Factors influencing pig farmers' perceptions and attitudes towards antimicrobial use and resistance

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Abstract

Background: Antimicrobial resistance (AMR[1]) is of increasing concern in livestock production as usage has been linked to the emergence of resistant bacteria in humans. The intricacies of the UK pig production system alongside limited research into farmers perceptions has highlighted the need to investigate farmers perceptions and attitudes to gain an understanding of the factors that influence antimicrobial use (AMU[2]). Therefore, this study aimed to qualitatively explore pig farmers views of AMU, AMR and to identify the specific factors that influence antibiotic administration practices in the UK pig industry.

Methods: 15 semi-structured interviews were conducted with independent pig farmers in Northern Ireland and vertically integrated pig farmers in England, eliciting perceptions towards AMU and AMR and exploring administration practices. The interviews were professionally transcribed and coded using thematic analysis.

Results: Eight themes were identified that influenced pig farmers AMU: (1) knowledge and awareness of AMR; (2) disease and perceived need for treatment; (3) use of alternatives; (4) farm characteristics; (5) economic considerations; (6) veterinary surgeon-farmer relationship; (7) external pressures and (8) production stage.

[1] Antimicrobial resistance
[2] Antimicrobial use

Conclusions: Our findings highlight the complexity of the UK pork industry and the myriad of factors that drive AMU. AMU in the pork sector is multifactorial as drivers of administration are diverse and differ between farms. Therefore, it is recommended that farms are assessed on an individual basis in collaboration with a veterinary surgeon to determine the most effective tailor-made antibiotic reduction techniques.

Keywords: Antimicrobial resistance, perceptions, farmer, antibiotics, pig

1. Introduction

As awareness of antimicrobial resistance (AMR) has increased over the years, prudent and responsible antimicrobial use (AMU) in both human and veterinary medicine has been placed at the forefront of risk mitigation (Sadiq et al., 2018). For decades antibiotics have been used within livestock production to maintain healthy stock and increase productivity (Lekagul et al., 2019). Although the debate concerning the potential zoonotic transfer of resistant bacteria and the risks this may pose to human health is ongoing, it remains clear that the animal sector is a high user of antibiotics (Coyne et al., 2016; Ekakoro et al., 2019); responsible for an estimated 70% of antibiotic consumption in Europe (Lekagul et al., 2020). Within the UK, it is the pig industry that is of particular concern due to its intensive nature, using more antimicrobials than other livestock sectors (Coyne et al., 2019). AMU typically varies between countries, species, production systems and individual farm (Hockenhull et al., 2017); and this is evident within British pig production due to the unique and varied production structure in the UK (Coyne et al., 2019). Comprising both indoor and outdoor systems, straw-based and slatted accommodation, and with outdoor systems accounting for 40% of pig production, these farmers face a diverse range of challenges specific to the UK pig sector (ter Beek, 2010; Garforth et al., 2013).

A plethora of research has sought to investigate and quantify AMU in pig production (Stevens et al., 2007; van der Fels-Klerx et al., 2011; Jensen et al., 2012; Bos et al., 2013; van Rennings et al., 2015;

Arnold et al., 2016); particularly at certain stages of production when antibiotics are commonly used (i.e. weaning and farrowing) (Casal et al., 2007; Callens et al., 2012; Backhans et al., 2016; Sjölund et al., 2016; Scoppetta et al., 2017). In addition, various studies have focused on disease risk mitigation (Hybschmann et al., 2011; Hall and Wapenaar, 2012; Berriman et al., 2013; Garforth et al., 2013; Alarcon et al., 2014) as a means to reduce AMU, thus, the proliferation of resistant bacteria (Jensen et al., 2014; Aarestrup, 2015; Postma et al., 2016). However, to gain an insight into the behaviours and factors that motivate antibiotic administration, it is imperative to understand farmers perceptions and attitudes towards AMU. Research that has investigated farmers perceptions is, in part, quantitative in design (i.e. descriptive, experimental, correlational) (Visschers et al., 2014; Visschers et al., 2015; Kramer et al., 2017; Sadiq et al., 2018; Ozturk et al., 2019); and of the limited qualitative research available (Friedman et al., 2007; Moreno, 2014; Chauhan et al., 2018; Di Martino et al., 2018; Lekagul et al., 2020), few address the factors that directly influence on farm AMU (Jones et al., 2015; McDougall et al., 2016; Ekakoro et al., 2019); especially within the UK pork industry (Coyne et al., 2014; Bokma et al., 2018; Coyne et al., 2019).

The complexity of the UK pig production system coupled with limited research into farmers perceptions and AMU practices, has highlighted the need to investigate farmers perceptions and attitudes to gain an understanding of the factors that influence antibiotic administration. Therefore, the aim of this present study was to qualitatively explore pig farmers views of AMU and AMR and to identify the specific factors that influence their antibiotic administration practices. In depth qualitative interviews were chosen as the method of data collection due to the sensitive subject areas explored and also to allow for maximum clarity and understanding of farmers attitudes and opinions, eliciting as much detailed information as possible. In addition, by uncovering farmers behaviours and AMU practices, a true assessment can be made to determine if this sector is using antibiotics responsibly and if they have implemented appropriate practices to meet reduction targets (Hockenhull et al., 2017). These findings will not only address current motivators of AMU within the pork industry, but they will also optimise the design and implementation of targeted interventions to effectively minimise AMU and encourage stewardship nationwide.

2. Methods

2.1 Participant selection

Participants from Northern Ireland (NI) and England were recruited using purposive and snowball sampling to take part in a semi-structured interview. The recruitment methods included face-to-face and telephone invitations. Every effort was made to include participants from different age groups, educational backgrounds and from farms of different size, type and pig-rearing system to capture a range of views. In total, fifteen participants were interviewed (Table 1). All participants provided informed verbal consent and the study was approved by an Ethical Committee.

2.1.1 Vertically integrated and independent farmers

In order to attain a wide range of views, participants were selected from independent farms in NI and from a vertically integrated food producing company in England. Vertical integration in livestock production refers to the amalgamation of two or more stages within the production of a single commodity at any point between the farm supplier and final retailer (Dunbar, 1958). For the purposes of this paper, the term 'vertically integrated' will be used to denote farmers in vertically integrated commercial pig production. Vertically integrated farmers were chosen as it was considered that they could provide valuable insights relevant to the area of research being investigated. In addition, by exploring the perceptions of farmers from different systems, it provides a more wholly formed understanding of the sector, capturing the variations and complexities within the UK pork industry.

Table 1: Characteristics of interview participants

Characteristic	**N = 15**

		N	%
Country	Northern Ireland	9	60
	England	6	40
Gender	Male	15	100
	Female	0	0
Age group	18 – 30	0	0
	31 – 45	8	53
	46 – 64	6	40
	65 +	1	7
Highest Education level	Primary school	2	13
	Secondary school	2	13
	Additional training	5	33
	Undergraduate university	3	20
	Postgraduate university	1	7
	Prefer not to say/unrecorded	2	13
Length of time farming (years)	1 – 5	0	0
	6 – 10	2	13
	10 +	13	87
Farm size* (independent farms only)	Very small	2	22
	Small	2	22
	Medium	2	22
	Large	2	22
	Very large	1	11

*Business size outlined in the Statistical Review of Northern Ireland Agriculture 2017 by the Department of Agriculture, Environment and Rural Affairs (DAERA, 2018).

2.2 Interview questioning guide

An interview guide of open-ended questions was created based upon a review of previous literature exploring perceptions towards AMU and AMR. The guide was piloted to assess content and clarity,

and appropriate minor modifications were made. The four main topic areas covered were: (1) chain verification; (2) stages of AMU; (3) antibiotics and alternatives and (4) an AMR statement. Questions were designed to elicit participants perceptions towards AMR and AMU in pig production, whilst exploring personal AMU and administration practices (See Table 2). Prompts were used when necessary to redirect discussion and encourage participants to express their views however, free conversation was actively encouraged.

Table 2: Outline of interview questioning guide

Topic	Example Questions
Opening question	• To get started, could you tell me more about your background/experience working within the pork sector? • How long have you been farming?
Chain verification	*(Participants were shown a visual map of the UK pork supply chain)* • Do you think this chain represents the UK pork supply chain? • Would you suggest any changes or modifications to the stages? • The original chain only portrayed three stages of production; breeding, rearing and finishing. Does it seem appropriate to remove the stage 'rearing' and add the processes 'farrowing', 'weaning' and 'fattening' in its place?
Stages of AMU	• When do you think farmers usually use antibiotics? And why? • At what stage/s do you use antibiotics? • Why do you administer antibiotics at these stages? • What age do you wean your pigs? Why? • What would trigger your antibiotic usage at this stage/stages? • Could you talk me through what sort of scenario would make you use antibiotics?

Antibiotics and alternatives	• What do you think are the benefits of using antibiotics on pigs? • Are you aware of any negative factors or drawbacks of antibiotic use on pigs? • Are you aware of any alternatives to antibiotic use? • Do you think these alternatives could be useful? • Are you aware of any drawbacks or negatives associated with using these alternatives? • Do you already use these alternatives and if not, would you be willing to use them?
AMR statement	• What are your thoughts on the following statement? '*Bacteria that we are creating through widespread use of antibiotics in agriculture are increasingly now impacting on human health. There is a link between antibiotic use in farming and increases in resistance in pathogens present in humans. There is a need for greater antibiotic stewardship in agriculture, and for rationalisation of farm use of antibiotics which are particularly prone to causing increased resistance.'*

2.2 Data collection

Interviews were conducted face-to-face between February and June 2019, by the author (HB) at a location most convenient to the participant. Interviewees were given assurances (e.g. that there were 'no right or wrong answers', they could choose not to respond to questions if they felt uncomfortable answering, their anonymity would be kept intact and they could withdraw from the interview at any time) before the interviewer proceeded with the questions (Table 2). Interviews were audio recorded and lasted between 20 and 90 minutes.

2.3 Data analysis

All interviews were professionally transcribed verbatim and coded using a thematic data analysis technique (Braun and Clarke, 2006). A qualitative thematic approach was undertaken to identify emerging themes. Transcripts were reiteratively read and examined to capture relevant concepts and findings of interest to the research. This data was given an initial code to highlight the perceived relevance or content of the extract. The transcripts were independently coded by another researcher (MD) and compared to reach a joint consensus on coding validity and ensure inter-code reliability. Data saturation was perceived to be reached when no new codes emerged from the final five interviews and additional data collection was not considered to yield any supplementary results. Subsequently, codes were grouped by commonality into various themes and organised into a hierarchical structure; broader (major themes) themes were placed at the top while codes at lower levels signified information that was more specific (minor themes). These themes were inspected and refined to ensure distinct communication of interview results. Finally, transcripts were re-examined for thoroughness and key quotes were selected to exemplify each factor influencing AMU.

3. Results

The demographic characteristics of the fifteen interview participants are shown in Table 1.

Eight key themes were identified that influenced pig farmers' practices and behaviour towards AMU: (1) knowledge and awareness of AMR; (2) disease and perceived need for treatment; (3) use of alternatives; (4) farm characteristics; (5) economic considerations; (6) veterinary surgeon-farmer relationship; (7) external pressures and (8) production stage.

(1) Knowledge and awareness of AMR

Participants displayed a high level of awareness towards AMR; however, it was clear that knowledge surrounding AMR was somewhat limited. Farmers discussed AMR as a drawback to agricultural

AMU and there was some concern towards potential negative consequences this usage may have on human health. Generally, vertically integrated farmers demonstrated a higher level of knowledge and awareness than independent farmers as the possibility of AMR transfer through the meat to humans was acknowledged.

"I suppose you have to watch out that you're not using a lot [antibiotics] for food, for resistance." – (Interviewee 2: small-scale independent farmer)

"…we are very similar to pigs…we've got the exact same bodies as pigs and if they're antibiotics going through the pig, and they are, then we're more likely to get it than anything else." – (Interviewee 13: vertically integrated farmer)

Despite this, farmers expressed scepticism and uncertainty as they felt there was a lack of evidence to verify AMR transfer, and also that the limited quantity of antibiotics used in food animal production could not make a substantial contribution.

"I don't think it's by putting in a tiny amount and being in a piece of meat is going to affect us as much as people think." – (Interviewee 13: vertically integrated farmer)

A shared belief among pig farmers was that agricultural AMU is not the sole cause of AMR and therefore, it is not solely responsible for resistance within the human population.

"I think in the world, there are a lot of things that need to be addressed and, like other things, I find that quite often farming gets the blame." – (Interviewee 10: vertically integrated farmer)

"…everybody seems to be wanting to attack the agriculture one [AMU] when, in actual fact, especially in the likes of Northern Ireland, it's very small. I think a lot of it is blown out of proportion." – (Interviewee 9: large-scale independent farmer)

Participants felt targeted as an industry for the emergence and spread of AMR despite having made considerable AMU reductions. Farmers argued that reductions were achieved through a notable evolution within the pork industry; through the introduction of new generation managers, facilitating improvements in performance and a willingness to try new and innovative methods for antibiotic reduction.

"...we have brought the use [AMU] right down. We're always trying new ideas. We've got to move forward. I know in the pig industry ten years ago, about fifteen years ago, we were all well behind. Performance was right down. We were a mile behind Denmark. Bring a load of young managers in and they are willing to try new things. I think that's probably the key. Younger, sometimes they want to try new things and they don't mind." – (Interviewee 11: vertically integrated farmer)

In addition, participants perceived strict adherence to withdrawal periods as a key factor limiting their contribution to AMR.

"...if the withdrawal period is properly adhered to there are no problems and farming cannot be blamed for antibiotic resistance in humans." – (Interviewee 5: very large-scale independent farmer)

Farmers felt that human AMU had led to the proliferation of AMR, within both the medical sector and also due to a lack of adherence to prescribed guidelines, resulting in antibiotic misuse among the general public. Farmers were concerned that general practitioners overprescribe antibiotics and that often the public have certain expectations toward accessing antibiotics.

"People are to blame as well because they might start to feel better halfway through a course and decide to stop taking the antibiotics." – (Interviewee 5: very large-scale independent farmer)

"…I think the biggest thing is free prescriptions. Sneeze twice, go to the doctor, antibiotic. He gives them the cheapest one to get rid of them. They don't need to give you a good antibiotic anymore, they give you one that keeps you quiet and if something's wrong you come back again. Then, you get better after two days and you don't finish the course." – (Interviewee 6: large-scale independent farmer)

However, whilst predominant responsibility of AMR was perceived to lay within the human sector, participants also considered antibiotic misuse within other livestock sectors as the next biggest offender.

"…cattle drugs, they're the ones that are closest to human ones. All these ones that are your second-generation drugs, 95% of them all go into cattle." – (Interviewee 6: large-scale independent farmer)

(2) Disease and perceived need for treatment

Farmers identified a range of benefits and barriers from antibiotic application. In general, they perceived more benefits from using antibiotics compared to drawbacks. Disease treatment, particularly for animal welfare purposes was recognised as a leading factor influencing antibiotic administration. Treatment was perceived as the only appropriate reason for AMU as farmers felt it was their responsibility to help their animals by maintaining health and controlling disease. For this reason, participants perceived their AMU as necessary for production.

"At the end of the day, if what you've in is not working and you've a sick animal, well, you're going to treat it with the antibiotic." – (Interviewee 8: medium-scale independent farmer)

"Would they [general public] want a pig that's suffered and had to be jabbed and had to be having all this in feed medication? Surely, they'd want a healthier pig by us treating them with that rather than the piglet suffering and dying." – (Interviewee 13: vertically integrated farmer)

Participants recognised the identification of signs or symptoms of disease as an imperative step before the administration of antibiotic treatment. A good stockman's eye was believed to be important. Farmers used their own personal knowledge and experience to identify disease and provide treatment.

"...you generally know the symptoms, or you know a sick pig. You would treat it as to what you think it would need." – (Interviewee 1: medium-scale independent farmer)

Disease management was cited as a beneficial outcome of AMU. Farmers spoke of the importance of controlling diseases and the valuable role that antibiotics play in reducing the disease burden, easing both farm management and maintaining pig health and welfare standards. Furthermore, farmers were concerned about the secondary diseases that may occur if a pig remains untreated; and justified the use of antibiotics to manage secondary illnesses, even for viral infections where antibiotics will not work effectively.

"If a pig had blue ear [PRRS] an antibiotic will be required even though it will not kill the virus, it is necessary for the management of secondary disease." – (Interviewee 5: very large-scale independent farmer)

Disease prevention was outlined as a factor affecting AMU. This was dependent on perceived disease burden as participants discussed administering antibiotics to prevent diseases that present recurrently (e.g. meningitis) before the identification of clinical symptoms. In addition, participants mentioned the use of antibiotics for growth promotion. It was noted that applying antibiotics at an early stage before the presentation of disease, aids animal growth.

"I would say there are probably growth advantages, growth promoter. Especially at weaning stage when they're not being checked with an issue…so they're growing on it." – (Interviewee 2: small-scale independent farmer)

In comparison to the vast array of beneficial aspects highlighted, a limited number of drawbacks were identified from the application of antibiotics. Farmers acknowledged antibiotic ineffectiveness whereby the drug chosen for disease treatment doesn't work; and also, the negative impact that antibiotics can have on animal gut health and feed efficiency.

There was an agreement among many participants that antibiotic application would occur as a last resort having exhausted alternative options prior. In addition, participants reported a desire to reduce AMU at both a personal level and as an industry. The projected 2020 target for antibiotic reduction announced by the Responsible Use of Medicines in Agriculture (RUMA) Alliance was considered as a driving factor to decrease both personal AMU and that of the pork industry.

"What are we doing about it [antibiotic reduction]? Can we do something about it? I'm not going to stand here and say I know all the answers. You know, we've got to sit down and say, well, what can we do about it? We're not all perfect, darling, but we'll give it a go." – (Interviewee 15: vertically integrated farmer)

(3) Use of alternatives

Participants often consider alternative measures of AMU when deciding whether or not to administer antibiotics. Of the alternatives mentioned, increased farm management, vaccinations and organic acids were commonly identified. Reponses relating to farm management encompassed high levels of biosecurity and cleanliness on the farm as well as lowering stocking density. Good management was perceived to be an integral aspect of both disease and AMU reduction.

"We give them every-, you know, we've got room for 60 in a tent. We're doing 20 in a tent. I know we've got room for another 40 pigs but the more space the better." – (Interviewee 11: vertically integrated farmer)

"Perhaps the alternatives are more from management process doing the all-In all-out. Like, good vaccination policy, having healthy stock in the first place and that sort of thing." – (Interviewee 12: vertically integrated farmer)

The use of vaccines was another common alternative method used among pig farmers to prevent disease and limit the requirement for antibiotics; having beneficial and long-term impacts throughout the lifecycle with observed benefits even at the finishing stage.

"They're vaccinated when they're small. I think it's a good job, definitely yes. It keeps them right. If they all come in vaccinated to us, then we know not much bother with them." – (Interviewee 7: very small-scale independent finishing farmer)

Responses varied when participants discussed the efficacy of alternative methods as several farmers reported a range of benefits (e.g. disease reduction) while others noted challenges resulting from implementing such measures. The use of organic acids, while often used experimentally, was perceived to have beneficial results regarding disease reduction however, plumbing issues were also observed due to corrosion of pipelines. Furthermore, participants reported feelings of scepticism towards their reputability, considering them to be *"marketing ploys"* sold by the companies producing them. There was a lack of trust placed in the companies selling alternative products and this led to high levels of uncertainty among farmers surrounding their value.

"You know, sometimes a company that has produced the product recommending it to you, you're wary because obviously their rep's trying to sell the product. It's just hard knowing at times what will work and what won't." – (Interviewee 8: medium-scale independent farmer)

Although opinions were diverse, the sample population stated that they would be willing to try new alternatives if they were made available, particularly following the zinc oxide ban in 2022. Interviewees speculated that usage will rise following the ban as there are currently no effective alternatives to replace its use. The uncertainty surrounding the impact that this ban will have, resulted in an increased willingness among participants to explore other alternative measures. This was on the basis however, that there was substantial research and evidence to support beneficial use.

"I don't understand why the zinc had to be banned in the first place, so I think banning is creating more of a problem than it's solving." – (Interviewee 9: large-scale independent farmer)

(4) Farm characteristics

Within this theme participants described how various agricultural factors such as farming system, breed of pig and external influences (i.e. season and weather) determine the need for antibiotic treatments.

Participants considered the flow and design of housing, particularly the use of an all-in all-out system, to be of more importance on farm than the number of animals being produced. This system was believed to limit cross-contamination by splitting farms and placing pigs at different lifecycle stages onto separate sites, reducing the disease burden and subsequent AMU.

"There would be a lot of farms that are starting to split out, where they're only getting sows on one herd and then the finishers are on separate sites, so that's reducing their antibiotics. It's healthier to keep them as separates…you can have a more stable herd." – (Interviewee 9: large-scale independent farmer)

"…production systems have got so much better…all-in all-out practices and healthier breeding herds, and all of that off-site weaning." – (Interviewee 12: vertically integrated farmer)

Responses also highlighted the influence that genetic predisposition and selective breeding can have on AMU. Increasingly farmers are selecting pigs based on their ability to produce a larger litter of piglets thereby increasing production and keeping overhead costs down. Despite this, participants expressed great concern towards these pigs as larger litters often result in smaller piglets, whereby insufficient colostrum results in stunted development and weakened immunity. Smaller pigs were believed to be extremely susceptible to disease, often requiring more antibiotic treatments than larger more developed pigs.

"…we're now producing a pig today that we never saw 20 years ago. It is like a formula one racing machine, the pig we produce today. It grows very quick. It does extremely well off the food it eats. It is an incredible animal, but it's very, very easily upset." – (Interviewee 15: vertically integrated farmer)

"These new pigs are lean; they have a thin layer of fat on their backs so the genetic robustness of these pigs can't be good. They are extremely prone to disease because of the lack of fat on them, if we could keep and sell fat pigs the use of antibiotics would be almost non-existent." – (Interviewee 5: very large-scale independent farmer)

The weather and season were stated to have a notable impact on disease prevalence and antibiotic requirements. At certain times of the year pigs were said to be more susceptible to certain diseases, with some participants mentioning the prevalence of flu, pneumonia and erysipelas. Specifically, it was considered that during the first part of the year problems tend to be the worst due to changeable meteorological conditions. Fluctuating temperatures can exacerbate ill health, a factor made particularly evident by farmers with outdoor production systems.

"Two years ago, we had a hot summer…the sow wants to lay in a wallow…she doesn't want to feed her little ones. She's too hot, she's worried about herself. But they're not getting their colostrum. In the wintertime, it's cold and it's wet. You get the smaller ones that aren't doing so well. They're the last ones to come out to eat and drink and they'll only eat just to get through the day, just to get through the night. They're not eating enough to get on and get going, so you've got to really be on the ball." – (Interviewee 15: vertically integrated farmer)

(5) Economic considerations

There was agreement among participants that the cost of both antibiotics and alternative measures has a substantial influence on AMU practices. The majority of participants discussed the high cost and expense endured from antibiotic administration and therefore, reduction was of great interest to them. This was deemed worthwhile to not only reduce AMU on-farm but also with the added benefit of reducing farm expenses.

"It's almost hardly cost effective [to use antibiotics]. It's nearly cheaper to let the pig die. It comes down to economics." – (Interviewee 6: large-scale independent farmer)

Despite this, participants shared the opinion that they would use antibiotics when necessary as they have a moral obligation to treat a sick animal. Furthermore, due to the high cost of antibiotics, farmers believed that it is unlikely that antibiotics are used imprudently within the sector as it is not financially viable.

"Obviously you don't want to spend money that you don't need to. Plus, it's beneficial for us if we can cut it out to save money, as well." – (Interviewee 1: medium-scale independent farmer)

"We don't use antibiotics for the sake of it. We just don't want it to cost money. We don't want to be doing that." – (Interviewee 14: vertically integrated farmer)

In addition, the high cost of antibiotics was discussed as a factor driving farmers to seek alternative methods to AMU. Participants stated that alternatives measures are often expensive, some farmers perceived this as a drawback to usage, particularly if they were to be ineffective, however, others considered the benefits of disease and AMU reduction, and therefore, deemed them worthwhile.

"…you only need to save a handful of pigs to justify it [use of organic acids] each week." – (Interviewee 1: medium-scale independent farmer)

(6) Veterinary surgeon – farmer relationship

Discussion within this theme referred to the relationship between farmers and their veterinary surgeon, with participants perceiving them to be the most credible source of information surrounding both antibiotics and alternative methods. It was found that interviewees administer antibiotics in line with veterinary recommendations, often referring to their advice to assess if antibiotics are required and following administration guidance.

"…I have a chart from the vet that I've got on how much to prescribe that unit. We'd have the advice because the vet's visits are quarterly." – (Interviewee 13: vertically integrated farmer)

"On our finishing farms, there is a veterinary health plan in the code of practice and that will say, if a pig is lame then you use this product, if a pig has got respiratory problems, then you use a different product. So, yeah, there is guidance for all the farmers." – (Interviewee 14: vertically integrated farmer)

435 Furthermore, scepticism among participants surrounding alternative measures to AMU resulted in a
436 high reliance placed on veterinary surgeons. Farmers trust that they will inform them of the
437 alternatives available and provide reliable and honest advice on how it may benefit their production.
438 In fact, participants would only consider using an alternative if it had been discussed previously with
439 their veterinary surgeon.
440
441 *"Well, even if somebody tried to sell me something, I would probably chat to the vet about it." –*
442 *(Interviewee 8: medium-scale independent farmer)*
443
444
445 ***(7) External pressures***
446
447 Whilst it was believed that the farm assurance scheme, Red Tractor, place responsibility on pig
448 farmers for using high amounts of antibiotics, participants also perceived the media as a source of
449 harmful allegations surrounding agricultural AMU, negatively impacting public perception.
450
451 *"The only real negative there is, is down to public perception and everybody saying you're using*
452 *endless antibiotics. You know, you'd think we were feeding them antibiotics instead of meal." –*
453 *(Interviewee 9: large-scale independent farmer)*
454
455 Farmers also voiced concerns in relation to the global spread of both disease and resistance as well as
456 imprudent AMU in less developed countries and the impact this can have within the UK. The travel of
457 pigs from foreign countries into the UK was believed to have introduced an array of new diseases to
458 what was otherwise a healthy and concealed industry.
459
460 *"So, in Denmark and Holland and places like that, they're all strep positive over there. I know my old*
461 *company; we brought some gilts over here about eight years ago. Got these gilts to come over and all*
462 *these people were going 'what the hell is going on?' We found that they were strep positive. So, we*

said 'look, you gave us this strain.' 'Well, all the farms are positive over here, so we have to test them for strep over here because all the farms are positive.' So, all our grandparents are all bringing us strep over." – (Interviewee 11: vertically integrated farmer)

Furthermore, due to favoured areas to farm in England, this has led to a high concentration of pig farmers within a confined area, increasing the probability of disease spreading from one farm to the next.

"Herd health is really poor compared to what it was around this area because there are so many pig farms now. It's easily spread. You've got all these lorries that come here. You got two roads in and if you've got pig farms around this area-, we're down one of the main roads, about 20 minutes away and literally, if you could sit there and count the amount of lorries that went past it every day, it'd probably be a good 60, 70 pig lorries. You don't know where those pigs have come from, what issues they've got, and everything like that." – (Interviewee 13: vertically integrated farmer)

Generally, participants from the vertically integrated system displayed a higher level of awareness surrounding global AMU and the spread of resistance, discussing the lack of antibiotic stewardship in other countries. Farmers considered the measures being taken in foreign countries and spoke about their concern for the meat entering the UK market as well as the ability for the public to buy antibiotics off the shelf.

"…in Africa you don't have scripts or anything like that…or other parts of the world. People just go and buy it off the counter and take whatever they want. That doesn't really help." – (Interviewee 10: vertically integrated farmer)

"If we're in the UK making this massive effort to reduce our antibiotic use, what are they doing abroad? We're bringing in a serious amount of meat from abroad, so what are they doing over there

to control it…because it'll be on our shelves. Then, the industry gets targeted by this but it's not from a product from the UK." – (Interviewee 13: vertically integrated farmer)

It was direct pressure from processors and retailers however, that was believed to influence administration patterns among some participants, sparking a rather emotive response. This pressure was perceived to ultimately stem from the consumer and their demands for leaner cuts of meat. Therefore, processors will only pay a fair price for lean pigs, pressuring farmers to meet these requirements. Retail pressure on prices were believed to force farmers to increase the number of pigs they produce to keep overhead costs down. As a result, farmers often keep a large number of animals on farm, leading to unfavourable conditions and requiring the use of antibiotics to keep health problems at bay and ease farm management. While only a small number of participants from both vertically integrated and independent farms shared this view, they believed this pressure heavily influenced their personal use of antibiotics on farm.

"They [processors] want us to have as many [pigs] as we can and produce as many as we can for as little price as we can. I said it once or twice. You're working with mother nature and there's a limit to what you can and can't do." – (Interviewee 15: vertically integrated farmer)

(8) Production Stage

Within this theme participants discussed an association between AMU and the various stages of pig production, identifying an increased need for antibiotic treatments at particular stages. It was commonly acknowledged that AMU practices vary and can differ between farms based on individual farm characteristics however, in relation to the specific stages of pig production, farmers considered older pigs to use the least amount of antibiotics, with the exception of sows during farrowing. Farrowing was recognised as a phase of higher disease susceptibility and complication whereby; antibiotics are required to treat infections, particularly farrowing fever which would be prevalent at

518 this stage. It was the weaning stage of production that was most commonly identified as a stage of
519 increased AMU among participants. The weaning stage was recognised as a particularly stressful
520 transition period as piglets are taken from their mother and placed into new housing with other pigs of
521 various immunological status, their feed is changed, and they no longer have access to milk.
522
523 *"...I would usually give her 20ccs after she farrowed." – (Interviewee 3: small-scale independent*
524 *farmer)*
525
526 *"Pigs will then go off-site. Absolutely fine, nothing wrong with them. I then get them mixed with*
527 *different sources, so different units. All the pigs go into a big pool. Well, about once a week, about*
528 *eight units fit all their pigs into one pool and it all goes on to one farm. So, we'll probably see a little*
529 *bit of disease from that unit pass on to that unit, and so on." – (Interviewee 11: vertically integrated*
530 *farmer)*
531
532 *"The point of the matter is, what I'm trying to say, when a piglet comes away from mum, whether any*
533 *of us like it or not, it'll form stress. I'm not saying the animals are stressed. They're not stressed but it*
534 *is the fact that you've taken them out of an environment that they consider to be their safe*
535 *environment. You then take them out and you then put them into a different environment. That can*
536 *then create sometimes a mycoplasma job. To the layman's eyes, that'll be lameness. It can also*
537 *sometimes kick off a stress point of view, which could then come out as, like, a Glasser's or something*
538 *like that." – (Interviewee 15: vertically integrated farmer)*
539
540 Consequently, many participants would administer antibiotics via a blanket treatment during this
541 period, allowing for mass treatment of a unit. Adding antibiotics to the feed or water was thought not
542 only to be the easiest and most convenient method of administration, but farmers also considered it to
543 be a responsible and less invasive way to treat pigs as injections could cause further stress at this
544 stage. Individual treatment, in contrast, tended to be used on older pigs on a one-off basis as they
545 would often have been vaccinated and require fewer antibiotic treatments.

"We haven't used antibiotics in quite a long time, really, but we always used to-, the, sort of, post-weaning phase of a piglet was a time when you'd use in feed antibiotics almost prophylactically. In years gone by, we had, a problem with streptococcus suis, type two meningitis, so it was just a damn sight easier to chuck in some Trimediazine and not have the problem." – (Interviewee 12: vertically integrated farmer)

On average, farmers stated that they wean their pigs at 28 days in order to achieve a better weaning weight and gain a stronger pig, particularly as it effects future performance. It was generally recognised that pigs weaned at 21 days tended to be smaller and more susceptible to disease, however, opinions differed when extended weaning times were discussed. While the majority of farmers acknowledged that extending weaning times to 32 days has a beneficial impact on achieving a stronger and more robust pig, other participants held a strong view that weaning piglets beyond 28 days could negatively affect the mother as the mature piglets are bigger and can cause her pain from suckling, raising potential animal welfare issues and possibility increasing the need for AMU. Participants explained that it offers no further benefit to lengthen weaning as the mother can only produce a limited amount of colostrum and that over time the quality of the milk deteriorates. In addition, interviewees discussed the impact that a later weaning time could have on their farms productivity by lowering production levels. Due to limited farrowing spaces, farmers often have to work with the flow of the farm, potentially restricting later weaning times and therefore, due to an impact on production, extending weaning was deemed impractical.

"We have often said it would be nicer to leave the pig on the sow another week…but it's about cost of production and getting the best-case scenario over a twelve-month period. If you knock [the gestation period of a sow/weaning] back another week and another week, you've actually lost half of a gestation period in twelve months. These guys [processors], numbers are in pounds and pence. If they left them with the sow a bit longer, I think sometimes it would be good but it's not always practical to do that." – (Interviewee 15: vertically integrated farmer)

574

575 *"…if the piglet is not weaned at this time [28-32 days] and they are left to week five or six it is no*
576 *good, not for the mother as the piglets will start to hurt her." – (Interviewee 5: very large-scale*
577 *independent farmer)*

578

579 4. Discussion

580

581 This study implemented a qualitative approach to gain a deeper understanding of the factors driving
582 AMU among vertically integrated and independent pork farmers in England and Northern Ireland. In
583 addition, this study identified farmers perceptions and attitudes towards AMR, alternatives methods to
584 AMU and possible avenues for effective reform within this sector. A myriad of factors influenced pig
585 farmers AMU, with many similarities and differences seen between management systems and
586 between independent and vertically integrated farmers. These factors often complemented one another
587 and collectively influenced AMU. These findings are in line with previous research in this field;
588 where knowledge of AMR, disease prevalence, external pressures, vet-client relationship and cost-
589 related factors, among other factors, have been identified as motivators of AMU (Coyne et al., 2016;
590 Lekagul et al., 2019).

591

592 In contrast to previous research, pig farmers were conversant with AMR but similarly lacked
593 knowledge surrounding transfer and effect on humans. Vertically integrated farmers exhibited higher
594 levels of knowledge and awareness of AMR than farmers from independently managed farms.
595 Integrated companies have ownership of different branches within the industry such as transport,
596 farms and slaughterhouses and are very common in intensive sectors i.e. pigs (Bokma et al., 2018).
597 Company-owned farms invest in educational campaigns and provide support to farmers in order to
598 achieve specific targets on drug use reduction to satisfy consumer demands (Wei and Aengwanich,
599 2012; Di Martino et al., 2018); this may explain why these farmers were more knowledgeable of the
600 importance and severity of AMR. However, vertically integrated farmers lacked knowledge in

601 comparison to independent farmers regarding antibiotic expenses and alternative measures used as
602 these companies tend to manage financial matters. Although participants were aware of AMR, they
603 lacked knowledge surrounding its transfer. In parallel with the literature, farmers typically
604 underestimated the threat of AMR as they felt there was insufficient evidence to confirm a link
605 between AMU in animals and the development of resistance in humans (Coyne et al., 2014; Moreno,
606 2014; Hockenhull et al., 2017). Although participants considered themselves to use antimicrobials
607 judiciously, research suggests that such perceptions could deter behavioural change in AMU practices
608 as farmers may not feel responsible for any negative outcomes (Speksnijder and Wagenaar, 2018;
609 Ekakoro et al., 2019). On-farm practices are difficult to change, especially when farmers do not
610 identify the need to make changes (Speksnijder et al., 2015); and this can create challenges for
611 communicating behavioural change, particularly for programmes or interventions. Participants
612 reported a desire to reduce their AMU suggesting that they are aware of the associated risks, however,
613 they were unwilling to discuss the drawbacks of AMU. This may reflect the increasing pressure from
614 the media (Coyne et al., 2014); often highlighting this sector as the primary source of AMR in
615 humans eliciting a defensive response from participants. Farmers also discussed concerns towards the
616 contribution that human medicine has on AMR, including both over-prescription by medical
617 professionals and the issue of patients not finishing their course (Beović, 2006; Huttner et al., 2013).
618 These findings suggest that there is a need to increase awareness among farmers of what constitutes
619 AMR and the mechanisms of zoonotic transfer, as well as educating the public on responsible
620 administration and how to reduce personal AMU.
621
622 Antimicrobials were commonly used for disease treatment and management to maintain animal health
623 and welfare. In parallel with the literature, participants identified the weaning period as the most
624 common phase of AMU in pig production (Callens et al., 2012; Jensen et al., 2012; Fertner et al.,
625 2015; Postma et al., 2015a; Sjölund et al., 2016; Lekagul et al., 2019); due to low levels of immunity
626 (Postma et al., 2015a) and exposure to a number of pathogens during commingling, increasing disease
627 incidence and subsequent AMU (Bokma et al., 2018). Participants believed that they were able to
628 effectively identify and treat disease based on their previous knowledge and experience within pig

629 farming. Furthermore, farmers placed an importance on highly skilled stock people as they can detect
630 early signs of disease. Ensuring that a unit is well managed by a team of skilled individuals increased
631 farm health and animal welfare, a concept echoed in the literature (Coleman et al., 1998; Jääskeläinen
632 et al., 2014; Fertner et al., 2015; Speksnijder and Wagenaar, 2018; Coyne et al., 2019). It was
633 believed however, that not all stockmen possess these skills as discussed by a participant who stated
634 that pig producers are often expected to improve farm management with worse staff. In any case,
635 these findings suggest that it is beneficial to educate and train stock people on disease detection and
636 herd management with a focus on prudent AMU (Coyne et al., 2019).
637
638 Several participants mentioned AMU for disease prophylaxis administered via feed or water,
639 however, this tended to be when they knew they were troubled with a particular disease or stage in
640 production, such as weaning. Prophylactic AMU is a common practice in intensive pig farming,
641 subsequently, it is widely accepted by farmers (Coyne et al., 2014); and often applied habitually at
642 familiar time points (Stevens et al., 2007; Callens et al., 2012; Visschers et al., 2014). According to
643 Stevens et al. (2007), 60-75% of pig farmers medicate their feed specifically during the weaning stage
644 of production, similarly, Callens et al. (2012) acknowledged that 90% of group antibiotic treatments
645 occurred between birth and ten weeks of age. Prophylactic AMU facilitates groups treatments and
646 participants believed this to be a convenient method of administration as it is time efficient and less
647 labour intensive in comparison to individual treatments. Additionally, farmers perceived this to be a
648 more responsible approach as individually injecting animals could result in increased levels of stress.
649 Interestingly, a minority of participants believe that the use of in-feed antibiotics can be used for
650 beneficial effects on animal weight and growth rates. This does not conclusively prove that pig
651 farmers are using antibiotics for this purpose however, it suggests that despite the 2006 EU ban on
652 AMU for growth promotion, antibiotics may still be used illegally for this purpose.
653
654 Participants exhibited high levels of awareness to alternative methods of AMU with majority of
655 farmers employing the use of at least one alternative approach on their farm. Vertically integrated
656 farmers had more experience with alternatives as they discussed experimenting with a multitude of

different methods in the hope of reducing AMU. This may be explained by the research and development budgets that these farmers would have access to, enabling them to test alternatives, independent farmers on the other hand, do not have the resources or financial support to access new and upcoming alternatives. Generally, participants stated that they would be willing to try new alternatives to reduce their AMU, contrasting to other findings suggesting that farmers perceive alternative methods as ineffective (Coyne et al., 2014; Visschers et al., 2016; Speksnijder and Wagenaar, 2018). Participants agreed that antibiotics cannot be completely removed due to animal welfare concerns, however, they did believe alternatives were an effective addition to support antimicrobial reduction when used in conjunction with antibiotics. Participants commonly identified vaccinations as an extremely valuable alternative for AMU, as reflected in various other studies (Allen et al., 2013; Coyne et al., 2014; Aarestrup, 2015; Coyne et al., 2016; Postma et al., 2016; Scoppetta et al., 2017; Bokma et al., 2018; Coyne et al., 2019; Ekakoro et al., 2019; Lekagul et al., 2019). Vaccines are identified as an alternative solution to combat AMR within the World Health Organisation, as vaccinations strengthen pigs' immunity and reduce the risk of clinical signs of disease, consequently, reducing the need for antibiotics (WHO, 2015; Postma et al., 2016; Coyne et al., 2019). The majority of participants discussed using vaccinations to prevent disease, a similar finding is reflected in a study conducted by Stevens et al. (2007) whereby 80% of pig farmers believed the use of vaccinations to be an effective alternative to AMU. In vast contrast however, Kruse et al. (2017) found that vaccinating weaners against porcine circovirus type 2 lead to increased AMU, however, this may be explained by the possibility that farms facing high levels of disease may vaccinate alongside the continuation of AMU until infection pressure is reduced (Postma et al., 2016). To date, there is no clear evidence that vaccination reduces AMU however, participants expressed the view that availability to an increased range of effective vaccinations would be beneficial in aiding their overall antibiotic reduction efforts and show beneficial return of investment, despite their cost (Lekagul et al., 2019). For this reason, participants identified the use of alternative measures to AMU as an area in which more research is needed.

According to Bos et al. (2013) increased pig stocking density and AMU are positively correlated. Despite this, other findings showed that pig density is not linked to on-farm AMU (Casal et al., 2007; van Rennings et al., 2015). The majority of pigs in the UK are farmed outdoors and therefore, it can be more difficult to control the spread of disease. Farms are often clustered in areas within close proximity, increasing the potential of disease transfer. In fact, Arnold et al. (2016) found oral antibiotic administration to be greater when pig farms are situated within 500 meters of one another. Internal and external biosecurity are considered essential aspects of farm management by participants. Appropriate external biosecurity is vital as the introduction of pathogens into a pig herd from an outside source is the leading cause of disease onset (Ribbens et al., 2009; Lambert et al., 2012). In studies conducted by Laanen et al. (2013) and Postma et al. (2016) a negative association between biosecurity and AMU was uncovered, implying that farms with higher biosecurity levels use less antibiotics. High levels of on-farm biosecurity was a factor commonly discussed by participants due to associations with a reduced need for antibiotic treatments and this has been identified by veterinary surgeons as a viable alternative to AMU by mitigating disease occurrence (Laanen et al., 2013; Postma et al., 2015b; Coyne et al., 2016; Ekakoro et al., 2019). When considering financial implications, improved biosecurity may be more cost-effective by reducing disease prevalence and routine AMU (Coyne et al., 2019); however, studies suggest that farmers are unable to invest into such changes due to economic constraints, subsequently, improving biosecurity is not always feasible (Laanen et al., 2013; Alarcon et al., 2014). Participants decision to use alternatives such as vaccines or improve on-farm biosecurity is based on an evaluation of factors such as expense and success rate, consequently, antibiotics were perceived to be the clear choice as they are more reliable despite the high cost associated with them. Efficient husbandry systems that aid the reduction of AMU whilst maintaining productivity and providing economic return, are not currently available, thus, participants discussed the development of alternative approaches that consider the individuality of each farm. Farmers opinions towards the efficacy of alternative measures were mixed, highlighting that a tailored approach at an individual farm level would be most effective. Although farmers are making an effort to incorporate alternatives, there is no baseline or alternative that is proven to work. Therefore,

711 research needs to focus on the development of evidence-based effective alternatives. This is
712 particularly important as we approach the ban on zinc oxide since the impact of this ban is unknown.
713
714 The majority of participants discussed economic considerations as they believed all matters related to
715 cost and expenses to have a significant impact on AMU, particularly focusing on the economic
716 benefits from antibiotic application. Various studies cited a reduced cost of production as the key
717 driver to reduce AMU among pig and dairy farmers from the UK, Denmark, Belgium, France,
718 Germany, Sweden and Switzerland (Jones et al., 2015; Visschers et al., 2015). While essential for the
719 management and treatment of disease, high prices of antibiotics encourage farmers to explore
720 alternative methods of AMU. Farmers willingness to use alternatives may be instigated by various
721 factors such as cost, animal welfare, awareness of AMR or withdrawal periods (Coyne et al., 2016). It
722 is possible however, that withdrawal periods may be considered at the expense of the correct
723 treatment as reduced withdrawal periods benefit farm productivity and profit. Participants discussed
724 the responsibility of ensuring animal welfare standards and would correctly treat where appropriate
725 and cull infected animals to preserve welfare and consumer food safety. Farmers concern with animal
726 welfare also contrasted greatly with findings of Visschers et al. (2014) showing farmers were more
727 concerned with the financial issues associated with pig farming than animal health. Furthermore, this
728 study also uncovered that Swiss pig farmers considered financial policy measures involving financial
729 compensation, bonuses and punishments to be the most effective measure to reduce AMU (Visschers
730 et al., 2014). Cost has a substantial influence on farming practices and motivates the reduction of
731 AMU however, as participants discussed, animal welfare must be considered and the potentially
732 detrimental implications that financial policy measures could have. In addition, many farmers face
733 financial hardships and are unable to reinvest into housing, biosecurity and management
734 improvements that are required to reduce dependence on AMU (Coyne et al., 2019); a concern that
735 was commonly highlighted by participants.
736
737 In addition to the direct pressures faced from processors and retailers, participants believed that the
738 spread of disease among animals and humans, and AMU in other countries contributed to the pressure

on-farm. It was the imprudent practices in foreign countries that farmers perceived to centre disease and resistance proliferation. While the medical sector was discussed, the agricultural sector was highlighted by participants as an area of concern, particularly in low- and middle-income countries. Similar concerns were outlined in the literature as Lekagul et al. (2020) uncovered the lack of guidelines available within the veterinary sector relating to AMU. Furthermore, research suggests that farmers have a limited understanding of responsible AMU due to insufficient availability of information (Kramer et al., 2017; Chauhan et al., 2018; Sadiq et al., 2018; Ozturk et al., 2019); often resulting in imprudent practices. Subsequently, farmers in Uganda were unaware of withdrawal regulations, while farmers across Sudan, Egypt and India believed antibiotics could be used to treat viral infections (Hockenhull et al., 2017; Ozturk et al., 2019). Similarly, limited knowledge may influence farmers' ability to correctly identify a diseased animal, again, resulting in imprudent AMU practices. Participants felt this was unfair due to stringent criteria in the UK, leaving their efforts redundant as this unregulated meat is imported into the UK alongside the travel of people globally, spreading disease and resistance.

Many external factors influence disease prevalence, exacerbate underlying issues and increase the requirement for antimicrobial treatments. Participants acknowledged the time of year, the weather and the type of production system as factors influencing their AMU. Similarly, research suggests that production system influences farmers AMU (Stevens et al., 2007; Coyne et al., 2014); as it was found that significantly less was spent on injectable antibiotics for outdoor bred pigs (Stevens et al., 2007) while piglet mortality from diarrhoea was less frequent in comparison to pigs reared indoors (KilBride et al., 2012). In addition, participants discussed the benefits of reducing disease incidence through the adoption of an all-in all-out production system, similarly, Fertner et al. (2015) found that this method of production has been associated with reduced disease transmission and lower AMU. However, in order to fully understand the influence that farming production systems have on antibiotic treatments in pigs, further research is needed.

Farmers considered themselves to have a good relationship with their veterinary surgeon and indicated that they value their opinion regarding farming practices, AMU and alternatives to such use. This was reiterated throughout the literature as several studies have reported veterinary surgeons to be the preferred source of information and advice (Friedman et al., 2007; Garforth et al., 2013; Visschers et al., 2015; Kramer et al., 2017; Di Martino et al., 2018; Lekagul et al., 2019); with farmers considering them as a trustworthy, credible, relevant and competent advisor (Friedman et al., 2007; Coyne et al., 2014; Speksnijder and Wagenaar, 2018). Therefore, this indicated an increased intention to reduce AMU and incorporate on-farm management practices to decrease the burden of animal diseases based on veterinary influence (Coyne et al., 2014; Jones et al., 2015; McDougall et al., 2016; Visschers et al., 2016; Speksnijder and Wagenaar, 2018). Veterinary surgeons' credibility and trust was enhanced due to the scepticism farmers exhibited when approached by representatives from pharmaceutical companies as there is a conflict of interest to offer their products (Lekagul et al., 2019). This study and additional research suggest that pig farmers perceive veterinary surgeons as a valued source of information, in addition, an enhanced relationship between farmers and veterinary surgeons benefits on-farm practices by relevant knowledge transfer, thus, reducing requirement of AMU (Coyne et al., 2016). Therefore, fostering a collaborative relationship between veterinary surgeons and farmers should be encouraged to drive effective communication and enhance education.

It is evident that pig farmers are aware of the issue of AMR and as such, demonstrated a willingness to aid reduction and explore potential methods for change. There was a clear indication however, that the sample population lacked knowledge regarding the mechanisms and transfer of resistance; highlighting an area of concern that must be addressed to effectively evoke change. Despite this, there is no simple solution as this sector boasts a complexity of challenges ranging from production systems, discrepancies between countries and a plethora of factors that influence each individual farms practices and AMU. Research across all livestock sectors has explored the use of government initiatives aimed at reducing AMU in food producing animals (Speksnijder and Wagenaar, 2018) and sector specific benchmarking (Bokma et al., 2018; Speksnijder and Wagenaar, 2018; Ekakoro et al., 2019). There are various government led policy options to aid antibiotic reduction within the pig

794 sector from provisions, regulations, investments into alternative methods of AMU and researching
795 best management practices. Care must be taken however, as the introduction of fines and regulations
796 to encourage behaviour change might also impair practices, negatively influencing animal welfare or
797 leading to hidden and illegal practices (Speksnijder and Wagenaar, 2018). In the Netherlands and
798 Denmark, benchmarking has shown to be beneficial and contributed to a reduction in AMU (Jensen et
799 al., 2014; Bokma et al., 2018) as it enables both farmers and veterinary surgeons to compare
800 themselves with others in the sector. Further, it allows farmers to critically reflect on their current
801 AMU practices, thereby increasing awareness (Ekakoro et al., 2019).
802
803 A focus should be placed on educating farmers surrounding the best practices for antibiotic reduction
804 and therefore, the best avenue of knowledge dissemination must be considered for effective
805 engagement. Information should be provided in a manner that farmers perceive as trustworthy and as
806 findings indicate that participants generally trust their veterinary surgeon's advice, they should act as
807 the main information source for pig farmers. Further, evidence has shown that farmers not only prefer
808 to mutually discuss recommendations with their veterinary surgeon, but they respond to this method,
809 increasing the likelihood that recommendations will be implemented (Hall and Wapenaar, 2012;
810 Speksnijder et al., 2017). It is therefore imperative to improve communications and strengthen this
811 relationship to effectively educate farmers and aid their understanding in the importance of amending
812 practices, ultimately increasing their awareness and knowledge. Furthermore, veterinary surgeons
813 have personal experience with their farm, allowing them to assess each farmers' needs and provide
814 them with not only the skills and knowledge required for responsible AMU, but also develop a
815 targeted intervention individualised to that farm. Veterinary surgeons should therefore have
816 comprehensive knowledge and supportive skills to assess individual farms' needs to successfully
817 communicate necessary skills and information to farmers (Visschers et al., 2016). Veterinary surgeons
818 are reliant on farmers compliance and the implementation of new practices, particularly as farmers are
819 the fundamental decision makers when deciding when to apply antibiotics, it is crucial that they have
820 appropriate education to make informed and judicious decisions regarding AMU. Despite this, it must
821 be taken into consideration that farmers can only embrace change within their means as compliance

822 has been linked to the physical characteristics of the farm and available resources, and this may
823 restrict the implementation of veterinary recommendations (Speksnijder and Wagenaar, 2018).
824 Further, farmers inability to reinvest into their farm also has an impact on efforts made to reduce
825 AMU however, this presents an opportunity for a regulatory intervention through the introduction of a
826 sector-specific scheme to aid farmers financially; modernising farming systems and increasing the
827 range of measures veterinary surgeons can therefore advise or implement to help farmers achieve
828 antibiotic reductions. It has also been noted that those working in the human medical sector have a
829 greater number of targeted information sources to educate and guide administration practices (Coyne
830 et al., 2016) compared to the agricultural sector; thereby, creating another opportunity to provide
831 funding into more information sources to guide not only veterinary practice but also farmers'
832 decision-making. It is evident however, based on the findings from this study, that there is difficulty
833 in suggesting initiatives or implementing regulations as the issue of antibiotic overuse is multifactorial
834 and extremely individualised, unique to each farm. Furthermore, there are various independent
835 variables that must be taken into account such as the weather and the geographic location of the farm.
836
837 **Strengths and limitations**
838
839 There are limitations which must be considered when interpreting findings from this research. Firstly,
840 as it was difficult to conduct a random selection of farms, purposive sampling was employed to
841 achieve a full range of farms, including those of different sizes and systems from various geographic
842 locations in England and Northern Ireland. Inevitably, this sampling technique may result in selection
843 bias whereby participants chosen for the study represent the extremities within the sector and have
844 vast differences in opinion with regard to their perceptions and behaviours towards AMU, excluding
845 the majority opinion. Furthermore, as findings suggest, farmers are facing increasing pressures from
846 the media with regard to their AMU and this may lead to feelings of distrust, resulting in an
847 unwillingness to disclose farming practices out of fear of scrutiny. It is therefore possible that farmers
848 self-reported behaviours may portray behaviours that they consider to be expected or responsible,
849 rather than their genuine practices. Lastly, it must be taken into consideration that the pork industry is

continually progressing and adapting to improve farming practices via the assistance of various industry groups, i.e., Red Tractor, and subsequently farmer's awareness and views are continuously evolving. Despite its limitations, this qualitative study offered an interactive forum for pig farmers to openly discuss highly emotive subjects, personal experiences and factors that they believe influence their AMU. Further, findings can be used to determine the drivers and motivators of AMU in the pig sector as a whole, providing a substantial basis for future research and possible targeted interventions and educational campaigns.

5. Conclusions

Our findings highlight the complexity of the UK pork industry and the myriad of internal and external factors that motivate antibiotic administration practices. AMU in the pork sector is multifactorial as drivers of administration are diverse and differ between farms. Results indicate that there is a need to increase farmers awareness of the risks that antibiotics pose to human and animal health, and what constitutes AMR. Therefore, interventions should focus on individual farm assessments in collaboration with a veterinary surgeon, to determine the most effective tailor-made antibiotic reduction techniques, ensuring that farmers are more actively involved in decision making, increasing their awareness. In addition, more research is needed to provide farmers with effective alternative measure that will aid their reduction of AMU, as currently there are no reliable alternatives available.

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Data Statement

The authors declare that the data supporting the findings presented in this study are available within the paper and raw data can be accessed at https://osf.io/b5c63/quickfiles.

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