such as AMU where UK farmers are making decisions on AMU on a daily basis.

An important component of the FAG research also included specific mechanisms to address identified and agreed knowledge gaps. These mechanisms were more directive, more science-led and were essentially delivered by the author of the current research as the resident veterinarian at the FAG meetings. To a large degree, these interventions complemented the farmer-led sharing of knowledge and experience and were seen, by the participant farmers, as a playing an important function within the FAGs. As one farmer said to the current author during an early FAG:

> *"Antibiotics are a real minefield aren't they? So we have learnt the wrong and right antibiotics but there's still a lot more to learn. That's why you spent five years at the veterinary college to learn it." FAGW3*

All the farmer participants wanted to know how AMR could develop from what they were doing on their farms, what a HPCIA was and what categories of antimicrobials they were using on their farms. They saw this as essential knowledge they did not have or of which they had only a peripheral understanding (i.e. some had heard the term HPCIA from sources other than their veterinarian). Moreover, many FAG participants were in fact required to know and act on knowledge of HCIAs by specific retailer contracts. Others saw the coming of legislation and restrictions on HPCIA use in the near future and wished to know more about them.

> *"It's just going to be one of those hot topics isn't it? You either get onboard and do it or you're going to be left behind and you're going to have to react to it at some point, so ...." FAGC1*

Following specific participant requests, HPCIA information was first presented to farmers in the recruitment meetings. The term 'Critically Important Antibiotic' (CIA) was introduced, and some example trade products were shown to demonstrate which antibiotics these were. At this point, the participants requested more formalised and detailed information in the form of information sheets. At the first few meetings for each FAG, the HPCIAs were re-introduced, and example trade names given. Posters were used to go through the drug classes and make the learning more visual. This was a decision taken by the primary researcher and the facilitator after reflecting on the first few meetings and the repeated request to have the information in an easy-to-digest format from the farmer participants.

> *"A crib sheet would be really good actually with all the drugs and what they are, definitely." FAGC1*

It was decided after the first few meetings to present this information in a variety of different ways over the course of the project to help farmers become confident in the newly acquired knowledge. At the second meeting for each group in phase one, the 'MilkSure' videos on how AMR could develop were shown (https://milksure.co.uk/about-antibiotic-resistance/). The third meeting for each group involved using A3 posters to list examples of certain classes of antimicrobial and highlight the HPCIAs. In phase two, there was a short informal quiz to test farmers' knowledge of the names of the HPCIAs and example products. The end result was the production of a laminated poster for each participant with a traffic light graphic listing the HP-CIAs, CIAs and first-line products. It included a space for the farmer to write the trade name of what was used on their farm, in discussion with their veterinarian (Figure five).

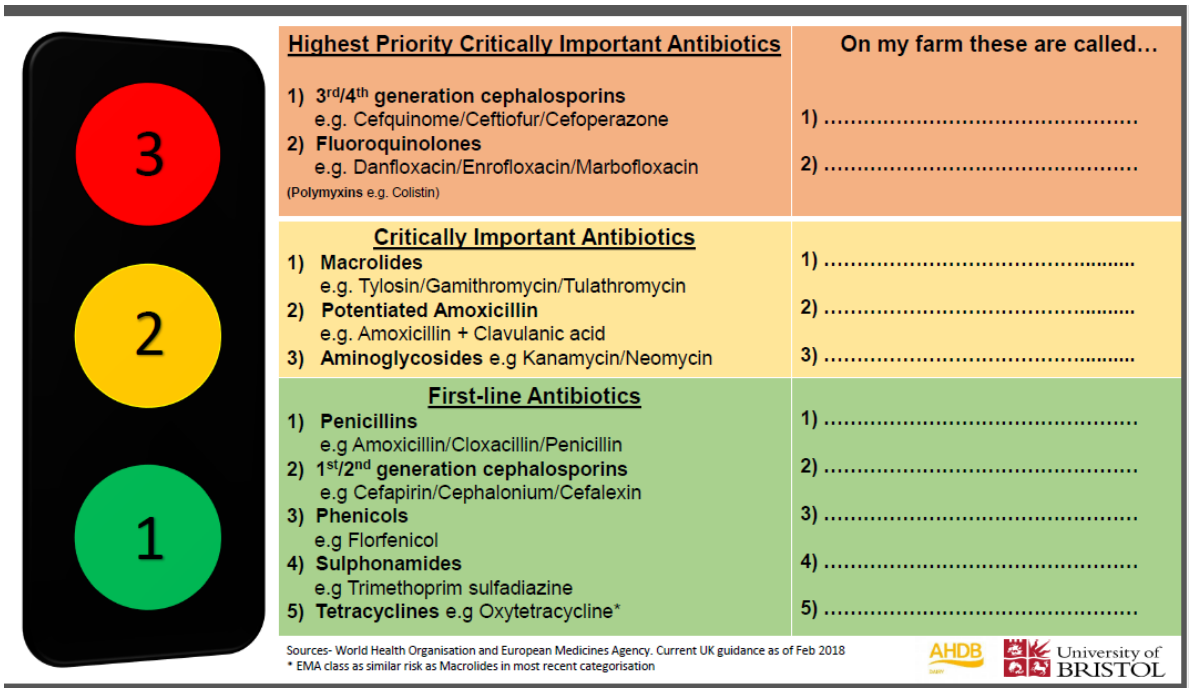


Figure five - HPCIA poster created by the author for the FAGs

This discernible farmer-identified knowledge gap around CIAs implied that the veterinary profession was lagging behind in their responsibility to ensure antimicrobials were being used properly and with sufficient understanding by farmers. At the outset of this study, the O'Neill report had just been published, which called on the food-producing sector to reduce their use of antimicrobials (O'Neill, 2015). RUMA were also starting to produce sector-specific antimicrobial reduction targets (VMD, 2018). There were multiple stories in the press about extensive overuse of antibiotics in farming (https://www.theguardian.com/society/2018/nov/16/uk-medics-call-for-government-ban-to-cut-antibiotic-resistance) and the farmers in the project were generally annoyed that they were getting a lot of the blame while it was the veterinarians who were prescribing them the medicines!

> *"I think we weren't knowledgeable enough to question them to start with. So they [vets] just carried on as normal and I think now that they're aware, particularly with us, that we're doing this study, then that's made them think a little bit more." FAGC2*

This farmer directly refers to the FAG project as a factor in encouraging their veterinarians to do more to ensure they were prescribing antimicrobials properly and that they were not being used irresponsibly by farmers. Many farmers in the project stated they were asking their veterinarians about what they were injecting their cows with and what classes of antimicrobials they were being sold. This behaviour was encouraged by the primary researcher and facilitator because it was seen as a good way to encourage more discussion about herd health between farmer and veterinarian. This tactic was popular with some veterinarians too, as this quote from email correspondence with the primary researcher shows:

> *"You have definitely got [FARMER] thinking. We have managed to discuss tube usage, respiratory [disease] treatments and colostrum management in the last three days!" V14 Email*

This particular veterinarian had more conversations about herd health issues as a result of the farmer participating in the FAG project. This is a positive result and despite the concerns veterinarians were having about the approach, the project provided a benefit to veterinarians through increased discussions about preventative health measures.

Knowledge mobilisation between farmers, veterinarians and the facilitators was a key element and critical ingredient in the FAG recipe. The farmers identified a lack of knowledge on HPCIAs and AMR through their collective participation in the FAGs. One might argue that this knowledge could and should have been provided by their veterinarians. Notably, veterinarians reported improved engagement with some clients after discussions at FAG meetings and farmers felt the new knowledge helped them make more responsible AMU decisions and have better discussion with

their veterinarians. Perhaps, farmer-led approaches offer a novel way in which veterinarians could improve and expand their advisory role?

What is important here is that the mobilisation of knowledge that underpinned the FAGs established for this study was multiple, flexible and iterative. The demand for more specific information on antimicrobials came from the farmer participants as a result of the establishment of the FAGs and emerged out of the discussions within them. The mobilisation of external expertise is not contradictory to the principles and purposes of farmer-led interactive innovation models but can be, as the current example demonstrates, a critical component and function of them. This synergy between knowledge types and collaboration between local and external knowledge is described by Lowe and colleagues as Vernacular Expertise and is crucial in rural development (Lowe et al., 2019).

4.2.2. Building a sense of solidarity

Undoubtedly, the new knowledge generated and shared in the FAGs, empowered farmers and, to a degree, set them apart from others who were not in the project.

> *"I feel a bit self-righteous sometimes, talking to people who don't know, "What do you give that cow?" "Excenel." "Oh?"" FAGD2*

There was a feeling of 'being in the know' associated with having obtained new and relevant knowledge through the FAGs and acting on it.

> *"I thought when I saw this, definitely, I thought we would learn something, and we have learnt a lot. When you start looking and see what we are using now and what we were using when you first came, it's all gone." FAGD3*

> *"I had been approached for a RETAILER contract. It was more or less definite, but it wasn't definite and I knew with mastitis or incredibly important antibiotics, could well be a thing to be aware of and I just thought two things at the same time, I thought this might well help me..." FAGDe6*

Moreover, this 'knowledge-edge' over other farmers was seen by some as a distinct benefit from participating in the FAG project. Farmers had learnt something that would help them adapt to future regulations in advance of many other farmers, which became evident by the end of the project in June 2018, with the introduction of Red Tractor Farm Assurance guidelines restricting use of HPCIAs on farm.

(https://assurance.redtractor.org.uk/contentfiles/Farmers-6912.pdf?_=636585117784901746).

The following quotes illustrate some conversations at the meetings on reducing HPCIA usage due to foreseeing upcoming regulation and using the FAGs as a tool to help them change before being forced:

> *"I think the milk buyer had highlighted it to a degree as well, with the selected dry cow therapy, he kind of alerted us to it. It didn't really alert us to the types of antibiotics we were using I don't think, more to the principles of targeting antibiotics better. But this is a step further certainly in the right direction." FAGDe2*

> *"I have got a horrible feeling our milk buyer is going to come in… [agreement] and they are going to look at what we bought and the next thing before our inspections we are going to have to pick out one of these like Draxxin and they will say where's it gone, as they will show us where the animal has gone. And half of people are not going to show, not going to have a clue." FAGDe3*

> *"Yes. Cobactan was working very well but the only reason I changed was it is a CIA and [RETAILER wanted it] Yes. Theoretically I could still use it, but I had to prove that it was the only thing that would work and the bacteriology samples proved it wasn't the only thing that would work!" Laughter + "...So no I have not got any CIAs on the farm, I used up anything I had, it's all gone. I am not buying anymore." FAGDe6*

Being part of the FAG and sharing knowledge meant they were supported making these changes and were ahead of many in the farming community who did not have this knowledge support. The second quote above refers to those not in the FAGs or acting on the pressure to reduce AMU as 'not going to have a clue'. The third quote demonstrates one participant sharing his knowledge on what retailers are already asking for in a supportive, 'raising awareness' manner. The end result was a group of 'switched on' farmers regarding AMU.

> *"I think people have got their heads around what they should and shouldn't [use]- in our group." FAGDe2*

The continual interaction and knowledge mobilisation was essential in assisting farmers to make changes to how they used antimicrobials and to reduce the need for them. The sense of solidarity that the FAG project helped to foster through sharing knowledge at regular meetings, farm walks, peer support and the building of new friendships were critical elements in what the farmer participants enjoyed and valued in the FAG approach.

> *"... all I know is that I felt that I got a lot out of the group, looking at other people. Even to the stage of where you're doing something, you sort of think, 'Oh maybe I am doing it okay.' For arguments sake, compared to somebody else, sort of thing. The trouble with the industry is you are always being hit by everything and anything. A prime example is your bactoscan. You get a result, a high one and you think, it's like a major catastrophe. When you speak to other people, they all have them, but you don't speak to them." FAGW4*

The idea that they were ‘going through this together’ was critical in the giving, accepting and acting on recommendations from each other. At each subsequent FAG meeting, rapport and trust grew, so the advice and ides shared became more highly regarded as the project progressed.

> *“I was... honestly; I thought I don't know whether I really want to carry on, after the first meeting. There was too many people there running their mouth but not actually willing to back anything up....[]...No. Then we went to the second meeting and they weren't there and I thought yeah maybe I'll carry it on.” FAGC3*

This participant and several more like him did not know anyone in their group initially and were put off by certain members. Once they got to know their group, they became much more convinced of the value of the contributions from the other farmers. This was important in the subsequent development and successful implementation of the farm Action Plans as detailed in the following section.

Although the FAGs established in this research relied heavily – at least at the start – on the role of facilitators, they became much more farmer-led in terms of knowledge support as they started trialling things on farm. This research has shown farmers that they can mobilise and benefit from each other’s shared knowledge to make real change. Although farmer-led initiatives could be criticised for a lack of longevity (Cornwall and Jewkes, 1995, Conroy, 2005), which has consequences for those communities that come to rely on them, the nurturing of a sense of collective endeavour and the learning journey that approach created suggests that there is a real demand for such farmer-led structures, albeit with a finite lifespan as this following quote illustrates:

> *“I am not sure that if this group was to continue whether it would have the same motivation perhaps, because everybody has been able to carry on and yes it might do but unless there is a particular reason for doing it, people will just drop by the wayside. It’s not a criticism, it’s just the way farmers are ..” FAGDe6*

Some participants certainly did not see the groups continuing in the same vein. They felt they had come to an end and farmers would not maintain the initial enthusiasm. Vaarst and colleagues also believed that once the goal has been achieved the groups should come to a natural conclusion (Vaarst and Fisker, 2013). The goal for these farmers was reducing the use of and need for antimicrobials on farm and this helped bring them together. This sense of a collective response to ‘something bigger’ further cemented the sense of community and solidarity amongst participants. The shared experience of reducing AMU together gave them further confidence to change practices and helped generate new knowledge.

4.3. Changes to practice

All farmer participants reported a change to the way they used antimicrobials or how they regarded them after participation in the FAG project. The feedback from participants was overwhelmingly positive and the desire to see the approach scaled-up was palpable.

> *"I know from experience that your approach of small stable schools with a good facilitator works but don't see much sign of it taking off, may be when your work is published there may be some Govt money thrown in the right direction?"* FAGW5

The majority of farms changed at least one aspect of their farm management or treatment protocols as part of their involvement in the project. This was related to the Action Planning process but often went beyond this based on the sharing of knowledge at the farm walks and with each other at the meetings.

4.3.1. Action Planning

The outcome from each Phase One meeting was the co-creation of an Action Plan (AP). This was led by the FAG after discussion on the farm walk and with guidance from the facilitator. The Action Plans consisted of a list of practical strategies for the host farm to work on between Phase One and Two that helped reduce the use of and need for antimicrobials. By Phase Two every farm had implemented at least one recommendation on their AP and on average 54.3% of the recommendations were implemented partially of fully by Phase Two. Many were ongoing or some had been 'disregarded' after a period of consideration. Very few recommendations led to 'disasters' on farm (see thesis for further detail).

Figure seven shows which topics occurred on the farmer-led AP, the number of times they occurred (white and black bars) and the proportion that were implemented by Phase Two (black bars). Recommendations to improve or change cubicles and bedding areas for the cows were the most commonly occurring and were implemented partially or fully just over half of the time by Phase Two. The least commonly occurring recommendations were in the topics of parasite control, vaccination and biosecurity. Nevertheless, when they featured on a farm's AP they were implemented 50% or more of the time. The topics of anti-inflammatory use and discussions with the vet had the highest proportion of recommendations that were implemented. Figure six shows four example AP.

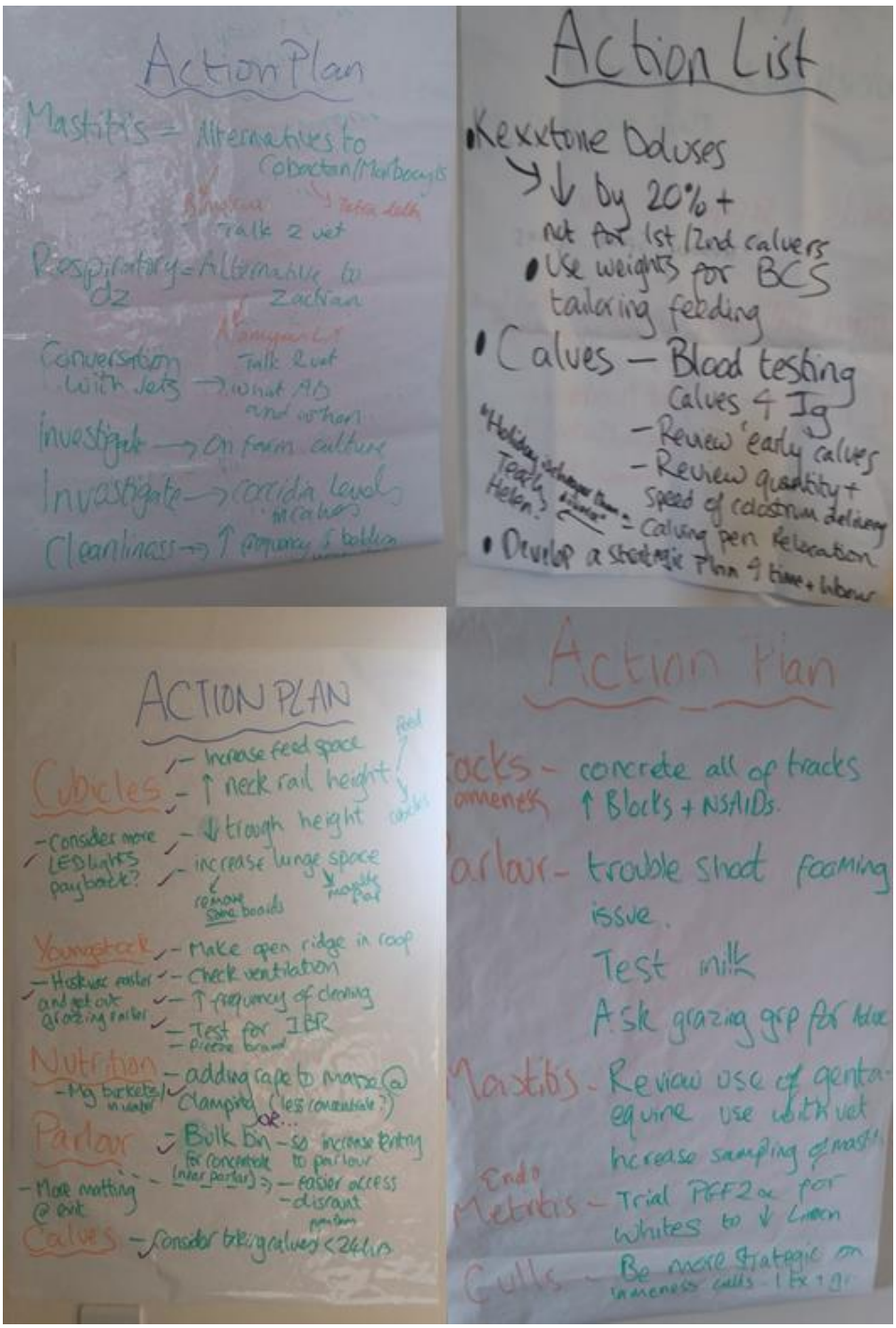


Figure six - Photos of example Action Plans

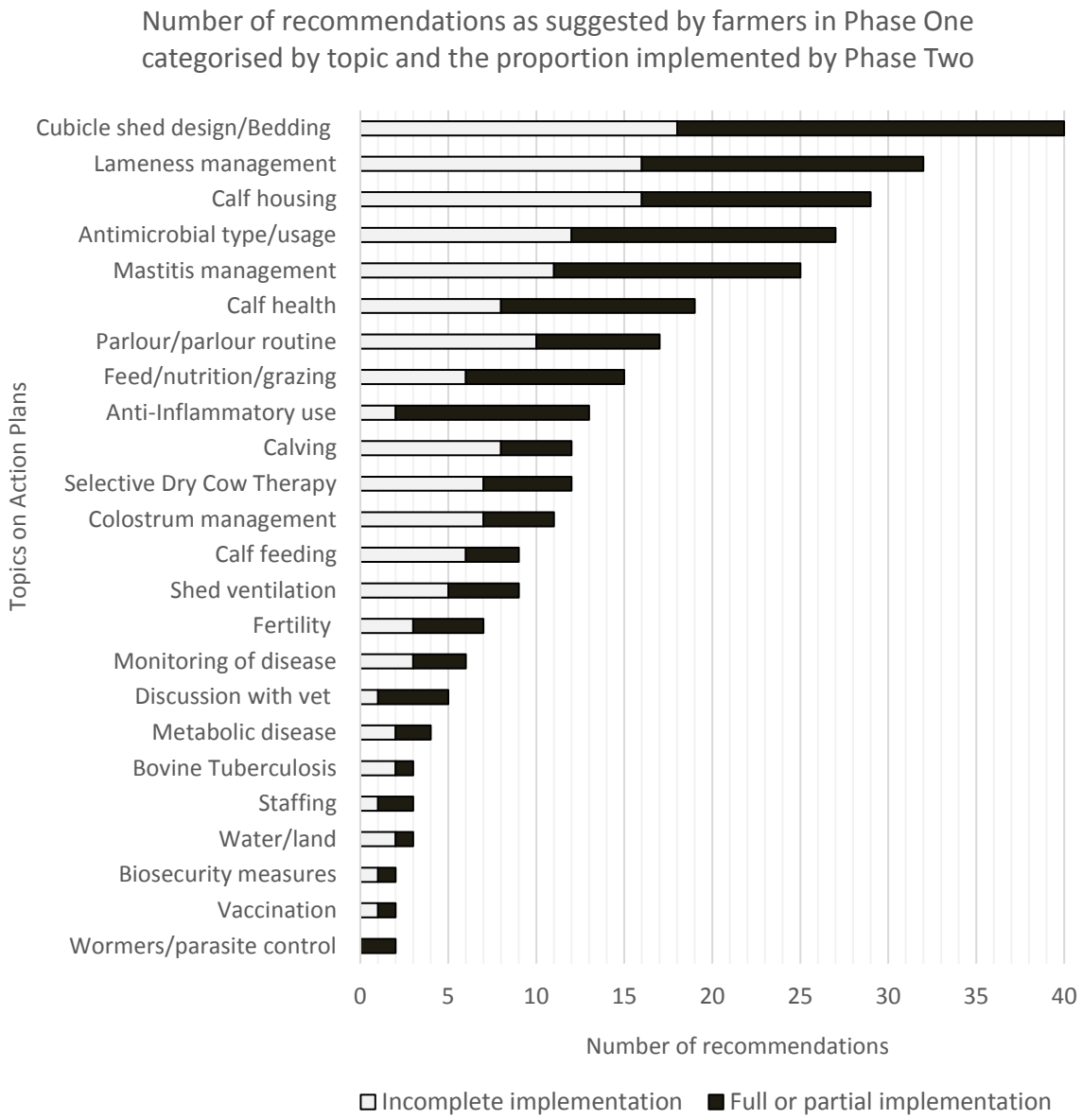


Figure seven – Number of recommendations categorised by Action Plan topic and the proportion partially or fully implemented

Cow environment – cubicle sheds and bedding areas

The most commonly featured topic on the APs concerned cubicle shed design and bedding. Farmers were good at suggesting and implementing changes to the cow environment, whether that was cubicle sheds or calf accommodation. Changes to the bedding areas, cow comfort, lighting and ventilation were all implemented.

> *"We gave them an outdoor loafing area which has worked very well. Got a bit wet at times but it just gave them somewhere to go out. We increased the lighting above our heifers feed silage bit, so put a new LED light in and stuff like that. Just above the silage so they could, we kept the lights on all the time in the shed." FAGC2*

These changes were practical and within the control of the farmer. They spent many hours in these environments and saw from visiting each other's farms the benefit it could have on cow welfare as well as observing changes to their health and behaviour;

> ***Host farmer*** *"Yield dropped by 3L a day when the lights were off for a day. The lights on timers, come on at 5am and off at 11pm. In feed yard, come on at 4 in afternoon and off at 2am, then on again at 5am.* ***Another Farmer*** *"Have you noticed much difference?".* ***Host*** *"They eat a lot more, you come out in the night and there will be cows out eating...Costs £1.20 a day to run the lights."* FAGC3

They also described cows being up and ready to be milked in the mornings, which made it much easier for staff doing morning milking. They noticed increases in their feed intake from increasing lux levels in the sheds in the day and providing 8 hours of darkness at night.

Lameness management

The next most frequently implemented topic on the AP was around lameness management.

> *"We have not treated a cow with antibiotics for feet trouble this year, full stop… We're doing more foot trimming. We haven't used any antibiotics for feet whereas I used to use a bit of Excenel." FAGC1*

The facilitator and primary researcher would ask farmers about their treatment protocols for a variety of conditions on the farm walks. One of these conditions was lameness and often revealed inappropriate use of antibiotics, rare use of anti-inflammatories and intermittent use of blocks. This sparked discussion from those already using blocks or thinking about giving pain-relief, and consequently appeared on the AP and was implemented on farm.

> *"Yeah we'd used blocks just not the anti-inflammatory so much." FAGC2*

> *"We use more Recocam haven't we?" FAGW1*

As can be seen in Figure seven, anti inflammatory use was the topic that had the highest proportion of recommendations implemented from the Action Plan. Generally, farmers were keen to use anti-inflammatory drugs and did not want to see their cows in pain. This was further heightened by the effect of social stigma from the group discussion - they did not want to be seen as 'bad farmers' through a lack of provision of pain-relief. The facilitator would point out that lame cows were painful and should receive anti-inflammatory, in her opinion. This peer pressure explained at least partially why many reported using more anti-inflammatories over the course of the project.

Some of the actions around lameness were adapted and changed from the AP, based on the host farmers' judgement and farm needs.

> *"We haven't installed the rubber matting, but we have put a walkthrough footbath." FAGW2*

This was evidence of the Action Planning process triggering further changes and ideas on farm, which the farmers took ownership of.

Calves

The next two most common topics from the AP that farmers reported completing partially or fully were on calf health and colostrum management. Farmer participants reported completing the design and building of new calf accommodation using feedback from their FAG. Some already had plans for new sheds, but acted on the input from their peers or were pushed to act by having a group of farmers visit and then the ideas being put on the AP.

> *"We've done that calve shed. We've done the first one." FAGDe3*

> *"We did on our action list, we did action temperature check those calves that were coughing" FAGC2*

Many farmers approached respiratory disease in calves differently after discussions at the FAG meetings, as can be seen in the previous quote, which was an outcome from a discussion around diagnosing respiratory disease in calves earlier. The above farmer goes on to elaborate that he was considering ear tag thermometers so he could pick-up disease sooner, which is evidence that some of the actions on the AP sparked further ideas and changes.

Another area where farmer participants made changes was around calf feeding. There were many discussions around feeding regimes and protocols for calves beyond colostrum management.

> *"Yeah we've gone to a whey-based powder instead of the other one, skimmed. What does everyone else use?* ***Another farmer*** *"You cannot get enough detail anywhere to compare milk powders!"* ***Host farmer*** *"Whey based milk powder separates out and leave a sludge. Skimmed don't." Most of group admit using whey-based.* ***Another farmer*** *"I prefer waste milk..."* ***Same farmer describes frustration about instructions on milk powders****- "Someone ought to be fired there, they do not listen".* ***Facilitator interjects*** *"if you only feed 300g then that would be not even the maximum weight gain...The bottom line on milk powders is, it should be the mixing equivalent, should be minimum equivalent as whole milk. Otherwise why feed it? You wouldn't substitute whole milk with something less than whole milk." FAGDe3*

The change in calf milk feeding regimes was encouraged by other farmers' experiences of using milk powders with occasional input from the facilitator due to her expertise in calf management and at the request of the farmers. This is evidence of the capabilities of farmers to come up with practical solutions of relevance to their daily work whilst being guided by a credible facilitator - knowledge exchange in action.

Following on from this were actions on colostrum management. The following farmer made definitive steps to improve his neonatal calf care by focussing on feeding colostrum as quickly as possible after birth.

> *"It's all sorted. Definitely the colostrum management, trying to get colostrum into calves, much more focused on that now than I was. In terms of taking cows away, I am taking them away earlier than I was, but still not by 24 hours." FAGDe6*

Colostrum management was a popular area where farmer participants made lots of changes as detailed on their AP. The peer pressure within the groups associated with ensuring colostrum management was following best practice guidelines was palpable.

> *"Yeah, also now we're testing all the colostrum which we weren't before. You can see we've put a spectrometer in there." FAGDe3*

During the project there was also a social media campaign called #ColostrumIsGold, which cemented some of these practices in farmers' minds. It was variable how participants managed colostrum, but all agreed that it should be fed as soon after birth as possible and should be stored clean. The volume given in the first feed was debated and dependent on the calf size; the industry agreed guideline of 10% of bodyweight was offered by the facilitator as a way to get around this. The facilitator also offered information on the differences between the ways to measure colostrum e.g. using a refractometer or a colostrometer. The knowledge sharing around calf health and colostrum was positively supported by the facilitator's involvement.

> ***Host farmer*** *"The colostrometer we use was a refractometer. The look through at the light one and read off. But is got really dirty and was confusing. No one ever cleaned it so we have gone back to *motions dropping something in milk* with red yellow green on it."* ***Facilitator asks*** *"but what temperature is the milk at when you use that?"* ***Host replies*** *"The temperature when it comes out of the cow."* ***Facilitator explains*** *"it will give you a false reading as it needs to be at room temperature to work". FAGS1*

A popular tactic to improve the health of calves were calf jackets. Several farmers in the project were already using calf jackets to some degree. Other farmers who were not using jackets often asked about their cost and how effective they were.

"We've got some calf jackets as a result of… RES 2: Of you being on holiday, wasn't it?...When you were away J bought them. J went crazy." FAGW1

"Yeah, we've got a total of 40 I think, which when they're calving at their very quickest, still isn't quite enough. We did find that if we did need to take jackets off for new calves, and it coincided with some cold days, you could see it really hit them. I don't doubt we should buy more this time, once we get to the time of year when it really needs them. We found that a great success, yes." FAGW2

"We're using more jackets, yeah we're using more of those…Yeah, you've got better use of feed. XX is a real convert." FAGW3

Antimicrobial usage

The next topic from the Action Plans that farmers reported implementing were changes to the types of antimicrobials used on farms. These were often the 'easy wins' and were something farmers felt their veterinarians should be helping them with more. The primary researcher encouraged all participants to discuss the AP and specifically the drug changes with their veterinarians, which many did.

"We had a chat with her [vet] in the office a little while ago about it." FAGW1

More on AMU is discussed in the next section. There were many more examples of peer-to-peer support and knowledge exchange contributing to changes to practice during the meetings that it has been impossible to include all examples here. For further discussion please see the author's thesis.

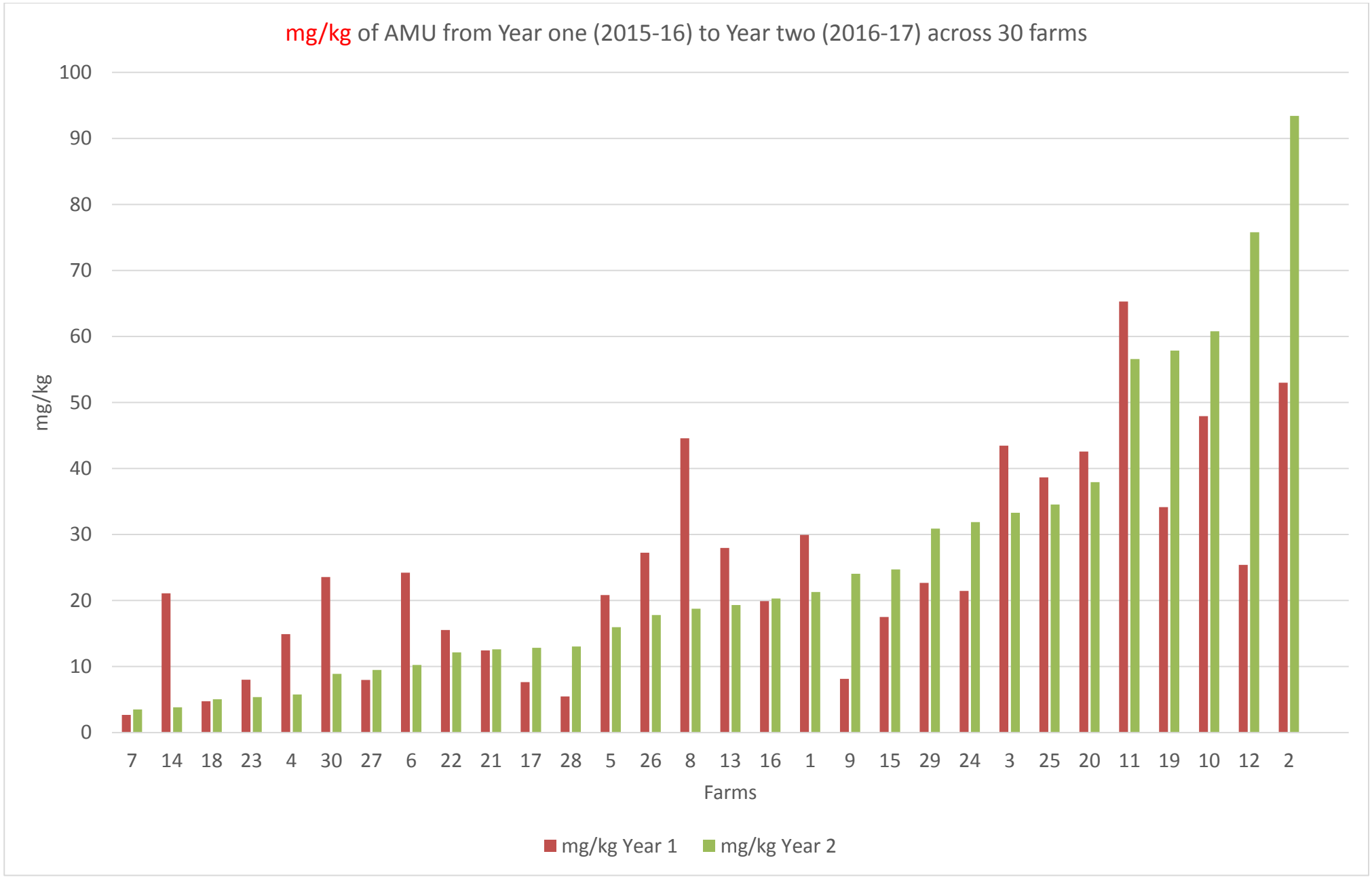
4.4. Reducing AMU

4.4.1. Medicine Reviews

Each participating farm had two consecutive years' medicine usage compared during the FAG study. The first year of data was analysed and presented back to participants in a farmer-friendly report (see thesis Appendix). This data was also used as the basis for discussion at each farm's first FAG meeting (Phase One). This was similar to the Stable Schools, which utilised herd health data for their farmer discussions (Vaarst et al., 2007b). Once enough data had been collected and at the request of the participants, benchmarking of AMU was done to allow farmers to see how they compared with other farms in their group, as well as the rest of the farms in the project. No benchmarking was done with farms outside of the project. UK averages for AMU (based on the VARSS reports for each corresponding year) were included in the reports to give farmers a sense of where they stood nationally; this was at the request of the participants. After two years of FAG meetings and data collection, the second year's medicine usage was calculated, and each farm was again benchmarked. Some farms received this data at their Phase Two FAG meeting. Many farms did not

receive this data until the finale meeting in July 2018, however. This was because many hosted a second time within a year of their first meeting, so the second 12 months had not yet elapsed. Figure eight shows one of the several benchmarking graphs used at the finale meeting depicting total AMU in mg/kg from Year one to Year two of the project. The range in AMU was vast (1mg/kg – 93.4mg/kg in Year two) and reflected a similar range from studies on larger samples in the UK (Hyde et al., 2017). Approximately half of participant farms reduced total AMU over the course of the project, as demonstrated in Figure eight, but there was no statistical difference from Year one to Year two using any of the five chosen metrics.

Figure eight (overleaf) - Example benchmarking graph of total AMU from Year one to Year two of the project across all 30 participant farms using milligrams/kilograms to measure AMU (mg/kg).


mg/kg of AMU from Year one (2015-16) to Year two (2016-17) across 30 farms
100
90
80
70
60
50
40
30
20
10
0
mg/kg
7 14 18 23 4 30 27 6 22 21 17 28 5 26 8 13 16 1 9 15 29 24 3 25 20 11 19 10 12 2
Farms
mg/kg Year 1
mg/kg Year 2

In contrast to total AMU, HPCIA use reduced across the majority of participant farms from Year one to Year two (n=27). Six farms were not using any HPCIAs from the start and many eliminated HPCIA usage completely after one year of the project. Figure nine demonstrates the reduction in HPCIA usage as measured in two different metrics. The difference in HPCIA usage from Year one to Year two using ADD was statistically significant (p = 0.015) whereas it was not statistically significant using mg/kg (p = 0.155).

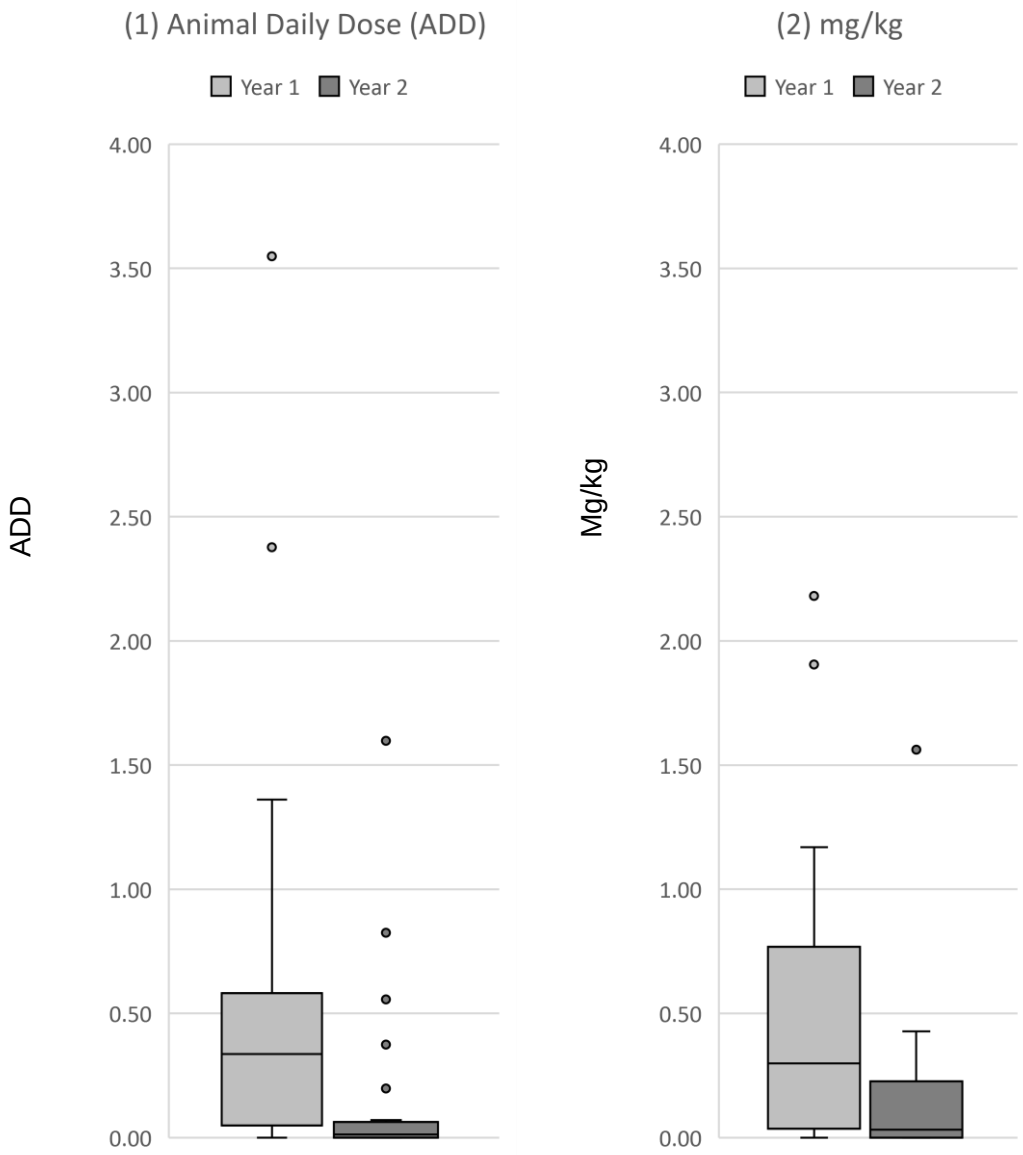


Figure nine – HPCIA usage measured in Animal Daily Doses (1) and mg/kg (2) from year one (light grey) compared to year two (dark grey) across all participant farms.

Two farms had substantial increases in their HPCIA usage over the course of the project and this was traced back to veterinary prescribing choice. The farmers reported trying to avoid the products they were prescribed and questioning their veterinarians on which products they were sold.

Measuring AMU was deemed necessary in this participatory project as a way of assessing any change in the target topic over the course of the study. Measuring AMU in the food-producing sector is not only important but has become an expectation to track and demonstrate reductions, as suggested by O'Neill (O'Neill, 2015) and commonly practiced across Europe (ECDC et al., 2015). A detailed review allowed the researcher and participants to actively keep track of changes not only in total AMU, but also in the types of antimicrobials used (i.e. moving away from HPCIAs to first-line antibiotics). This added an element of collective accountability which contributed to action. The Medicine Review data evolved to become a discussion tool to support the farmer's learning.

Total AMU was measured using various metrics (see 3.4.5) but the HPCIAs became the primary focus as a first step in the effort to demonstrate responsible AMU and equip farmers with the knowledge to become responsible users of antimicrobials.

> *"I've definitely learnt quite a lot from doing this and it does make me think when I use stuff, is it critically important?" FAGC1*

The study duration was only two years and meaningful changes to total AMU were not anticipated by participants whilst changing types of antimicrobials used on farm (see thesis for further discussion). Only Animal Daily Doses (ADD) and mg/kg are included here for discussion.

There are many limitations to measuring AMU and a detailed published account of the general limitations can be found in (Mills et al., 2018). It is worth noting four main issues pertinent to the particulars of this study though. Firstly, the data collected for the medicine reviews presented in this chapter covers only two consecutive years - 2015/2016 and 2016/2017. The farmer participants were quick to point out the low value in this when switching antimicrobial products with differing dosages. They would have preferred to see several years of data or the continuation of the medicine review process. Many participants saw their total AMU increase in year two when measured in milligram metrics as many farmers were switching from using products such as marbofloxacin or ceftiofur (i.e. HPCIAs), which tend to have lower dosages and concentrations (see Figure eight). Thus, when measuring AMU using weight-based metrics such as milligrams, the outcome can be falsely lowered by using products that are higher risk to human health i.e. marbofloxacin – a HPCIA.

Secondly, the inclusion of antimicrobials in addition to just antibiotics in the Medicine Reviews differed to many other measures of AMU occurring in the industry at the time (VMD, 2018). This study included products such as 'Halocur' (Halofuginone) and topicals where relevant information existed. This could skew the dose metrics (i.e. ADD) due to reflecting blanket treatments of calves in the case of 'Halocur' but changes mg/kg metrics very little. It did, however, lead to discussions

within the FAGs on controlling cryptosporidium. It is the view of the author that all antimicrobials should be included not just antibiotics.

Thirdly, collection of complete veterinary sales data for all 30 farms was not possible. Three farms had their total AMU based on their medicine book as recorded by themselves. This has been shown to be a less reliable source of medicine data compared to veterinary sales data (Rees et al., 2018) and thus could have resulted in falsely lower AMU on these three farms than if veterinary sales data had been used.

The Medicine Reviews for each farm were compiled using a combination of veterinary sales data, on-farm medicine records supplemented with discussion with individual farmers. This meant that farm-specific course lengths and daily doses for many antimicrobials, particularly intra-mammary tubes could be ascertained instead of relying on data sheet recommendations. Farm-specific course lengths often differed substantially from the data sheet and affected the way the metrics were calculated. For more on this please see (Mills et al., 2018)

The final limitation to note is that the Medicine Reviews reflect a change in AMU on participating farms that was subject to multiple factors and drivers e.g. veterinary advice, media pressure etc. The FAGs were not the sole cause of the observed changes and this was not a study to establish this relationship. The other sources of data described above alongside these results suggest the project had a supportive and critical role to play in helping farms change their practices around AMU but were not solely responsible.

5. Conclusions

The FAG project was a participatory intervention study that aimed to change farm practices around using antimicrobials, preventing disease and general improvements to herd health and welfare for the long-term reduction in AMU. The FAGs have helped farmers identify, commit to and achieve changes on their individual farms through the facilitated process of Action Planning and peer-to-peer support. The changes on farm, reductions in AMU and experience of being participants have been documented, analysed and triangulated in order to evaluate the impact this approach had in supporting these changes and the adoptability of the methodology in a wider context.

The evidence collected from this study has shown that for all participants there were positive changes made on their farms to reduce the need for antimicrobials, as well as direct changes to how antimicrobials were used. All participants changed at least one thing based on their Action Plans. Across all farms, 54.3% of the average AP was partially or fully implemented by the project conclusion. The majority of farms reduced or eliminated HPCIAs (n=27) and approximately half of participant farms reduced total AMU from year one to year two of the study, although any direct cause and effect relationship has not been established and these changes in AMU are likely to be multi-factorial. Participants changed their practices around using antimicrobials (e.g. dosing correctly, avoiding use of HPCIAs), preventing disease (e.g. improvements to cow and calf housing), and had more discussions with their veterinarians.

Participants learnt more about HPCIAs, AMR, AMU and how to improve their farm from the participatory mechanisms of the FAGs. The intervention revealed a gap in their knowledge, which participants deemed essential knowledge to have as administrators of antimicrobials on farm, and was not forthcoming from many veterinarians at the time of the study. This knowledge was provided by the primary researcher in a facilitatory capacity at the farmers' request. The role of facilitation in co-ordinating and supporting the FAGs was key and was voiced by participants as a critical part of the knowledge mobilisation process. This movement of knowledge in a participatory environment has been termed knowledge mobilisation in this study. It was a critical factor in empowering participating farmers and helping them to change certain practices.

The knowledge sharing and practicalities of seeing and hearing from other farmers gave participants confidence to trial new things, which were laden with risk and uncertainty (e.g. delaying antibiotic treatments to allow for self-cures). They felt part of a peer group that was going through the same challenges at the same time (e.g. the groups earnt the nickname "Antibiotics Anonymous"). They also made new friendships, which could prove beneficial for social resilience in an uncertain future (Darnhofer et al., 2010). The sense of solidarity farmers experienced played a vital role in fostering change on farms, empowering them in the food supply chain (i.e. encouraging discussions with

others in the industry to include veterinarians) and has supported them to become antibiotic stewards by reducing the use of and need for antimicrobials on their individual farms.

The feedback from farmers was overwhelmingly positive and many want to see the approach scaled-up and widely adopted. The level of attendance at the FAG meetings and engagement with the study demonstrated a high level of participation, hence the project proved to be of value to farmers. Farmers' participation in this learning journey enhanced their positions in their wider community by arming them with an 'AMS knowledge-edge' and the confidence that arose from collective action.

The results from this research support the rationales for adopting a PAR methodology. PAR often stems from an inequality of power within a society or community (Cornwall and Jewkes, 1995). It could be argued that farmers are vulnerable to imbalances in the supply chain as end users that have to deal with risk on a daily basis (Meuwissen et al., 2001). Vulnerable or disempowered communities have been said to be weaker and find it more difficult to improve their situation (Chomsky, 2014). This research argues that many of the farmers in this study were not equipped with the necessary knowledge to make responsible treatment decisions when the project commenced. Farmers were not often in a strong negotiating position with their milk contract to challenge decisions that seriously affected their ability to improve herd health (i.e. receiving a record-low price for their milk in 2014 – 2015, hindering farm investment). They were also in a weak position to question their veterinarians on treatment and prescribing choices because of a gap in their knowledge on antimicrobials. Consequently, farmers were at a disadvantage in terms of adapting farm practices, infrastructure or treatment protocols, which this project aimed to improve through a bottom-up approach. Until this inequality or imbalance is addressed, then it is arguably difficult to encourage change on farms.

The findings revealed a subtle power differential in the food supply chain, particularly around acceptable knowledge types and knowledge acquisition. Farmers at one end of the food supply chain are being asked to make quite significant changes to their businesses and herds and have a vital role to play in AMS (Hocknell et al., 2018). On the other hand, this research revealed an absence of relevant knowledge to support the required changes and it could be argued that farmers have little negotiating power or control over the environment in which they can make these changes (Meuwissen et al., 2001, Ullah et al., 2016). Farmers are used to dealing with uncertainty (Meuwissen et al., 2001), but does this inherently disempower them?

When using the Arnstein Ladder of Participation as an evaluation of the degree of participation in an initiative, existing attempts to involve farmers in the decisions that shape their markets, contracts and income barely meet the level of 'placation', which is token participation (Arnstein, 1969). Arnstein's typology would argue that having regional farming representatives through which large

companies gather feedback and opinions from their producers, for instance, is not true participation but an attempt to 'placate'. The views of the farmers are not often heeded – they do not have a seat at the executive table making the decisions. A recent stakeholder report into the food supply chain's role in tackling AMR recommends corporate retailers have a fundamental responsibility and more collaborative action could occur (Hocknell et al., 2018). Practitioners of PAR argue that for long-lasting change that people value and carry forward, then more participatory and thus empowering approaches are necessary (Cornwall and Jewkes, 1995, Macdonald, 2012). One potential opportunity could be for large corporates to embrace a more participatory, farmer-led approach to the way they communicate and collaborate with the supply chain, to include farmers. This would then allow farmers to improve their situation and corporate retailers could meet their responsibilities in tackling AMR within the food supply chain.

For the reasons outlined above, this PAR project aimed to empower farmers with (1) knowledge and (2) confidence from a sense of solidarity fostered in the peer-to-peer environment to enable reductions in AMU to occur. These results in combination suggest that a farmer-led, bottom-up approach like the FAG project has a role to play in helping farmers change practices in the UK and there is an argument for including veterinarians and AHDB Dairy in its adoption and delivery (for results on veterinarians see author's thesis). The approach has limitations in that it will not work for all farms on all topics (see thesis for barriers to participation) – there is evidence to suggest there is a selectivity in those who tend to participate. Nonetheless, if a focus on fostering community and a sense of solidarity when going through a process of change, in combination with mobilising knowledge, then there is potential for the approach to work more widely and be scaled-up with success.

Limitations to the findings

Despite the strength in collective action and the benefits farmers experienced from participating, there are some issues to consider. Practices around using antimicrobials and managing the farm may well have changed over the same time period if the intervention had not happened. They may have reduced their AMU or moved away from HPCIAs, despite being in the FAG project. Certainly, many farmers in the UK would be doing that due to milk contract stipulations (van Dijk et al., 2017) or under the supervision of their veterinarians. The media coverage of AMU in farming (Alliance to Save Our Antibiotics, 2014), the pressure on the agriculture industry after the release of the O'Neill report in 2016, the introduction of RUMA AMU targets in 2017 (VMD, 2018) and the enforcement of Red Tractor Farm Assurance guidelines on HPCIA use on farm in 2018, have all played a part in affecting on farm practices in this area. This participatory intervention is in addition to that and only part of the process of change. Therefore, the changes farmers have made and documented as part of this study can only in part be attributed to participating. This research does not claim any simple and direct relationships between participating in a FAG and the evidenced reductions in AMU or

changes to practice. The farms might not have made as many changes as discussed or felt as empowered and confident to change their practices without the help of the project. Nevertheless, it has not been the remit of this study to extract and quantify the individual influence of each factor on farmer behaviour, or to assign each change or reduction in AMU to the FAGs only.

One aspect missing from this intervention, which is arguably crucial for most interventions, is a control group. This intervention was not about comparing what these farmers did to those who did not participate in these groups; a control would be needed for this comparison to be made. This was about seeing if the participatory process can empower and motivate farmers to make changes on farm that they said they would do. The interest and emphasis was not on how they compare to other farmers generally (which we know will be vastly different when it comes to attitudes, beliefs, habits, support networks etc), but how they compared with themselves over time. What did they change once they participated in the project? How many things were altered and adapted since commencing the participatory journey that they said they were going to adapt or change? These were the questions that the intervention aimed to answer, not how effective this approach is for all farmers compared to all other techniques, which would require much more funding and time to answer!

Future work

As discussed in the introduction, there are calls in the literature for more participatory methodologies and multi-pronged approaches to today's complex challenges. At a European level, EIP AGRI (European Innovation Programme for Agricultural Productivity and Sustainability) has encouraged and championed a multi-actor approach using the Interactive Innovation Model to solve farm-level problems through Operational Groups (https://ec.europa.eu/eip/agriculture/). The FAGs share many similarities with this international initiative. A farmer-led, participatory approach is well positioned here to tackle the complexity of antimicrobial stewardship. It embraces the holistic nature of farming and gives a voice to all actors, which can bring valuable lessons and motivation to achieve solutions as reported in the EIP AGRI evaluation report (Fotheringham et al., 2016). Nevertheless, further involvement of all actors and aligned industries to farmers would be potentially fruitful. The inclusion of the veterinary profession at farmer meetings (particularly on the topic of AMS) could be an area of further research. The role and affect veterinarians or other advisors have on the functioning of a farmer-led group should be investigated. The use of facilitated group work within veterinary practices may also yield some interesting results in terms of reducing AMU and responsible prescribing.

There are many ways in which to get farmers (and veterinarians) to reduce AMU and to use antimicrobials more responsibly (e.g. online courses in partnership with veterinarians, milk contract stipulations). Different people will need different approaches (Rose et al., 2018). A multitude of options are needed to enable, motivate, and support changes in practice on farm. This research argues that for practical changes to solve complex challenges that farmers really value and persist

with, then a participatory approach can be very productive and should be built into future agriculture policy. This would allow farmers to meet legislative requirements or tackle future challenges in farming by accessing a facilitator that would help mobilise multi-actor groups within a participatory framework to realise a common goal. This ties in nicely with the goals set out by EIP AGRI and is similar to the obligatory health advisory service using Stable Schools in Denmark (Vaarst and Fisker, 2013).

6. Industry messages

6.1. Farmer Action Groups: scaling-up

The Farmer Action Groups (FAGs) demonstrated that when small groups of farms worked together to achieve a common goal, such as reducing Antimicrobial Use (AMU), then practical, valuable changes can occur on farm. Through regular farm visits and peer support from other farmers (especially on topics that involved an element of risk and uncertainty such as altering treatment protocols), the FAGs co-created and implemented multiple practical solutions to the challenge of responsible AMU. The FAGs reduced the use of Highest Priority Critically Important Antibiotics (HPCIAs) and made numerous changes to cow housing, calf health and the management of conditions such as lameness. Farmers in the study found the experience an essential part in building their confidence to change the way they used antimicrobials and reduced their reliance on them. With the guidance of a credible facilitator, the exchange of knowledge empowered farmers to make significant improvements to their herd and farm business. The sharing of experiences in a group with like-minded farmers created a sense of solidarity that helped them to learn, adapt and improve their own practices on farm, instead of a culture of blame or being made to change due to external pressure. The results from this study show that this approach works well to support change on farms and should be incorporated into future agriculture policy, similar to Denmark. The authors are calling for funding from government for facilitation to help mobilise and support future Farmer Action Groups on a whole host of issues, not just AMU. AHDB, vets and other advisory services could be delivery partners of the approach with adequate training in facilitation for action.

7. References

ALLIANCE TO SAVE OUR ANTIBIOTICS, C. 2014. Antimicrobial resistance why the irresponsible use of antibiotics in agriculture must stop. UK.

ARNSTEIN, S. R. 1969. A ladder of citizen participation. *Journal of American Planning Association,* 35**,** 216 - 224.

ATKINSON, O. 2010. Communication in farm animal practice 1. Farmer-vet relationships. *In Practice,* 32**,** 114.

B.A. WALL, A. M., L. MARSHALL AND D.U. PFEIFFER 2016. FAO. 2016. Drivers, dynamics and epidemiology of antimicrobial resistance in animal production. *In:* NATIONS, F. A. A. O. O. T. U. (ed.). Rome.

BARNES, A. P., TOMA, L., WILLOCK, J. & HALL, C. 2013. Comparing a 'budge' to a 'nudge': Farmer responses to voluntary and compulsory compliance in a water quality management regime. *Journal of Rural Studies,* 32**,** 448-459.

BAUM, F., MACDOUGALL, C. & SMITH, D. 2006. Participatory action research. *J Epidemiol Community Health,* 60**,** 854-7.

BENNEDSGAARD, T. W., KLAAS, I. C. & VAARST, M. 2010. Reducing use of antimicrobials — Experiences from an intervention study in organic dairy herds in Denmark. *Livestock Science,* 131**,** 183-192.

BRADLEY, M. G. A. 2013. Mastitis- The changing face of mastitis control. *Veterinary Record.*

BROGUE, P. 2013. Impact of Participation in Teagasc Dairy Discussion Groups Evaluation Report January 2013.

BURTON, R. J. F. 2004. Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. *Journal of Rural Studies,* 20**,** 359-371.

CHAMBERS, R. & GHILDYAL, B. P. 1985. Agricultural Research for resource-poor farmers: The Farmer-First-and-Last model. *Agricultural Administration,* 20**,** 1 - 30.

CHOMSKY, N. 2014. *Power Systems. Conversations with David Barsamian on global democratic uprisings and the new challenge to US empire*, Penguin.

COLLIGNON, P. 2015. Antibiotic resistance: are we all doomed? *Intern Med J,* 45**,** 1109-15.

COLLIGNON, P. C., CONLY, J. M., ANDREMONT, A., MCEWEN, S. A., AIDARA-KANE, A. & WORLD HEALTH ORGANIZATION ADVISORY GROUP, B. M. O. I. S. O. A. R. 2016. World Health Organization Ranking of Antimicrobials According to Their Importance in Human Medicine: A Critical Step for Developing Risk Management Strategies to Control Antimicrobial Resistance From Food Animal Production. *Clin Infect Dis,* 63**,** 1087-93.

CONROY, C. 2005. *Participatory Livestock Research. A guide*, ITDG Publishing.

CORNWALL, A. & JEWKES, R. 1995. What is participatory research? *Social Science & Medicine,* 41**,** 1667-1676.

DARNHOFER, I., BELLON, S., DEDIEU, B. & MILESTAD, R. 2010. Adaptiveness to enhance the sustainability of farming systems. A review. *Agronomy for Sustainable Development,* 30**,** 545-555.

DERKS, M., VAN WERVEN, T., HOGEVEEN, H. & KREMER, W. D. J. 2014. Associations between farmer participation in veterinary herd health management programs and farm performance. *Journal of Dairy Science,* 97**,** 1336-1347.

DIJK, L. V., BULLER, H., MACALLISTER, L. & MAIN, D. 2017. Facilitating practice-led co-innovation for the improvement in animal welfare. *Outlook on agriculture,* 46**,** 131 - 137.

DODUNSKI, G. 2014. Knowledge transfer to farmers. *Small Ruminant Research,* 118**,** 103-105.

DOWN, P. M., BRADLEY, A. J., BREEN, J. E., HUDSON, C. D. & GREEN, M. J. 2016. Current management practices and interventions prioritised as part of a nationwide mastitis control plan. *The Veterinary Record,* 178**,** 449.

ECDC, EFSA & AGENCY), E. E. M. 2015. ECDC/EFSA/EMA first joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals. *EFSA Journal,* 13.

ENTICOTT, G., DONALDSON, A., LOWE, P., POWER, M., PROCTOR, A. & WILKINSON, K. 2011. The changing role of veterinary expertise in the food chain. *Philos Trans R Soc Lond B Biol Sci,* 366**,** 1955-65.

ESCOBAR, M. P. & DEMERITT, D. 2016. Paperwork and the decoupling of audit and animal welfare: The challenges of materiality for better regulation. *Environment and Planning C: Government and Policy,* 0**,** 1 - 22.

ESCOBAR;, M. P. & BULLER;, H. 2013. Projecting Social Science into Defra's Animal Welfare Evidence Base: A review of current research and evidence gaps on the issue of farmer behaviour with respect to animal welfare. *In:* DEFRA (ed.). UK: © Queen's Printer and Controller of HMSO 2013.

FAO AND THE FARMER FIELD PROMOTION SERVICES, N. 2013. Pastoralists Field Schools. Training of Facilitators Manual. *In:* NATIONS, F. A. A. O. O. T. U. (ed.). Rome.

FERNER, C., OBRITZHAUSER, W., FUCHS, K. & SCHMEROLD, I. 2014. Development and evaluation of a system to assess antimicrobial drug use in farm animals: results of an Austrian study. *Vet Rec,* 175**,** 429.

FIELDING, N. G. G. C. A. C. A. C. J. 2001. *Researching Social Life. Second edition*, SAGE publications.

FINLEY, R. L., COLLIGNON, P., LARSSON, D. G., MCEWEN, S. A., LI, X. Z., GAZE, W. H., REID-SMITH, R., TIMINOUNI, M., GRAHAM, D. W. & TOPP, E. 2013. The scourge of antibiotic resistance: the important role of the environment. *Clin Infect Dis,* 57**,** 704-10.

FIORET, C., JOHNSON, K., LAM, S., THOMPSON, M. & HARGREAVES, S. K. 2018. Towards farmer-led research: A guidebook. Guelph, Ontario: Ecological Farmers Association of Ontario.

FOTHERINGHAM, J., HETHERINGTON, A., KOBILSKY, A., ROHMER, B., CHEVER, T., RENAULT, C., ROMIEU, V., CARILLO, J., GIAMBENEDETTI, G., VUKOVIC, M., COLLISON, M. & KUEHNEMUND, M. 2016. Evaluation study of the implementation of the European Innovation Partnership for Agricultural Productivity and Sustainability. *In:* COMMISSION, E. (ed.). Coffey.

GREY, S. & GORDON, N. 2018. Approaches to Measuring Attendance and Engagement. *New Directions in the Teaching of Physical Sciences,* Volume 13.

HEUER, O. E., HAMMERUM, A. M., COLLIGNON, P. & WEGENER, H. C. 2006. Human health hazard from antimicrobial-resistant enterococci in animals and food. *Clin Infect Dis,* 43**,** 911-6.

HOCKNELL, S., HUGHES, A., ROE, E., KEEVIL, B., WRIGLEY, N. & LOWE, M. 2018. Corporate Food Retailers, Meat Supply Chains, and the Responsibilities of Tackling Antimicrobial Resistance STAKEHOLDER REPORT 2018. University of Newcastle, University of Southampton, Food Standards Agency.

HORIGAN, V., KOSMIDER, R. D., HORTON, R. A., RANDALL, L. & SIMONS, R. R. 2016. An assessment of evidence data gaps in the investigation of possible transmission routes of extended spectrum beta-lactamase producing Escherichia coli from livestock to humans in the UK. *Prev Vet Med,* 124**,** 1-8.

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.

IBRAHIM, O. M. & POLK, R. E. 2014. Antimicrobial use metrics and benchmarking to improve stewardship outcomes: methodology, opportunities, and challenges. *Infect Dis Clin North Am,* 28**,** 195-214.

JANSEN, J., STEUTEN, C. D. M., RENES, R. J., AARTS, N. & LAM, T. J. G. M. 2010. Debunking the myth of the hard-to-reach farmer: Effective communication on udder health. *Journal of Dairy Science,* 93**,** 1296-1306.

JENSEN, V. F., JACOBSEN, E. & BAGER, F. 2004. Veterinary antimicrobial-usage statistics based on standardized measures of dosage. *Prev Vet Med,* 64**,** 201-15.

KIRCHHELLE, C. 2018. Pharming animals: a global history of antibiotics in food production (1935–2017). *Palgrave Communications,* 4.

KNETSCH, C. W., CONNOR, T. R., MUTREJA, A., VAN DORP, S. M., SANDERS, I. M., BROWNE, H. P., HARRIS, D., LIPMAN, L., KEESSEN, E. C., CORVER, J., KUIJPER, E. J. & LAWLEY, T. D. 2014. Whole genome sequencing reveals potential spread of Clostridium

difficile between humans and farm animals in the Netherlands, 2002 to 2011. *Euro Surveill,* 19**,** 20954.
KRISTENSEN, E. & ENEVOLDSEN, C. 2008. A mixed methods inquiry: How dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program. *Acta Veterinaria Scandinavica,* 50**,** 50-50.
KUMAR, S. 2002. *Methods for Community Participation. A Complete Guide for Practitioners*, Practical Action Publishing.
LACY, J. 2011. Cropcheck: Farmer benchmarking participatory model to improve productivity. *Agricultural Systems,* 104**,** 562-571.
LOWE, P. 2009. Unlocking_Potential.
LOWE, P., PHILLIPSON, J., PROCTOR, A. & GKARTZIOS, M. 2019. Expertise in rural development: A conceptual and empirical analysis. *World Development,* 116**,** 28 - 37.
MACDONALD, C. 2012. Understanding Participatory Action Research: A qualitative research methodology option. *Canadian Journal of Action Research,* 13**,** 34 -50.
MAIN, D. C. J., LEACH, K. A., BARKER, Z. E., SEDGWICK, A. K., MAGGS, C. M., BELL, N. J. & WHAY, H. R. 2012. Evaluating an intervention to reduce lameness in dairy cattle. *Journal of Dairy Science,* 95**,** 2946-2954.
MEUWISSEN, M. P. M., HARDAKER, J. B., HUIRNE, R. B. M. & DIJKHUIZEN, A. A. 2001. Sharing risks in agriculture; principles and empirical results. *Netherlands Journal of Agricultural Science,* 49**,** 343 - 356.
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.
O'NEILL, J. 2015. Antimicrobials in agriculture and the environment, reducing uncessary use and waste. *In:* O'NEILL, J. (ed.) *Review on Antimicrobial Resistance.* London: Wellcome Trust, HM Government.
ORGANIZATION, W. H. 2015. Global Action Plan on Antimicrobial Resistance. *In:* ORGANIZATION, W. H. (ed.). Switzerland.
POSTMA, M., SJOLUND, M., COLLINEAU, L., LOSKEN, S., STARK, K. D., DEWULF, J. & CONSORTIUM, M. 2015. Assigning defined daily doses animal: a European multi-country experience for antimicrobial products authorized for usage in pigs. *J Antimicrob Chemother,* 70**,** 294-302.
PRETTY, J. N. 1995. Participatory learning for sustainable agriculture. *World Development,* 23**,** 1247 - 1263.
REES, G., BARRETT, D., BULLER, H., MILLS, H. & REYHER, K. 2018. Storage of prescription veterinary medicines on UK dairy farms: a crosssectional study. *The Veterinary Record*.
RICHARDS, L. 2009. *Second Edition. Handling Qualitative data. A Practical Guide*, SAGE publications.
RITTER, C., JANSEN, J., ROCHE, S., KELTON, D. F., ADAMS, C. L., ORSEL, K., ERSKINE, R. J., BENEDICTUS, G., LAM, T. & 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.
RITTER, C., JANSEN, J., ROTH, K., KASTELIC, J. P., ADAMS, C. L. & BARKEMA, H. W. 2016. Dairy farmers' perceptions toward the implementation of on-farm Johne's disease prevention and control strategies. *J Dairy Sci,* 99**,** 9114-9125.
ROSE, D. C., KEATING, C. & MORRIS, C. 2018. Understand how to influence farmers' decision-making behaviour
a social science literature review. Agriculture and Horticulture Development Board.
SCOTT, H. M., MIDGLEY, G. & LONERAGAN, G. H. 2015. Antimicrobials in animal agriculture: parables and policy. *Zoonoses Public Health,* 62 Suppl 1**,** 3-9.
SHERSON, D.I., G., J.I., R. & J., G. The Facilitation of Learning Groups: A Study of a Dairy Discussion Group Facilitator. 13th International Farm Management Congress Wageningen, 2002 Netherlands.
SNOO, G. R. D., LOKHURSTT, A. M., DIJK, J. V. & MUSTERS, C. J. M. 2010. Benchmarking biodiversity performances of farmers. *Aspects of Applied Biology,* 100.

SPEKSNIJDER, D. C., JAARSMA, D. A., VERHEIJ, T. J. & WAGENAAR, J. A. 2015a. Attitudes and perceptions of Dutch veterinarians on their role in the reduction of antimicrobial use in farm animals. *Prev Vet Med,* 121**,** 365-73.

SPEKSNIJDER, D. C., MEVIUS, D. J., BRUSCHKE, C. J. & WAGENAAR, J. A. 2015b. Reduction of veterinary antimicrobial use in the Netherlands. The Dutch success model. *Zoonoses Public Health,* 62 Suppl 1**,** 79-87.

STOECKER, R. 2012. Communitybased research and the two forms of social change. *Journal of Rural Social Sciences,,* 27**,** 83 - 98.

SUMNER, C. L., VON KEYSERLINGK, M. A. G. & WEARY, D. M. 2018. How benchmarking motivates farmers to improve dairy calf management. *J Dairy Sci,* 101**,** 3323-3333.

TANG, K. L., CAFFREY, N. P., NÓBREGA, D. B., CORK, S. C., RONKSLEY, P. E., BARKEMA, H. W., POLACHEK, A. J., GANSHORN, H., SHARMA, N., KELLNER, J. D. & GHALI, W. 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**,** e316-e327.

ULLAH, R., SHIVAKOTI, G. P., ZULFIQAR, F. & KAMRAN, M. A. 2016. Farm risks and uncertainties: Sources, impacts and management. *Outlook on Agriculture,* 45**,** 199 - 205.

VAARST, M. 2011. Minimising medicine use in organic dairy herds through animal health and welfare planning ANIPLAN FINAL REPORT. Denmark.

VAARST, M., ALBAN, L., MOGENSEN, L., MILAN, S., THAMSBORG & KRISTENSEN, E. S. 2001. Health and welfare in Danish dairy cattle in the transition to organic production: Problems, priorities and perspectives. *Journal of Agricultural & Environmental Ethics,* 14**,** 367-390.

VAARST, M., BENNEDSGAARD, T. W., KLAAS, I., NISSEN, T. B., THAMSBORG, S. M. & OSTERGAARD, S. 2006. Development and daily management of an explicit strategy of nonuse of antimicrobial drugs in twelve Danish organic dairy herds. *J Dairy Sci,* 89**,** 1842-53.

VAARST, M., BYARUGABA, D. K., NAKAVUMA, J. & LAKER, C. 2007a. Participatory livestock farmer training for improvement of animal health in rural and peri-urban smallholder dairy herds in Jinja, Uganda. *Trop Anim Health Prod,* 39**,** 1-11.

VAARST, M. & FISKER, I. 2013. Potential contradictions connected to the inclusion of stable schools in the legislation for Danish organic dairy farms. *Open Agriculture Journal,* 7**,** 118-124.

VAARST, M., NISSEN, T. B., OSTERGAARD, S., KLAAS, I. C., BENNEDSGAARD, T. W. & CHRISTENSEN, J. 2007b. Danish stable schools for experiential common learning in groups of organic dairy farmers. *J Dairy Sci,* 90**,** 2543-54.

VAARST, M., PAARUP-LAURSEN, B., HOUE, H., FOSSING, C. & ANDERSEN, H. J. 2002. Farmers' choice of medical treatment of mastitis in Danish dairy herds based on qualitative research interviews. *J Dairy Sci,* 85**,** 992-1001.

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 Anti-Microbial use on Farms. *Zoonoses Public Health,* 64**,** 476-484.

VMD 2018. UK Veterinary Antibiotic Resistance and Sales Surveillance Report (UK-VARSS 2017). *In:* VETERINARY MEDICINES DIRECTORATE, A. A. P. H. A. (ed.). UK.

WENGER, E. 1998. *Communities of Practice. Learning, Meaning and Identity. Learning in doing: Social, cognitive and computational perspectives*, Cambridge University Press.