Drivers and Motivators of Antimicrobial Prescribing Practices by Veterinary Surgeons and Farmers in Pig Production in the United Kingdom

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by

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This thesis is based on research carried out in the Department of Epidemiology and Population Health, Institute of Infection and Global Health, University of Liverpool. Except for where indicated, this thesis is my own unaided work.

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Abstract

Drivers and motivators of antimicrobial prescribing practices in pigs

Indiscriminate prescribing practices and the overuse of antimicrobials have been identified as a key driver for the emergence of antimicrobial resistant strains of bacteria in both humans and animals. Thus, it is essential that antimicrobial use practices are optimal and responsible to minimise these selection pressures. Antimicrobial use in pigs has been highlighted as an area of particular concern in the UK and Europe. The aims of this thesis were to provide a clear understanding of the motivations, practices, behaviours and attitudes surrounding the prescribing and use of antimicrobials in the UK pig industry, deemed an essential step optimising antimicrobial use.

This thesis combines both qualitative and quantitative methodologies. Six initial focus group studies were held with pig veterinary surgeons (n=9) and farmers (n=17) to explore open-ended themes surrounding antimicrobial use and prescribing behaviours in pigs. The themes that emerged were explored in more detail using in-depth individual, face-to-face interviews with both farmers (n=22) and veterinary surgeons (n=21). A thematic approach was used for analysis. These results informed a quantitative questionnaire study which tested and explored key themes. The questionnaires were distributed to pig veterinary surgeons and farmers across England, Wales and Scotland. Results from 261 farmers and 61 veterinary surgeons were analysed using a predominantly descriptive approach, with analysis used to test the statistical significance of comparative respondent categories and multivariable logistic regression to explore risk factors for antimicrobial use on respondent farms. Additionally, open questions were analysed using a thematic approach.

Most veterinary surgeons and farmers showed personal confidence that their own antimicrobial use was prudent and demonstrated a social responsibility to reserve the use of the critically important antimicrobial classes. However, many described clinical examples of the use of a critically important antimicrobial as a first line treatment, and farmer awareness of critically important antimicrobials was low. At odds with this sense of individual responsible use there was concern that antimicrobial use by other veterinary surgeons and farmers may be less responsible. The ‘habitual’ use of in-feed antimicrobials for disease prevention and use to overcome poor management were used to exemplify irresponsible use.

Antimicrobial resistance was seldom cited as a clinical issue on farms, however there was dissonance in the perception of resistance on farms; both veterinary surgeons and farmers highlighted issues of treatment failures but could not, or did not, directly relate these to resistance. Additionally, whilst diagnostic testing, to identify causative agents and the most appropriate antimicrobial, were considered important their use was infrequently reported with financial implications and the time delay cited as reasons for this.

Respondents expressed a desire to seek alternatives to prevent disease and decrease the use of antimicrobials such as improved internal and external biosecurity measures, more effective vaccination strategies, improved housing and improved herd health. However, the high cost required to make facility improvements coupled with the poor economic return on pig meat were commonly cited as a hurdle to reducing antimicrobial use on farms.

Veterinary surgeons felt a major professional and moral obligation for animal health and welfare and this was also a recurring theme for farmers. It is clear that farmers and veterinary surgeons need to be able to make informed decisions to change and minimise antimicrobial use without compromising the health and welfare of animals under their care. There were contrasts in the way in which veterinary surgeons and farmers perceived their relationship; farmers identified a partnership where decisions are made mutually, whilst many veterinary surgeons identified pressure from clients to prescribe antimicrobials and some had concerns over poor farmer compliance in administering antimicrobials.

The complexity surrounding prescribing decisions and use on farms suggests a combination of approaches is likely to be needed to ensure that antimicrobial prescribing is optimal and to achieve significant reductions in use.

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'It always seems impossible until it's done', Nelson Mandela, 1918-2013

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Abbreviations

AGP	Antimicrobial Growth Promoters
AHDB Pork	Agricultural and Horticultural Development Board Pork (Formerly BPEX)
AHVLA	Animal Health and Veterinary Laboratories Agency (Presently APHA)
APHA	Animal and Health Plant Agency (Formerly AHVLA)
BPEX	British Pig Executive (Presently AHDB Pork)
BVA	British Veterinary Association
CAFOs	Concentrated Animal Feeding Operation
CVMP	Committee for Medicinal Products for Veterinary Use
DEFRA	Department for the Environment Food and Rural Affairs
EEA	European Economic Area
EMA	European Medicines Agency
ESVAC	European Surveillance for Veterinary Antimicrobial Consumption
EU	European Union
FDA	Food and Drug Administration
MIC	Minimum Inhibitory Concentration
MRSA	Methicillin Resistant *Staphylococcus aureus*
OIE	World Organisation for Animal Health
PHE	Public Health England
PRRSv	Porcine Respiratory and Reproductive Syndrome
PVS	Pig Veterinary Society
RCVS	Royal College of Veterinary Surgeons
RSPCA	Royal Society for the Prevention of Cruelty to Animals
RUMA	Responsible Use of Antimicrobials in Agriculture Alliance
UK	United Kingdom
USA	United States of America
VMD	Veterinary Medicines Directorate
WHO	World Health Organisation

Chapter 1

General Introduction

General Introduction

Background to Antimicrobial Use

The discovery and rise of antimicrobials

Since their first introduction in 1910 antimicrobials have been considered to *'…have had an effect not only on the treatment of infectious disease but also on the development of our society changing its morbidity and mortality'* (Zaffiri et al., 2012). Ehrlich's discovery in 1909 of the organoarsenic compound arsphenamine was to pave the way for a whole new era in human medicine in which common bacterial diseases such as pneumonia, diarrhoea and diphtheria could be treated with antimicrobial drugs (Jones, 1911). This first antimicrobial was widely used against syphilis and trypanosomiasis and remained the most commonly used antimicrobial until the 1940s (Schwartz, 2004).

The discovery of *Penicillin notatum* by Fleming in 1928 revolutionized modern antimicrobial therapy. The scientist defined microbiological techniques, which later, were developed into the recognisable techniques of minimum inhibitory concentration (MIC) and disc diffusion (Fleming, 2001, Zaffiri et al., 2012). Following on from Fleming's work, the therapeutic value of penicillin was described by Florey and Chain in early 1930. Its antibacterial properties were first demonstrated in experimentally infected animals in 1940 (Chain et al., 1993) and its use was extended to injured soldiers in North Africa during World War II (Grossman, 2009, Florey et al., 1943).

The 1940s continued to be a crucial decade in the discovery of antimicrobials with Watsman and Schatz describing the first aminoglycoside, streptomycin, in 1943 (Zaffiri et al., 2012). This was to become the first antimicrobial therapy for tuberculosis (Comroe, 1978). Brotzu continued this trend with the discovery of the second class within the beta-lactams with the defining of the cephalosporin class in 1943. From its first license in the 1960s this continues to be an antimicrobial of frequent use in both human and veterinary medicine (Zaffiri et al., 2012, Wick, 1967). As time progressed the 1960s saw the discovery of the fluoroquinolones as a broad-spectrum antimicrobial with action against gram-negative organisms, such as *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* (Zaffiri et al., 2012). This was followed closely by the development of the carbapenems another broad-spectrum antimicrobial (Papp-Wallace et al., 2011).

The concept of antimicrobial resistance was first recognised in 1961 with the emergence of methicillin resistance *Saphylococcus aureus* (MRSA) (Dowling, 1961). The rise of antimicrobial resistance has resulted in infectious bacterial diseases for which antimicrobial choices are very limited due to multi-drug resistant bacteria. This threat was first considered by Fleming and as time has progressed resistance has developed as each new class of antimicrobial has been licensed for use (McEwen, 2006). Strategies proposed to reduce the spread of resistance involve the development of new antimicrobial drugs, to which pathogens are susceptible to, and to promote prudent use to reduce, or delay, the onset of resistance (Anon, 2001).

The history of antimicrobial use in livestock

Penicillin was widely used in human medicine during World War II but towards the end of the war its use in farm animals was first described. A lyophilized penicillin was prepared with saline for the intra-mammary treatment of bovine mastitis. This initial therapeutic use of antimicrobials proved to be far more effective than existing treatments for mastitis (Gustafson and Bowen, 1997).

Following on from its use for therapeutic purposes its potential for growth promotion was recognised after World War II. Streptomycin was found to have a positive effect on the growth of chicks when added to the diet (Moore et al., 1946). However, the significance of this discovery was not recognised until Jukes and colleagues identified that feeding the by-products of chlortetracycline to chickens increased their weight-gain (Stokstad et al., 1949). Further studies highlighted the growth promotion potential of these antimicrobials in cattle and swine (Bartley et al., 1950, Cunha et al., 1950, Loosli and Wallace, 1950, Mcginnis et al., 1950, Rushoff, 1950, Stokstad and Jukes, 1950). The method by which antimicrobials promote growth is still not fully understood but is thought to be related to antimicrobials suppressing commensal bacteria within the gut, which normally divert nutrition away from the animal, and thus improve the efficacy and absorption of the gut (Dibner and Richards, 2005).

These broad spectrum antimicrobials were found not only to promote growth and increased feed efficiency but also to control endemic disease in large herds of animals and poultry flocks. With reduced antimicrobial costs and increasingly intensive rearing systems the use of antimicrobials multiplied, particularly in animals post-weaning or those exposed to stress. This sparked the use of prophylactic antibiosis, whereby a whole herd is medicated in response to clinical signs in as few as one or two animals (Gustafson and Bowen, 1997).

As time progressed through the 1950s and 1960s the range of antimicrobials, formulation of drugs and indications for use increased, shadowing the rise in human medicine. Regulation on the use of antimicrobials in veterinary medicine was under the control of the Ministry of Agriculture in England during this period (Gustafson and Bowen, 1997). Regulation was first passed in 1968 with the Medicines Act, which regulated the use and sale of human and veterinary medicines (Jones, 2010). Regulation for veterinary medicines initially considered only animal safety and efficacy, but later food, animal and environmental safety were included (Gustafson and Bowen, 1997).

Antimicrobial prescribing practices in pigs

Historically, antimicrobials have been used in the pig industry for the treatment and prevention of disease and growth promotion; whereby beneficial effects are seen on growth rates and feed conversion efficiency. However, the use of antimicrobials for growth promotion was banned in the European Union in 2006 but its use continues in many other countries worldwide (Stevens et al., 2007). Global intensification of pig production has resulted in pigs being reared in close proximity where disease is easily spread (Van Boeckel et al., 2015). Both bacterial and viral diseases contribute towards antimicrobial usage; with the latter often requiring antibiosis for secondary infections (Glass-Kaastra et al., 2013).

A survey of antimicrobial use across Europe revealed that respiratory disease, diarrhoeal disease and diseases caused by *Streptococcus suis* were the most common indications for the use of antimicrobials in pigs; of the conditions caused by *S. suis* postpartum dysgalactia syndrome was the most frequently cited by the study followed by arthritis, lameness and meningitis (De Briyne et al., 2014).

Therapeutic, prophylactic, and growth promotional use

The therapeutic use of antimicrobials has been defined as being the *'administration of an antimicrobial to an animal, which exhibits frank clinical disease'* (Anon, 2008c). Thus, in principal an antimicrobial is used to treat a known or suspected bacterial infection following the diagnosis of a particular disease or clinical pathogen (Schwarz et al., 2001).

At an individual level antimicrobials for therapeutic indications are most commonly administered via the injectable route in pigs (Stevens et al., 2007, Sjölund et al., 2015). However, with the intensive structure of the pig industry it is often impractical to administer antimicrobials to individual animals when the number requiring treatment is significant. In addition, group level administration for metaphylactic or prophylactic indications is a common practice. Metaphylaxis is defined as the use of antimicrobials at a group level when only a single animal or a small percentage of the group are exhibiting clinical signs of disease, but it is recognised that the rest of the in-contact group are at high risk of becoming affected and may already be sub-clinically infected (Schwarz et al., 2001, Anon, 2013b). In contrast, prophylaxis is distinct from metaphylaxis as its use is solely for the prevention of disease in pigs which are otherwise clinically healthy and before clinical signs are observed in either an individual animal or a group of pigs (Callens et al., 2012, Anon, 2013b).

The prophylactic use of antimicrobials to prevent disease in pigs is a widespread practice in the UK and elsewhere in Europe (Callens et al., 2012, Timmerman et al., 2006, Chauvin et al., 2002, Stevens et al., 2007). It is most commonly used in the pig industry at key time intervals where it is expected, from experience, that animals will become clinically diseased. Common indications include high stress situations such as weaning and the mixing of animals from multiple sources. The prevention of scour and respiratory disease are the most frequent disease indications which drive such use and antimicrobials would most commonly be administered through the water or feed route (Callens et al., 2012, Schwarz et al., 2001).

It has been proposed that antimicrobial use early in the course of an infection may reduce the chances of the development or acquisition of antimicrobial resistance by the bacterial population. This hypothesis states that in early disease there is a smaller bacterial population for antimicrobials to target and so there is less of a risk of resistant mutants being present in this smaller bacterial population, when compared to later in a disease state where the pathogen population is greater (Canton and Morosini, 2011, Kesteman et al., 2009). Thus, this theory proposes that metaphylactic or prophylactic antimicrobial use may be beneficial in minimising resistance when compared with later therapeutic use; once clinical signs are apparent. However, it should be noted that there is limited evidence to support this theory and the majority of the literature supports the contrasting theory that an increased frequency in the use of antimicrobials is correlated with increased levels of resistance in human medicine (Canton and Morosini, 2011) and livestock (Shyrock and Richwine, 2010, Akwar et al., 2008, Benedict et al., 2008, Gibbons et al., 2015, Garcia-Migura et al., 2014, Aarestrup and Wegener, 1999). Thus, the widespread use of antimicrobials for disease prevention and metaphylaxis is likely to drive an increased tendency towards the development of antimicrobial resistance compared to if use was more sparing, and perhaps if it was only allowed for therapeutic indications. As a consequence the prudence of such practices has been questioned (Jenks, 2014).

Antimicrobial use for non-therapeutic indications conflicts with the 'Good Agriculture Practices' devised by the Food and Agriculture Organisation of the United Nations that proposes that such practices should be minimised (Anon, 2003). In parallel, whether prophylaxis is considered to be responsible has been debated across Europe and the 2011 recommendations by the European Parliament called on the European Commission 'to make legislative proposals to phase out the prophylactic use of antimicrobials in livestock farming' (Anon, 2011a). Whilst there are currently no European-level legislative restrictions on the practice such use is banned in Austria where antimicrobials are only allowed to be used for therapeutic or metaphylactic reasons (Trauffler et al., 2014). Despite growing pressure on veterinary surgeons over the use of antimicrobials for disease prophylaxis it is recognised as a prudent and justifiable practice by veterinary prescribers (Speksnijder et al., 2015b) and pig farmers (Stevens et al., 2007).

Antimicrobial growth promoter restrictions in the European Union

Antimicrobial use for growth promotion began in the post-war years and increased with the intensification of livestock until a decline, with prohibition within Europe from the 1980s onwards. Antimicrobial growth promoters have been shown to have a positive effect on growth rates and feed conversion efficiency in pigs (Wahlstrom et al., 1952). The methods by which antimicrobials promote growth have not been proven, however, it is presumed to be related to their ability to reduce the overall numbers and variety of species of bacteria in the gut (Visek, 1978, Jensen, 1998, Close, 2000, Gaskins et al., 2002, Collier et al., 2003). This is supported by studies which show that growth promotion from antimicrobials does not occur in germ-free animals (Coates et al., 1963).

Since the discovery of MRSA, concerns were raised over antimicrobial resistance which culminated in the Swann report in 1969, which suggested that antimicrobials used in human medicine should not be used as growth promoters in agriculture (Swann, 1969). This resulted in chlortetracycline, penicillin, and the sulphonamides only being available under veterinary prescription from 1970 (Anon, 1970).

In 1997 the European Union (EU) began to restrict the use of antimicrobial growth promoters with a total ban on their use in 2006 (Casewell et al., 2003, Soulsby, 2007). In 1997 a ban was placed on the use of avoparcin for growth promotion purposes, with the addition of tylosin alongside bacitracin, spiramycin, tylosin and virginiamycin in 1999 (Casewell et al., 2003). The remaining antimicrobial growth promoters (monensin, avilamycin, salinomycin and flavomycin) were banned across all the member states in January 2006 (Soulsby, 2007).

There was widespread concern that the ban would result in the increased use of antimicrobials for therapeutic and prophylactic purposes (Anon, 2002a). A study on the effect of the 2006 ban in Denmark showed an overall increase in the frequency of requiring antimicrobials to treat diarrhoea conditions in the year following the ban, however use varied between farms with some experiencing no effects and others having more substantial disease issues (Vigre et al., 2008). Similar slight increases in the therapeutic use of antimicrobials were observed in Finland following the 1999 withdrawal of the antimicrobial growth promoters carbadox and olaquindox in Finland (Laine et al., 2004).

Formulation of antimicrobials

Antimicrobial administration in pigs is via either an injectable or oral route. Injection is most frequently used for individual animals and is usually given via an intra-muscular route in pigs (Dunlop et al., 1998). In order to avoid tissue reaction in valuable cuts of meat this is commonly given in the muscle caudal to the base of the ear (Page and Gautier, 2012). Oral formulations can either be in the form of oral drenches for the dosing of individual animals or in-feed or in-water medication for use in groups of animals. Oral drenches are used most commonly in neonatal piglets for the treatment of alimentary and respiratory mixed infections (Anon, 2013a).

The administration of antimicrobials through feed is a widely adopted practice in pigs (Page and Gautier, 2012); this may be in the form of top-dressing whereby an antimicrobial is mixed with food for an individual or small group of animals or it may be in the form of a premixed medicated feed, whereby the antimicrobial is incorporated into the feed at an approved feed mill site. Top-dressing is the favoured route of administration in many European countries such as Denmark, Germany and Belgium, yet it is seldom used in the UK and other areas of Southern Europe; where medicated feed is the preferred method (Anon, 2010c).

In-water medication is commonly used in pigs in an acute disease outbreak due to the ability to medicate water immediately. It has also been shown to be advantageous in inappetant animals as they will often continue to drink even if their feed intake is depressed (Page and Gautier, 2012). The use of water medications can be limited by problems with drinkers which can result in variable wastage and may result in increased costs (Li et al., 2005, Torrey et al., 2008). Antimicrobials commonly used in this formulation in pigs include amoxicillin and chlortetracycline (Anon, 2007).

Critically important antimicrobials

The definitions and classifications of critically important antimicrobials are diverse with different national and international organisations having their own categorisation systems and advice on appropriate use. The most widely recognised guidelines are produced by the World Health Organisation (WHO) (Anon, 2012d) and the World Organisation for Animal Health (OIE) (Anon, 2015f). The WHO categorises fluoroquinolones, third and fourth generation cephalosporins, macrolides and glycopeptides as the highest priority critically important antimicrobials and thus it is essential that their use is prudent in both human and veterinary medicine. These classes are considered to be of the highest priority for risk management in their use and prescribing practices to maintain efficacy for human use (Anon, 2012d). In contrast the OIE list of critically important antimicrobials focuses on appropriate use of antimicrobials of importance to veterinary medicine; in particular for diseases where there are few or no alternative antimicrobials. In parallel, the OIE also consider the aforementioned classes as being veterinary critically important antimicrobials with the exception of the glycopeptides, which are not described in the guidelines. Glycopeptide use in animals was discontinued within the European Union with the ban on antimicrobial growth promoters (Cogliani, 2011). However, in addition the aminoglycosides, penicillins, sulphonamides, sulphonamides and diaminopyrimidines in combination, diaminopyrimidines and tetracyclines also are classified as veterinary critically important antimicrobials in the guidelines (Anon, 2015f).

Currently, the polymixin antimicrobial colistin is classified as ‘highly important’ by the WHO, thus it is not presently considered to be a highest priority critically important antimicrobial (Anon, 2012d). However, since the publication of the WHO recommendations colistin has come under the spotlight; with increasing concern over its use in food producing animal species. Lui and others (2015) have demonstrated the presence of a *mcr*-1 gene in raw meat, livestock and humans in China, which is capable of transferring resistance via a plasmid-mediated polymyxin resistance mechanism (Liu et al., 2015). Following testing by Public Health England (PHE) and the Animal and Plant Health Agency (APHA) the *mcr-1* gene has subsequently been identified in humans and pigs in the UK (Woodmansey, 2015, Webb et al., 2015, 2016b) and additionally it has been detected in samples in France and Denmark (Hasman et al., 2015, Webb et al., 2015). Due to the ability of the *mcr-1* gene to be transferred between bacterial species by plasmid transfer, and the potential for the zoonotic transmission to humans via the food chain, the Responsible Use of Medicines in Agricultural Alliance (RUMA) announced that the use of colistin would be voluntarily restricted by the UK veterinary sectors (pigs, poultry and cattle) from 4 December 2015 whilst the public health risks are assessed. The restrictions agreed by RUMA members state that colistin should be an antimicrobial of last resort and only if susceptibility testing shows that it is the only effective antimicrobial available to treat pigs (Anon, 2016a). Additionally, following this concern the Pig Veterinary Society (PVS) have reclassified the polymixins as an antimicrobial class of last resort (Anon, 2014d).

The use of the highest priority critically important antimicrobials in veterinary medicine has been highlighted as an area of concern in Europe with agreement that their use should be limited to cases where it has been concluded by a veterinary surgeon, based on antimicrobial susceptibility testing or epidemiological data, that there are no other non-critically important antimicrobials suitable for use (Anon, 2014b). The European Medicines Agency (EMA) Committee for Medicinal Products for Veterinary Use (CVMP) have produced specific guidelines for the use of fluoroquinolones (Anon, 2006b), third and fourth generation cephalosporins (Anon, 2009) and macrolides (Anon, 2011c). Some countries within the European Union have banned or restricted the use of the critically important antimicrobials in animals. For example, Denmark restricted the use of fluoroquinolones in 2002 and introduced a voluntary ban on the third and fourth generation cephalosporins in 2010 (Agers et al., 2013), whilst the Netherlands introduced a voluntary ban on the third and fourth generation cephalosporins in 2012 (De Briyne et al., 2014).

In the UK the PVS have published prescribing guidelines promoting the responsible use of antimicrobials in pigs in which it specifies that fluoroquinolones, third and fourth generation cephalosporins and colistin should only be used *'when no other options are available and supported by laboratory sensitivity tests or in extreme circumstances when all else has failed'*. Whilst these guidelines do not recommend quite such restrictions on use for the macrolides, they do highlight the importance of only using the macrolides as a second line therapeutic option if other classes of antimicrobials are ineffective from antimicrobial susceptibility testing results or clinical experience (Anon, 2014d). In the wider context all of these guidelines identify antimicrobials of importance to human and veterinary medicine whose use needs to be targeted in order to minimise the risk of antimicrobial resistance developing in human and veterinary medicine (Anon, 2014d, Anon, 2012d, Anon, 2015f).

The influence of economic factors on prescribing

Antimicrobial prescribing decisions in food producing animals have unique economic considerations when compared to prescribing decisions in human or companion animal medicine; profitability and high animal performance are essential for pig production businesses (Anon, 2015d). The literature shows that overall veterinary surgeons strived to minimise veterinary costs for farmers and sought to minimise their overall antimicrobial costs (Sheehan, 2013, Speksnijder et al., 2015b). In parallel, studies investigating farmer opinion acknowledged that the high economic costs of pig production were a considerable pressure on their professional lives and that this pressure has increased with time (Alarcon et al., 2014). Similarly, farmers correlated poor quality and inadequate housing with high use of antimicrobials (Stevens et al., 2007) and identified that disease had a negative financial impact on their farm as a business (Alarcon et al., 2014). The economic uncertainty and high cost of pig production described in the literature has been directly linked with pressure from the retailers by both veterinary surgeons and farmers (Alarcon et al., 2014, Sheehan, 2013).

Specific economic factors which have been identified as driving antimicrobial prescribing decisions in pigs include the withdrawal period of an antimicrobial and diagnostic testing. The use of an appropriate withdrawal period in pigs near slaughter weight has been identified as an economic factor motivating antimicrobial prescribing decisions (Speksnijder et al., 2015b, Sheehan, 2013, Lubbers and Turnidge, 2014). Despite widespread acknowledgement of the advantages of antimicrobial susceptibility testing it is described as being an underutilised tool in farm animal veterinary practice with the high cost and farmer reluctance frequently being cited as justifications for this infrequent use (Sheehan, 2013, De Briyne et al., 2013, Speksnijder et al., 2015b).

Alternatives to the use of antimicrobials to prevent disease in pig production

Feed additives such as prebiotics and probiotics have been considered as an alternative to the use of antimicrobials for disease prevention. The use of probiotics in pigs has been linked with improvements in the gastrointestinal health of pigs (Badia et al., 2013, Upadrasta et al., 2013) and in broiler flocks they have been shown to have a positive effect on production parameters (Mookiah et al., 2014). In addition, feed additives such as phytotherapeutics (Chu et al., 2013) and the use of organic acids in feed (Visscher et al., 2009) have been described as alternatives to the use of antimicrobials in pigs. The acidification of drinking water has also been considered as an alternative to antimicrobial use in pigs (Walsh et al., 2007).

The use of metals such as copper and zinc as food additives at concentrations in excess of dietary needs have been used in pigs to prevent diarrhoeal disease and as an alternative to the use of antimicrobials (Amachawadi et al., 2011, Yazdankhah et al., 2014). Zinc oxide is currently permitted for use as a feed additive in Europe and has been assessed by the European Food Safety Agency as being safe for animals and consumers at a maximum concentration (150-250ppm). However, its use at concentrations in excess of this level are currently permitted on prescription in the UK, Sweden and Denmark amongst other European countries whilst other countries such as Germany, France and the Netherlands do not allow such use (Buhot, 2014, De Briyne et al., 2014). In Denmark its use at high concentrations is widespread and it is currently the most significant medicated feed in Denmark (Buhot, 2014); a country which has reduced its use of antimicrobials in livestock by around 60 % since the 1990s (Aarestrup, 2012). There are a number of concerns with the use of zinc oxide including the potential environmental contamination of groundwater by manure and zinc run-off to surface water; a concern which is high in areas of high pig density (Buhot, 2014). In addition, some studies have suggested that zinc oxide might promote the spread of antimicrobial resistance via co-selection mechanisms; it has been identified as potentially playing a role in co-selection of resistant MRSA and macrolide resistance (Bednorz et al., 2013, Buhot, 2014, Hasman et al., 2006).

Vaccination is a vital component of a disease control program as a means to improve animal health and as an alternative method to the use of antimicrobials in preventing disease (Anon, 2015d, Postma et al., 2015b). For example, the introduction of a vaccination for porcine reproductive and respiratory syndrome virus (PRRSv) has resulted in a dramatic improvement in the health of pigs and a reduction in the requirement for antimicrobials. The vaccination prevents the requirement for antimicrobials to treat concurrent bacterial infections (Baker, 2006).

Biosecurity in its simplest form can be defined as a series of measures which aim to prevent disease. This definition can be further divided into internal and external biosecurity; external biosecurity being the prevention of pathogens entering the herd whilst internal biosecurity is prevention of pathogens from spreading within a group of animals (Ribbens et al., 2008). It has been found that there is a positive association between effective biosecurity measures, high production parameters and low antimicrobial usage in pig herds (Laanen et al., 2013, Postma et al., 2015a).

Ensuring that optimum hygiene management practices are maintained have been found to be beneficial in ensuring that the herd health status is maintained and such practices have been associated with low antimicrobial use (Stevens et al., 2007, Postma et al., 2015b). The literature shows that the relationship between the farming system employed and the antimicrobial requirements on a unit are complex and multifactorial; there is no general consensus on what farming system would be considered to be a lower or higher antimicrobial user (Stevens et al., 2007, Moreno, 2012, Guy et al., 2002, Scott et al., 2006). However, studies show that ensuring that pig climatic and housing conditions are optimal results in fewer clinical disease signs, improved productivity and consequently this may lead to lower antimicrobial use (Hessing and Tielen, 1994, Dee et al., 2010). Genetics of the pig herd has also been considered to play a role in minimising antimicrobial requirements. Genetically enhanced and disease resistant breeds have been used to try and eradicate disease and therefore can be considered as a potential alternative method to the use of antimicrobials to prevent disease (Opriessing et al., 2009, Doeschl-Wilson et al., 2009)

A global look at antimicrobial consumption in pigs

To gain a global perspective on the use of antimicrobials in pigs it is useful to examine the geographical sales patterns of veterinary drugs for use in food production animals alongside the world's distribution of the pigs. In 2010, it was estimated that the five countries with the greatest antimicrobial sales for food producing animals were China (23%), the United States (13%), Brazil (9%), India (3%) and Germany (3%) (Van Boeckel et al., 2015). With an increasing livestock population and a move towards intensive agriculture it has been forecast that antimicrobial consumption in food producing animals could rise by around 67% by 2030 (Van Boeckel et al., 2015). Similarly, a steady increase in the global population of pigs has been observed to around 9986.7 million in 2014. Asia accounts for the greatest proportion of this worldwide population (59.9%), followed by Europe (18.8%), the Americas (17.3%), Africa and Oceania (3.5%). If these data on global antimicrobial consumption and pig production are observed in parallel, China, followed by the United States of America, are found in the first and second positions on both global scales (Anon, 2014c, Van Boeckel et al., 2015).

A survey by the World Organization for Animal Health (OIE) found that only 91% of its 178 member countries have legislation relating to veterinary medicinal products. These data also show that antimicrobial growth promoters continue to be used in 49% of countries. The use of antimicrobial growth promoters is under global debate following concerns over antimicrobial resistance (Nisi, 2013). It is useful to consider how this relates to pig production in each country at an individual level.

The United Kingdom

The UK pig breeding herd consisted of around 407 thousand sows in June 2015, having suffered a steady decline since the 1970s (Anon, 2015k). The pig industry is typically cyclical but has suffered a steady decline in production and profitability in recent years with increased importation of pig meat (Anon, 2008a). Higher welfare standards in the UK for pigs raised under the Red Tractor farm assurance scheme necessitate higher production costs than other EU countries. The prices paid by consumers and retailers is not sufficient to cover this expense; putting strain on producers (Anon, 2001d, 2008a).

There are estimated to be around 10,000 commercial pig holdings in the UK with around 92 % of the pig production coming from Red Tractor farm assured units. The methods of pig rearing employed in the UK are diverse and range from indoor units, outdoor units, straw-based and slatted pig accommodation; such diversity makes the industry different from many other countries. For example, around 40 % of the female breeding population are reared outdoors (Anon, 2015g).

It is possible to gain some perspective on antimicrobial use in pigs through the UK antimicrobial sales data collated by the Veterinary Medicines Directorate (VMD). In 2014 17.3 % of the total tonnes of antimicrobial sold were authorised for use solely in pigs, whilst products authorised for use in pigs and poultry only contributed 61.0 % towards the total 369 tonnes of antimicrobials sold for veterinary use in solely food producing species (Borriello et al., 2015). In addition, antimicrobial sales for medicated feed contributed 63 % towards the total sales in 2014, most of which were for use in pigs and poultry (Borriello et al., 2015). Recent initiatives such as those by Red Tractor Farm Assurance which has required all member farms to record antimicrobial use (Anon, 2014g), and a future voluntary scheme, through a collaboration of the VMD and the Agricultural and Horticultural Development Board - Pork (AHDB Pork), to quantify use across all UK pig farms (Anon, 2015c) will offer superior quantifiable data with the potential for benchmarking of similar farms.

A study by Stevens and others (2007) described the characteristics of antimicrobial use in pigs in the UK. The practices in formulation mirror the data from the VMD on veterinary antimicrobial sales. The most frequently used antimicrobial formulation for use in pigs in the UK was found to be injectable, followed by in-feed and in-water; with 56 % of farmers having medicated their weaners or growers feed in the two weeks prior to the study. When compared to in-water medication, in-feed administration was found to be used more frequently for respiratory disease than in-water in all age groups of pig (Stevens et al., 2007).

Antimicrobial use and data collection in Europe

The two most common indications requiring antimicrobial use in pigs across Europe include respiratory and diarrhoeal disease which accounted for approximately 60 % of prescriptions (De Briyne et al., 2014). For respiratory disease the tetracyclines (47 %) are the most commonly used antimicrobials followed by the penicillins (21 %). In contrast there was a greater diversity of antimicrobials which were commonly used in enteric diseases with polymixins, namely colistin (30 %), macrolides (22 %) and fluoroquinolones (12 %) being the most widespread (De Briyne et al., 2014).

If the use of the critically important antimicrobials is considered, those classified as highest priority by the WHO (Anon, 2012d) contributed 20 % towards the total use of antimicrobials in pigs across Europe; macrolides, fluoroquinolones and third and fourth generation cephalosporins (De Briyne et al., 2014). However, across Europe 10 % of antimicrobials used in pigs were found to be polymixins, most commonly colistin. Colistin is used infrequently in the UK compared to other European countries; it represented 0.3 % of the milligrams (mg) per population correction unit in 2013. In contrast, colistin sales formed 4.6 % of the mg of population correction unit in Germany, whilst the figure stood at 3.0 % and 2.1 % in Italy and Spain, respectively (Anon, 2015j).

There is an increasing move towards the collation of antimicrobial usage data. The European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) was launched in 2009 and currently collates data on the sales of veterinary antimicrobials from 26 European Union (EU) and European Economic Area (EEA) countries. Data are collectd using a standardised protocol; the Population Correction Unit (PCU). This protocol attempts to account for differences between the size of animal populations in different countries. The PCU is a theoretical measurement unit which considers the weight of food producing animals at the likely time of treatment. Therefore, data is expressed as mg active ingredient sold per population correction unit (mg/PCU) in order to create a unit which allows the comparison of data between countries (Anon, 2015j).

There are some limitations to the use and interpretation of these data. For example, there are discrepancies between authorised dose rates for some antimicrobials between countries and many antimicrobial products are authorised for use in multiple species, including products authorised for use in both food producing and non-food producing species. In addition, there are major species differences in usages; this is particularly significant in the context of the varying animal demographics between countries (Anon, 2015j, Grave et al., 2012). For example, pigs would tend to be higher antimicrobial consumers than extensive beef rearing (Silley et al., 2012).

In order to better understand the risks associated with antimicrobial use and the development of resistance in food producing animals it is essential that surveillance of antimicrobial use is carried out. Currently a small number of EU countries (Denmark, Netherlands and Sweden) already conduct continuous surveillance data on antimicrobial use whilst Belgium, Finland and Norway are currently developing systems to examine data (Anon, 2013h). ESVAC are currently developing a system for collecting harmonised data on the consumption of antimicrobial agents by animal species at EU-level and developing a technical unit of measurement to analyse consumption data by species to account for any differences in dosing (daily dosing and length of treatment) in antimicrobials when reporting data (Anon, 2013h, 2015h).

The United States of America (USA) and Canada

The USA is the third largest producer of pork in the world and the largest exporter with exports accounting for 10 % of global production between 2008 and 2012. In contrast, Canada is the seventh largest pork producer in the world; however, it is the largest exporter of pork with the majority of these exports being to the USA (Giamalva, 2014). The swine industry in the USA and Canada is highly intensive, with systems frequently referred to as confined animal feeding operations (CAFOs) (Sarmah et al., 2006). This close proximity of animals has resulted in a historic and continued high reliance on antimicrobials for therapeutic, prophylactic and growth promotional reasons (Sarmah et al., 2006, Anon, 2002b, Dunlop et al., 1998, Rajic et al., 2006, Teillant and Laxminarayan, 2015).

The overall sales of antimicrobials authorised for use in food producing animals have increased in the USA over the last 5 years from around 12.6 million kilogram (kg) in 2009 through to around 15.3 million kg in 2014 (an increase of around 22%). Due to the limitations of the data it is not possible to apportion sales of products authorised for use in pigs or the percentage of sales attributed to growth promoter use, however, only 29% of the sales for 2014 were products authorised for therapeutic use only with the remaining 71% being either a combination of growth promotion production and therapeutic indications or production only (Anon, 2014h).

Studies in both the USA and Canada have identified antimicrobials belonging to the tetracycline class of antimicrobials and a macrolide, tylosin as being the most common antimicrobials administered via an in-feed formulation; these are also authorised for use for growth promotional reasons (Anon, 2002b, Apley, 2012). The third and fourth generation cephalosporins and fluoroquinolones are both authorised for use in pigs in the USA however, concerns over their use and the importance to human medicine led the Food and Drug Administration (FDA) to prohibit the extra-label use of both classes in 2012 in an attempt to promote prudent use (Anon, 1997, 2012a). In Canada the fluoroquinolones are not currently permitted to be used off label. The use of fluoroquinolones and third and fourth generation cephalosporins in Canada is the subject of guidelines on ensuring that such use is justifiable and responsible due to their status as antimicrobials of importance to human medicine (Anon, 2002b, Talor, 2015).

Although the practice has come under scrutiny, the use of antimicrobial growth promoters is still commonplace in the USA and Canada (Apley, 2012, Klotins, 2005). In 2006 it was estimated that around 84 % of ‘grower/finisher pigs’ were exposed to growth promoters in the USA (Anon, 2007). The USA has come under increasing international pressure from the World Health Organisation to withdraw the use of growth promoters in food producing animals and in response a 2012 FDA report recommended the voluntary withdrawal of antimicrobial growth promoters of medical importance in human medicine (Anon, 2012c). This voluntary ban coupled with increasing retailer pressure for growth promoter free meat may result in changes in the non-prescription use of antimicrobials in the future (Teillant and Laxminarayan, 2015).

Australia and New Zealand

Across Australia and New Zealand pigs are reared intensively with a trend towards larger herd sizes on fewer farms (Cutler, 2007, Anon, 2005). The use of antimicrobial growth promoters is still a current practice across Australia and New Zealand however there are some restrictions on their use. Due to global concerns over the threat posed by vancomycin-resistant enterococci in human medicine and links with avoparcin use in farm animals (Acar, 2000); the use of avoparcin in Australia and New Zealand has ceased (Anon, 2006a, Manson et al., 2004). The related compound virginiamycin is no longer available for use in New

Zealand (Anon, 2010a), but it continues to be licensed in Australia, however its use is infrequent and is under review (Manson et al., 2004, Anon, 2013f).

Antimicrobials in Australia have been classified in a way which considers the effect each drug would have if resistance were to develop in human medicine. Antimicrobials are given a rating of ‘high’, ‘medium’ or ‘low’. Antimicrobial classes used in veterinary medicine classified as ‘high’ includes the fluoroquinolones, colistin, and the third and fourth generation cephalosporins (Anon, 2014a). The use of fluoroquinolones in food producing animals is not currently permitted in Australia and whilst there are currently no third and fourth generation cephalosporins authorised for use in pigs, there is concern that off label use may be an issue (Anon, 2013f). Confirming this concern Jordan and others (2009) found ceftiofur to have been used by 25% of pig herds within a twelve month period for diarrhoea.

There are currently no restrictions over the therapeutic and prophylactic use of antimicrobials considered critical to human health in pigs in New Zealand, however, the use of such classes for growth promotional reasons is no longer practiced. The continued use of the antimicrobial carbadox in pigs in New Zealand (Baoumgren, 2013) has been highlighted as an area of concern due to global fears over human safety due to its potential carcinogenic and reproductive toxicity; this has resulted in its prohibition in the EU, Canada and Australia (Giguère et al., 2013). Controversially, use continues in New Zealand with it being an additive for around 80% of weaners for the prevention of enteric disease (Anon, 2005).

Asia

It has been forecast that antimicrobial use in food production within Asia is likely to increase with a move towards more intensive production; by 2030 this could be 82% of the 2010 total world consumption estimate (63,151 tonnes) (Van Boeckel et al., 2015). After China, Vietnam was considered to the second biggest producer of pigs in Asia in 2009 (Page and Gautier, 2012). In Vietnam antimicrobials for veterinary use are widely available and their use is often indiscriminate and without a prescription. Currently there is no routine monitoring of maximum residue levels of antimicrobials and there is very limited data on use (Pham Kim, 2013). Vietnamese legislation restricts the use of certain antimicrobials for growth promotional purposes in pigs including amoxicillin, the macrolides, colistin and tetracycline. Despite such regulation, the use of colistin and chlortetracycline has been found to be a common occurrence in pigs (Ton, 2010, Pham Kim, 2013).

Pig production is the second most common livestock industry after dairy farming in Japan (Oh and Whitley, 2011), with pigs consuming more antimicrobials than any other food producing animal in the country (Kawanishi, 2013). Whilst antimicrobials are only available under veterinary prescription there are no regulations or restrictions on the use of antimicrobials for growth promotion in Japan. However, its Food Safety Commission is reportedly considering restricting some uses of antimicrobials for growth promotion in response to consumer anxiety over food safety (Kubota, 2010, Maron et al., 2013).

South Korea began tightening restrictions on antimicrobial use in animal feed in 2008 with a gradual reduction in the number of allowable drugs through to 2011 (Anon, 2008b). Since 2011 eight antimicrobials have been prohibited from inclusion in animal feeds including tiamulin and virginiamycin. These restrictions were announced to the World Trade Organisation in August 2010 to come in to effect late in 2011 (Johnson, 2011, Maron et al., 2013). This move followed legislation in 2007 which made the strict labelling of meat products such as ‘antimicrobial free’ and ‘organic’ compulsory (Anon, 2008b).

China

China is the world’s largest consumer of antimicrobials in food producing animals (Van Boeckel et al., 2015) and when compared with the USA it has been estimated that China uses around three times the total amount of antimicrobials in pigs and poultry (Krishnasamy et al., 2015). This, coupled with the position of China as the largest consumer and producer of pork (Giamalva, 2014), highlights antimicrobial use in pigs as an area of concern. There is currently no monitoring of antimicrobial residue levels in meat (Krishnasamy et al., 2015) resulting in residues in animal manure and environmental contamination (Li et al., 2012, Zhou et al., 2013).

There is a high consumer demand for quick growing and efficient pig production in China and to meet this demand antimicrobial use for growth promotion is widespread and all of the major antimicrobial classes are used in pigs (Zhu et al., 2013, Krishnasamy et al., 2015). It has been estimated that around 70% of total antimicrobial use in pigs is in the finishing phase and that the use of chlortetracycline, tylosin (classified as a critically important antimicrobial of the highest priority by the WHO) and carbadox are commonplace. This use is most likely for growth promotional reasons, however this cannot be quantified due to a lack of routine surveillance of antimicrobial use or resistance. There is no requirement for a prescription for antimicrobials for either growth promotional or therapeutic use (Zhu et al., 2013). In addition, the use of combinations of antimicrobials is a frequently described practice (Krishnasamy et al., 2015) and, whilst the effects of this are currently unknown (Zhu et al., 2013), the mixture of resistance selecting agents is presumed to select for bacteria with resistance to multiple antimicrobials (Gillings and Stokes, 2012).

Africa

It has been proposed that across Africa food producing animals are more likely to die due to a lack of access to antimicrobials than from a resistant infection; there is currently limited capacity to monitor antimicrobial use and resistance across the continent. In a survey conducted by Grace and others (2015) of Chief Veterinary Officers across Africa only 7 out of 34 were able to provide any quantitative data on antimicrobial use in livestock (Grace, 2015). This study estimated that the average use for individual African countries was around 418 tonnes, half the proposed value in developed countries which has been estimated to be around 864 tonnes per year (Van Boeckel et al., 2015). With the exception of South Africa, where farming is more intensive, farming is currently predominantly in extensive systems across Africa (Henton et al., 2011, Robinson, 2011). However, with an increasing population and accompanying food requirements it has been forecast that the African continent will see an increase in livestock populations and an inevitable move towards more intensive systems (Robinson, 2011).

Antimicrobial growth promoters are restricted in approximately 40% of countries across Africa with wide variation in regulation (Nisi, 2013). There is very limited data available on what restrictions are in place across the countries. Mitema and others report that Kenya restricts the use of carbadox, virginiamycin, vancomycin and avoparcin for this purpose. In addition, there are anecdotal reports that the tetracycline and sulphonamide classes are used commonly for growth promotion in Kenya (Mitema et al., 2001). The widespread use of antimicrobial growth promoters in intensive pig rearing in South Africa has been commonly reported with macrolides and virginiamycin being frequently cited (Tilman et al., 2002, Henton et al., 2011, Moyane et al., 2013).

Regulation surrounding antimicrobials is rarely enforced with prescription drugs being readily available over the counter and pigs seldom being seen by a veterinary surgeon (Dipeolu and Alonge, 2002, Ezenduka and Ugwumba, 2012, Adesokan et al., 2015). A study by Adesokan and others found that antimicrobials were commonly available over the counter and farmers frequently administered these without contact with a veterinary surgeon. The study also found that it was common practice to administer higher doses of antimicrobials than they are authorised at and to combine different classes due to the poor response commonly seen. Whilst this treatment failure may indicate resistance problems there are no data to support or disprove this theory (Adesokan et al., 2015). In addition, withdrawal periods are not usually adhered to and there have been reports of antimicrobial residues in food animals and their products (Ezenduka and Ugwumba, 2012, Adesokan et al., 2015).

Central and South America

Brazil has the highest density of pigs across Central and South America and is currently the world’s fourth largest producer of pigs (Giamalva, 2014, Robinson et al., 2014); there has been rapid growth in the swine industry in recent years with a move towards more intensive production (Grace, 2015). It has been estimated that in 2010 Brazil had an 8% share of the total world livestock antimicrobial consumption and Mexico alongside Brazil have also been highlighted as countries likely to see a substantial increase in antimicrobial consumption in the future (Van Boeckel et al., 2015). Despite the scale of production there is limited information on veterinary antimicrobial use across the countries with two thirds of the Americas having no routine surveillance of use (Nisi, 2013).

Growth promoter use is either freely or partially permitted in over 80% of the Americas (Nisi, 2013). Brazil prohibits the use of carbadox, tetracyclines, penicillins, chloramphenicol and sulphonamides for growth promotional reasons (Kroismayr, 2007, Regitano and Leal, 2010). However, enforcement of this regulation is questionable with one study reporting that tetracyclines and sulphonamides are used frequently for this purpose in broiler chickens (Regitano and Leal, 2010). Mexico has restricted the use of antimicrobial growth promoters since 2007 and requires that veterinary antimicrobial use is on prescription. Whilst this ban covered most antimicrobial growth promoters 15 were not included in these restrictions which included antimicrobials such as virginamycin, avoparcin and the macrolide tylosin (Maron et al., 2013). Virginamycin and avoparcin were banned from being used as growth promoters across Europe as their use was found to be a selective force for streptogramin resistance in *Enterococcus faecium* in humans (Cogliani, 2011).

Of the Americas 93% are reported to have legislation surrounding antimicrobial use, however, there is much variation between countries (Nisi, 2013). For example, the Alliance for the Prudent Use of Antibiotics (APUA) reports that Argentina does not currently regulate veterinary antimicrobial use (Gustavo Lopardo, 2012), whilst existing regulation in Mexico is reported as being poorly enforced (Lopez, 2011). This conclusion is supported by academic research, with residues of tetracycline being found in around 50% of pig meat sampled in Mexico; showing poor adherence to meat withdrawal times (Medina et al., 2008).

Russia

Russia has seen growth in its pig production capacity with a 26% increase in pork production between 2008 and 2013 (Giamalva, 2014). There are currently no data available on veterinary antimicrobial use in Russia, however, it has been forecast that there will be around a 99 % increase in antimicrobial consumption in food producing animals in the next 20 years (Van Boeckel et al., 2015); this proposes that there is likely to be a continued upward trend in pig and other intensive livestock production.

There are presently no data available relating to any regulation on the use of antimicrobial growth promoters in food producing animals in Russia (Maron et al., 2013). However data from 1997 identified that the use of bacitracin, flavomycin and virginamycin were permitted in food producing animals. Russian regulation in the 1990s only allowed the use of antimicrobials that were not used in human medicine, or for therapeutic or prophylactic indications in veterinary medicine to be used for growth promotion (Panin, 1997).

Antimicrobial use and the threat from antimicrobial resistance

Bacterial evolution has occurred over the last 3.5 billion years. Bacteria have acquired mechanisms by which they can exchange genetic material through horizontal gene transfer and as such it is inevitable that alongside this evolution they have responded to the threat of antimicrobials with Darwinian survival mechanisms; resulting in antimicrobial resistance (Sykes, 2010).

Mechanisms of acquiring antimicrobial resistance

The acquisition of antimicrobial resistance by bacteria can be considered to fall into two main categories: those that are intrinsic or those that are acquired. Intrinsic resistance is considered to be the natural ability of some bacterial species to resist the activity of specific antimicrobials through structural or functional features (Poole and Sheffield, 2013). For example, *enterococci* are intrinsically resistant to cephalosporins due to having insufficient binding affinity to penicillin binding proteins (Hollenbeck and Rice, 2012). In general, the genetic basis for intrinsic resistance is located on the bacterial chromosome and thus is not easily transferred horizontally or expressed in other bacterial strains (Poole and Sheffield, 2013).

In contrast, acquired resistance is when a bacteria obtains or 'acquires' the ability to resist the activity of an antimicrobial agent. This occurs through two general mechanisms. Firstly, when a mutation occurs on a gene located on the bacterial chromosome, and secondly when bacteria acquire exogenous genes on mobile DNA elements, thus increasing the spread of resistance. Cross resistance is the concept whereby one resistance mechanisms results in resistance to multiple antimicrobials or classes of antimicrobials (Poole and Sheffield, 2013).

Drivers for the development of antimicrobial resistance

The drivers of antimicrobial resistance are complex and often multifactorial; however, the exposure to antimicrobial drugs is believed to be a major driving force towards resistance. It has been estimated that in human medicine up to 50% of antimicrobial prescriptions are considered to be unnecessary (Frieden, 2013) and this indiscriminate and overuse has been directly linked with the development of resistance (Aiken et al., 2014, Holmes et al., 2016). This link is further confirmed by the modest reduction in antimicrobial resistance identified following a reduction in antimicrobial prescriptions in humans (Livermore et al., 2013).

Whilst the link between antimicrobial use and resistance is clear it must be considered that this association is complex. For example, factors such as pathogen-host and pathogen-drug interactions, horizontal gene transfer, and the transmission rates of pathogens between humans, animals and the environment, and cross-resistance to different antimicrobials and classes need to be considered when antimicrobial resistance mechanisms are assessed. Other factors such as population vaccination rates, hygiene measures, migration, different healthcare settings and population densities also influence resistance prevalence (Turnidge and Christiansen, 2005, Grijalva, 2014).

The literature reveals that a number of factors have been associated with variability in antimicrobial resistance in populations of pigs, poultry and cattle. For example, differences in exposure to antimicrobials, variations in management practices that might contribute towards antimicrobial resistance and contrasts in the association between antimicrobial exposure and resistance have been demonstrated in these different livestock species (Thibodeau et al., 2008, Morley et al., 2011, Akwar et al., 2008, Benedict et al., 2015). The direct study of the relationship between exposure to antimicrobials and resistance development is problematic. Firstly, it is difficult to quantify the effects of specific antimicrobial use on resistance levels in a bacterial population and secondly, the diverse methodologies by which antimicrobial resistance is tested can result in testing biases and data which cannot be easily compared (Aarestrup, 2005). For example results from some methodologies may be quantitative (MIC) whilst all tests can provide qualitative categorical results, such as susceptible, intermediate or resistant. Other tests such as disc diffusion testing only provide these categorical data (Benedict et al., 2014, Benedict et al., 2015, Jorgensen and Ferraro, 2009).

There has been concern over the potential transfer of resistance from animal populations to human medicine through the zoonotic transfer of resistant bacteria or corresponding resistance determinants from bacteria in livestock species to humans (Schwarz et al., 2001, O'Neill, 2015). This phenomenon has been recognised as a potential threat to human health through the use of antimicrobials in pigs (Burow et al., 2014). Whilst isolated incidents of such transfer are described in the literature for *E.coli, Staphylococcus aureus, Salmonella* and *Campylobacter* species (Agersø et al., 2012, Lewis et al., 2008, Taylor et al., 2008, Mølbak et al., 1999), it is impossible to quantify or assess the level of the risk at present (O'Neill, 2015). Thus, it is essential that prudent antimicrobial practices are adopted in veterinary as well as in human medicine to minimise selection pressures with the aim of slowing the emergence of resistant bacteria (Llor and Bjerrum, 2014, Aarestrup, 2005).

Antimicrobial stewardship initiatives to encourage responsible prescribing behaviours are increasingly common in veterinary medicine, with various organisations producing guidelines on responsible use. For example the British Veterinary Association produce general guidelines on responsible use (Andrews, 2009), whilst the British Equine Veterinary Association (BEVA) and the British Small Animal Veterinary Association (BSAVA) have produced specific use guidelines for equine (Anon, 2014e) and small animals (Anon, 2012f). In the UK general guidelines on the requirement and responsible use of antimicrobials in pigs are published by the Responsible Use of Medicines in Agriculture (RUMA) and the Pig Veterinary Society (PVS) publishes guidelines on the appropriate first, second and third line antimicrobial choices in pigs (Anon, 2013g, 2014d).

Currently, disease specific guidelines are only published for small animal species (Anon, 2012f) and veterinary guidance is not available at a regional level. In human medicine national prescribing guidelines are widely adopted (Dixon and Duncan, 2014) however, in contrast, primary care trusts produce and advocate their own local level guidance (Anon, 2015e) targeting specific disease conditions and bacterial pathogens (Ali, 2006). Consequently, whilst the decision whether or not to prescribe an antimicrobial is an individual choice, those working within a human medicine environment have a much broader spectrum of information to guide such decision-making when compared with veterinary prescribers. Thus, there is a potential for greater variation between individual prescribing practices by veterinary surgeons, when compared with physicians.

The use of qualitative methodologies to investigate antimicrobial prescribing behaviours in human medicine

Background to qualitative methodologies

Qualitative research does not seek to quantify data but wishes to understand the participants' perceptions, views and emotions surrounding a particular question or subject (Mays and Pope, 1995). Such methodologies fall into two basic categories either observation or interview. Interviews can be either on an individual basis or in a group or focus group. The way in which an interview is conducted varies from highly structured closed questions often offering almost quantifiable data, through semi-structured interviews, whereby the interview content is guided but the order and conduct is flexible, through to in-depth and narrative interviews where the participant is able to express opinions and tell stories freely. Observational methods are less clearly defined but can be either direct observation with the researcher acting as an outside observer, or as an active participant in the environment which is being studied. Data may consist of written accounts such as case notes or other documents, and audio or video recordings (Bryman, 2012).

Qualitative research is often queried by quantitative researchers as lacking scientific rigor. Strategies to minimise bias and to maximise reliability of data are very different to those utilised in quantitative research methods. Such concerns are present due to the different aims and approaches of the two contrasting methods. For example, quantitative research aims to present data representative of the sample population such that if the study was repeated the data would be consistent with the original findings. However, qualitative research seeks to purposively sample individuals who are relevant to the research question and as such does not claim to show representative opinions; it often seeks opinions from different or diverse groups of participants in order to obtain a range of opinions (Mays and Pope, 1995). However, whilst these different results may be unique to the participant group, data may inform a more generalised theory to explain the subject and research area being studied (Bryman, 2012, Christley and Perkins, 2010).

Qualitative data analysis involves interpreting study findings and it is often considered to be more subjective when compared to quantitative data. For example, some quantitative researchers will argue that qualitative data accounts cannot be considered to represent the social world as different researchers may interpret the data in different ways. Thus, there are concerns from quantitative advocates that it is difficult to prove the trustworthiness of qualitative data (Pope et al., 2007, Burnard et al., 2008).

Data saturation

There is no definite method to prove validity or trustworthiness of qualitative data. Thus, it is essential that data analysis is systematic and rigorous for the whole corpus of data; it may be appropriate to seek findings that are opposite or a minority opinion to the main findings. Qualitative researchers need to use a constant comparison approach which involves reading and reiterative reading of data to identify themes in order to investigate and understand the meaning of the data (Bryman, 2012, Burnard et al., 2008). If a grounded theory approach is used it is essential that data collection continues until theoretical saturation is achieved whereby no new themes or relevant insights are identified in the data (Bryman, 2012). This ensures that the study has explored and covered all of the themes in the population.

Member checking and peer review

Whether researchers should have their data analysis verified or validated by a third party is debated (Barbour, 2001, Mays and Pope, 1995); some argue that it makes analysis more rigorous and minimises the effects of bias. Data can be validated using two main approaches. Firstly, the researcher validates data by asking the study participant to review analysis, secondly, peer review is used whereby a second qualitative researcher is approached to analyse the data independently (Mays and Pope, 1995, Burnard et al., 2008, Barbour, 2001).

The process of peer review involves a second researcher reviewing transcripts, data analysis and themes independently. This process can minimise the impact of researcher bias and can provide additional and deeper insights into the development of themes and theories (Barbour, 2001, Cutcliffe et al., 1999). However, this approach is also criticised as it is possible that both of the researchers may interpret the data in different ways. If this does occur and both viewpoints are grounded in and supported by the data it is argued that both are equally valid (Burnard et al., 2008).

Triangulation

Triangulation involves the use of either multiple methods or multiple data sources in order to produce a detailed understanding. This can be considered to increase the trustworthiness of qualitative data as it ensures that data is comprehensive, rich and well-developed (Patton, 2002). Triangulation can be achieved using different methods in the data collection, different theories to analyse and interpret data, different data sources or investigator triangulation whereby two researchers are involved in the data collection. An example of triangulation is the use of two different qualitative data methods in order to address the same research question for example, focus groups and interviews. This allows for different perspectives that might otherwise be overlooked (Carter et al., 2014).

Reflexivity

It is widely accepted in qualitative research that a researchers' background, perspectives and beliefs will influence the way in which data is collected and analysed. Reflexivity is the process in which the researcher systematically reviews their research in order to validate their own research practices. It is perceived to be an integral process in qualitative research whereby the researcher continually reflects on how their own actions, values and perceptions within the research setting may influence data collection and analysis (Malterud, 2001). Reflexivity can be achieved through the use of a reflexive journal in which the researcher records method decisions, logistics and reflects upon their personal values throughout the research process. In order to provide evidence of reflexivity it may be valuable in published studies to briefly outline how data were collected and analysed alongside the researchers' own preconceptions and beliefs in order to allow the reader to critically assess the trustworthiness of the study (Barry et al., 1999, Malterud, 2001).

The use of a qualitative approach to investigating human antimicrobial prescribing behaviours

The use of qualitative methodology has increased in popularity in human medicine in both primary care and general practice settings. Britten states that *'the nature of general practice is such that a variety of research methods are needed to explore all its intricacies'* and he considers that such methods can explore areas and topics not currently accessible through quantitative methodology. For example factors such as patient expectation and satisfaction, physician-patient relationship, behavioural influences and detailed information on attitudes and the reasoning behind these can all be sought through qualitative research (Britten, 2005, Bamford et al., 2011).

Such sociological techniques have been adopted to investigate factors influencing antimicrobial prescribing. Antimicrobial prescribing does not happen in isolation, but takes place within an environment where factors both intrinsic and extrinsic to the prescriber influence decisions. Qualitative research allows antimicrobial prescribing to be investigated in context and amongst other factors that might drive use (Rodrigues et al., 2013); it enables the researcher to cover areas not amenable to quantitative methodologies such as physician and patient perceptions on antimicrobial resistance. In addition, it can be used to identify hurdles to behaviour change and investigate the reasons why interventions may or may not be successful (Szymczak et al., 2014).

The relationship and communication between the prescriber and patient are the essential components in antimicrobial use decisions, however such decisions require the prescriber to consider both the factors intrinsic and extrinsic to this situation (Bradley, 1992a). Due to the multifactorial and patient specific nature of these decisions qualitative enquiry offers a route through which these factors can be explored (Al-Busaidi, 2008). In-depth qualitative interviews are the most widely used of the qualitative methodologies for exploring antimicrobial prescribing decisions in human medicine (Jamshed, 2014, Rodrigues et al., 2013). The semi-structured nature of these interviews allows the interviewer to explore pre-determined subject areas and so allows all interviewees to discuss their own perceptions of parallel themes and topic areas (Jamshed, 2014).

Ethnographic studies which require the researcher to immerse themselves within the participants' environment are used less frequently to investigate prescribing practices than the semi-structured interview (Grant et al., 2013, Rodrigues et al., 2013). Ethnography has the advantage of providing observational data where the researcher is able to directly visualise and capture the interaction of prescriber and patients within the healthcare setting. This allows actual antimicrobial prescribing behavioural practices to be captured (Grant et al., 2013, Farre and Cummins, 2016). There is concern that reported behaviours, such as those described by participants in an interview setting may not reflect actual practices and thus, ethnography allows an analysis of true behavioural practice (Kumar et al., 2003, Gray, 2004).

Intrinsic Factors

Intrinsic factors defined in human antimicrobial prescribing were considered to either relate to sociodemographic factors or physicians' attitudes. Sociodemographic factors that were identified as influencing antimicrobial prescribing practices included clinical experience (Gould et al., 2007, Kumar et al., 2003b, Wood et al., 2007) and the continuous professional development of medical professionals (Kumar et al., 2003, Paluck, 2001). Physicians' attitudes that were considered to influence prescribing decisions included confidence, complacency, fear, ignorance, indifference, and responsibility of others.

The personal confidence of the doctor making the clinical judgement was identified as an issue in antimicrobial prescribing decisions (Lopez-Vazquez et al., 2012, Rodrigues et al., 2013). Complacency was defined by Rodrigues as *'attitude that motivates the prescribing of antimicrobials to fulfil professionals' perceptions of their patients'/parents' expectations'* (Rodrigues et al., 2013). This attitude is generally accepted as being primarily as a result of both direct and indirect pressure exerted by the patient on the prescriber (Altiner et al., 2004, Rodrigues et al., 2013, Vazquez-Lago et al., 2012). In parallel, studies have identified that fear of the potential consequences should antimicrobials not be prescribed, such as medical complications for patients or patient death, motivated prescribing behaviours. Practical interventional strategies to reduce the influence of complacency and fear on antimicrobial prescribing may be difficult to implement (Petursson, 2005). However, continuity of care with follow up appointments with the same physician and education of patient populations on the value of delaying antimicrobial prescriptions could assist in reducing the effect of these pressures on physicians (Vazquez-Lago et al., 2012).

Qualitative research has identified that ignorance of the relationship between overprescribing and antimicrobial resistance may be an issue in some clinical situations (Butler et al., 1998, Kumar et al., 2003, Simpson et al., 2007, Björkman et al., 2010, Vazquez-Lago et al., 2012). Some studies even identified that prescriber indifference to this link may be a factor in prescribing decisions (Vazquez-Lago et al., 2012, Wood et al., 2007). In some cases there was a belief that antimicrobial resistance was the responsibility of others and such studies described a culture of blame, whereby physicians saw antimicrobial resistance as an issue for other medical professionals in other institutions (Barden et al., 1998, Butler et al., 1998, Vazquez-Lago et al., 2012).

Extrinsic Factors

Extrinsic factors were those factors which were beyond the control of the prescriber but were considered to influence prescribing behaviours. These were considered as either relating to the patient, the healthcare setting or other external factors influencing prescribing decisions. Patient-related factors included clinical signs either described by the patient or identified on clinical examination by the physician; for example, the presence or absence of pyrexia, pain, and appearance of the patient were all factors identified as motivational in a physician prescribing decisions (Walker et al., 2000, Björnsdóttir and Hansen, 2001, Vazquez-Lago et al., 2012). Other patient characteristics such as age (Wood et al., 2007, Zaffani et al., 2005), economic and social factors (Kumar et al., 2003), and other clinical conditions (Midthun et al., 2005) were also considered to drive prescribing behaviours. In addition, a patient expressing a desire for a *'quick fix'* for clinical signs was identified as a factor influencing prescribing in some studies (Barden et al., 1998, Altiner et al., 2004).

Physicians have identified patient expectation as a major extrinsic and non-pharmacological pressure on prescribing decisions (Petursson, 2005, Altiner et al., 2004, Vazquez-Lago et al., 2012, Coenen et al., 2006). Such decisions have been described as being very uncomfortable by general practitioners (Bradley, 1992b) with parental requests in paediatric prescribing identified as a specific pressure (Zaffani et al., 2005, Barden et al., 1998). However, it has been found that patients applying explicit pressure on doctors for antimicrobials is not a common behaviour (Butler et al., 1998) and in fact prescribers' have been shown to overestimate the patients' expectations. Thus, it has been suggested that the physicians' judgement of patient expectation is the major influence on prescribing behaviours in the absence of overt pressure from patients (Rodrigues et al., 2013, Weiss et al., 2004, Ong et al., 2007, Butler et al., 1998). Research investigating public perceptions on antimicrobial use and resistance show uncertainty of opinion with a low sense of relevance to their own situation (Nancy et al., 2007, Cliodna et al., 2007). The importance of communication with patients in both a primary and hospital setting has been shown to be essential in maximising awareness of antimicrobial need and the importance of compliance (Bamford et al., 2011, Altiner et al., 2004, Hawkings et al., 2007, Brooks et al., 2008).

The healthcare setting can directly affect the series of drivers and motivators behind physician prescribing decisions. By their very nature doctors working within a hospital environment are working within a large institution with healthcare professionals trained in specialist care; as such the influence of colleagues and institutional protocols on antimicrobial prescribing decisions are high (Charani et al., 2013). The influence of senior physicians on junior doctors prescribing behaviours is a significant influence on antimicrobial use behaviours and there is pressure to conform to expected behaviours within these environments (Sterkenburg A., 2010, Santana et al., 2011). In contrast, studies on antimicrobial prescribing in a general practice setting seldom focus on the influence of colleagues and focus much more on the doctors' individual moral and social responsibility behind prescribing decisions and the patient expectation (Wood et al., 2007, Britten, 2005, Coenen et al., 2000). The information sources utilised by doctors have been shown to be different between general and hospital practitioners with those in primary care more frequently consulting pharmaceutical companies and less frequently citing academic sources when compared to doctors within a hospital setting (Allery et al., 1997, Armstrong et al., 1996, Jones et al., 2001). As such it has been suggested that evidence based medicine decisions are less adopted in a general practice setting than a hospital (Tomlin et al., 1999, Berkwits, 1998).

Pressure of time within the healthcare setting was an extrinsic pressure on physician prescribing behaviours (Butler et al., 1998, Kumar et al., 2003, Coenen et al., 2000). There are contrasting conclusions on the influence of policy and guidelines on antimicrobial use across the literature (Rodrigues et al., 2013). On one hand such interventions have been found to be beneficial in driving responsible prescribing decisions in human medicine (Skodvin et al., 2015, Bekkers et al., 2010, Wood et al., 2007). However, the implementation and adoption of such guidelines can be problematic and in some environments these may not have a practical influence on prescribing decisions (Mol et al., 2004, Schouten et al., 2007). The influence of senior practitioners on junior physicians in prescribing decisions has been identified as a driver for antimicrobial use in human medicine (Charani et al., 2013, Ljungberg et al., 2007).

Other external factors identified as driving antimicrobial prescribing in human medicine included the influence of pharmaceutical companies and economic considerations. On review of the literature the influence of pharmaceutical companies on antimicrobial prescribing decisions divided opinion with some identifying it as a pressure on prescribing practice (Paredes et al., 1996, Barden et al., 1998), whilst other studies considered them to have little or no effect on behaviours (Wood et al., 2007, Vazquez-Lago et al., 2012). Economic considerations identified as influencing antimicrobial use behaviours included the expense for both the healthcare system (Simpson et al., 2007) and the cost for the individual patient (Björnsdóttir and Hansen, 2001). In addition, the desire to minimise costs for the patient was found to influence prescribing decisions (Rodrigues et al., 2013, Wood et al., 2007).

The use of a mixed-method approach to investigating human antimicrobial prescribing behaviours

Mixed methods research, which combines both qualitative and quantitative methodologies, has become increasingly popular in the human health field (Wisdom et al., 2012). For example, a study in 2000 found that mixed methods were employed in less than 1 % of studies published on human health (McKibbon and Gadd, 2004), but by 2007 it was identified that around 13 % of the studies funded in the UK use a mixed methodology (O Cathain et al., 2007).

Mixed methods plays on the strengths of both methodologies by combining them into one study which increases the depth and breadth of the understanding for researchers (Johnson et al., 2007). The integration of qualitative and quantitative methodologies provides a more complete picture of perceptions and beliefs than either method can do individually (Wisdom et al., 2012). Mixed methods are used in human healthcare research to unite the data and to allow one method to substantiate the findings of another and therefore act to triangulate and validate the datasets. In addition researchers use the combination of methods to elaborate, enhance and to clarify the results from the initial method so that the two complement each other. Conversely a mixed methodology can be used to uncover contradictions in findings which may be missed in a single method approach. In some cases researchers use one method to inform the approach taken in the second method, for example the use of qualitative data to advise the content of a quantitative questionnaire study. However, overall, mixing methods also allows researchers to increase the depth of insights into participants' perceptions and reasoning behind decisions and shows the diversity of views (Greene et al., 1989, Bryman, 2006).

Although the popularity of mixed methods is growing in human health research it is still rarely utilised as a tool in investigating antimicrobial prescribing practices (Liabsuetrakul et al., 2003, Palmer and Bauchner, 1997, Kuehlein et al., 2011b, Liabsuetrakul et al., 2007, Mangione-Smith et al., 2006, Moro et al., 2009, Ong et al., 2011, Paluck, 2001). For those studies which do apply a mixed methods approach the authors most commonly identify that qualitative enquiry adds value in the depth and detail of the perceptions on prescribing behaviours whilst the quantitative enquiry allows generalisation of ideas on a larger and representative sample (Kuehlein et al., 2011b, Wisdom et al., 2012).

The use of qualitative data to add greater depth to respondent perceptions, than those possible with quantitative questionnaire studies alone, was the most frequently cited reason for use of the mixed methods approach to investigate antimicrobial prescribing (Liabsuetrakul et al., 2003, Palmer and Bauchner, 1997, Mangione-Smith et al., 2006, Moro et al., 2009, Paluck, 2001). One study used qualitative interviews with physicians to explore the opinions and drivers behind antimicrobial prescriptions in order to understand the quantitative prescription data (Liabsuetrakul et al., 2007) whilst another explored patient perceptions on antimicrobial need in parallel with prescription data (Ong et al., 2011). Additionally, an interventional study by Kuehlein and others investigated the effects of an intervention whereby physicians conducted an additional follow-up consultation with patients after prescribing antimicrobials for urinary tract infections. For this study both qualitative data in the form of a focus group and quantitative prescription data were utilised both before and after the intervention in order to assess any physical effects on prescribing in parallel with shifts in the perceptions of physicians to antimicrobial use and their opinions of the current guidelines (Kuehlein et al., 2011b).

The use of qualitative methodologies to investigate antimicrobial prescribing behaviours in veterinary medicine

Research into antimicrobial prescribing in veterinary science has typically relied on quantifying antimicrobial use and quantitative enquiry into decision making on prescribing and use. The majority of the latter focuses on veterinary surgeon perceptions on prescribing in livestock (Williams et al., 2012, Gibbons et al., 2013, Busani et al., 2004, Sheehan, 2013, Cattaneo et al., 2009), companion animals (Hughes et al., 2012, Jacob et al., 2015, Weese, 2006), and equines (Hughes et al., 2013, Schwechler et al., 2016) with one paper reporting veterinary surgeon prescribing behaviours across all species (De Briyne et al., 2013). Additionally, there are also a limited number of studies investigating the perceptions of farmers on antimicrobial use in cattle (Friedman et al., 2007, Jones et al., 2015) and pigs (Moreno, 2012, Visschers et al., 2014).

Qualitative approaches to investigate factors relating to human health are well established in medicine (Britten, 2005) however, they remain an emerging discipline in veterinary science and one which has the potential to add great depth and insight into behaviours and perceptions (Christley and Perkins, 2010). Qualitative studies investigating human prescribing behaviours are numerous (Rodrigues et al., 2013), however there has been limited qualitative exploration into antimicrobial use in the veterinary field. First, one paper used a qualitative approach to investigate small animal practitioner antimicrobial use behaviours in the UK and identified that factors external to clinical evidence such as drug efficacy, ease of administration and owner compliance influenced veterinary surgeon decisions (Mateus et al., 2014). A second study which explored veterinary prescribing in farm animal practices in the Netherlands explored the concept of conflicting interests between a veterinary surgeons' responsibility to alleviate animal suffering and ensuring that prescribing is prudent and minimal so as to minimise the risk to public health. This study also highlighted concerns over the economic pressures on farmers and the financial barriers in implementing disease prevention measures (Speksnijder et al., 2015b). Thirdly, Pardon and others investigated antimicrobial and anti-inflammatory use in veal calves and identified the commonality of group treatments and described the frequent use of antimicrobial dosages which deviated from the leaflet recommendations; predominantly the under-dosing of calves (Pardon et al., 2012). In addition, a mixed method approach, incorporating both quantitative data and qualitative methodologies, was used to explore the antimicrobials used in Sudan alongside farmer opinion and knowledge on use and resistance. This study highlighted that farmers had a poor knowledge and awareness of the potential risks of antimicrobial resistance and zoonotic disease transmission (Eltayb et al., 2012).

A review of the literature relating to antimicrobial use in pigs shows that the majority of studies relate to quantifying antimicrobial consumption (Chauvin et al., 2002, Rajic et al., 2006, Trauffler et al., 2014, Timmerman et al., 2006, Jordan et al., 2009) whilst a small number of studies explore farmer perceptions surrounding antimicrobial use in pigs and associated public health concerns (Moreno, 2014, Visschers et al., 2014, Visschers et al., 2015, Dunlop et al., 1998). Two European studies focused on methods of reducing antimicrobial use in pigs and highlighted the importance of finding economically viable and practically feasible alternative approaches to prevent disease and identified a need to raise farmer awareness of the concerns over antimicrobial resistance (Visschers et al., 2015, Visschers et al., 2016). Moreno explored pig farmers' opinions on the risks to public health from the use of antimicrobials in pigs and identified that farmers considered the benefits of antimicrobials more frequently than the potential negative consequences for public health (Moreno, 2014).

Stevens and others quantified antimicrobial use by formulation and for different disease conditions in UK systems and assessed farmer perceptions on the consequences, responsibility and justifications behind antimicrobial use in pigs. Whilst the majority felt that antimicrobial use for therapeutic and prophylactic reasons was justifiable half of the respondents acknowledged that antimicrobial resistance in humans was a potential consequence from the use of antimicrobials in livestock (Stevens et al., 2007). Visschers and others have also published a comparative study on veterinary surgeon and farmer opinion on perceptions on antimicrobial use, resistance and policies to reduce usage in six European countries. The study concluded that farmers and veterinary surgeons had parallel perceptions on the risks associated with antimicrobial use in pigs; however farmers were generally less optimistic that overall use could be reduced when compared to veterinary surgeons (Visschers et al., 2016). In addition, there has been both quantitative questionnaire studies (Postma et al., 2015b, Visschers et al., 2015) and a focus groups study (Anon, 2015d) published which sought methods to reduce and replace antimicrobials in pigs. Effective biosecurity, improved housing conditions, vaccination, and maintaining a high health status herd were found to be essential in minimising antimicrobial use on farms (Anon, 2015d, Postma et al., 2015b). Additionally, Visschers and others identified that financial incentives for farmers were a practical method of implementing effective policy measures to reduce use (Visschers et al., 2015). A small number of qualitative studies have been conducted on pigs exploring the perceptions of pig farmers on disease risk management (Garforth et al., 2013), decision making in disease control (Alarcon et al., 2014), pig welfare assessment (Spooner et al., 2014, Devitt et al., 2016, Jaaskelainen, 2014) and biosecurity (Simon-Grifé et al., 2013). However, to date there are no mixed methods studies relating to any aspect of pig health and welfare.

General Introduction to the Qualitative Approach and Methodology used in this Thesis

Epistemology and Ontology

Kuhn (1962) defined a research paradigm as ‘the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed’ and Guba (1990) identified that research paradigms can be characterised through their epistemology, ontology and methodology. Epistemology concerns the theory and nature of knowledge, their assumptions consider how knowledge is known, captured and communicated (Cohen et al., 2007, Scotland, 2012), which was defined by Guba and Lincoln (1994) as the nature of the relationship between the individual seeking to know (researcher) and what can be known (reality). Ontology considers the study of being and the nature of reality. Thus, an ontological approach considers what constitutes reality (Crotty, 1998).

The qualitative studies presented in this thesis are based on a social constructionist epistemology; thus the researcher considered that knowledge and meaning were constructed through social interaction (Hudson and Ozanne, 1988, Guba and Lincoln, 1994). The theoretical approach taken was interpretivist and thus reality was considered to be multiple and relative. The overall aim of interpretivist research is to understand and deduce the reasoning behind human behaviours to understand motivations, reasoning, meaning and subjective experiences which are defined by time and context (Hudson and Ozanne, 1988, Simpson, 1967). As such the research studies presented here were flexible and sought to capture the underlying meanings in the interaction and relationship between the researcher and participant to understand what the participants perceived as their reality (Black, 2006, Hudson and Ozanne, 1988). This approach allowed the evolution of knowledge and the adoption of theories through participants' sharing their perceptions.

Positionality of the primary researcher

The background of the primary researcher (LC) as a veterinary surgeon who has previously worked in mixed species practice was disclosed to participants in the recruitment process. Due to considerable political pressure and sensitivity around the subject of antimicrobial use in pigs it was considered to be advantageous to reveal the background of the researcher to minimise the possibility of participants feeling vulnerable and defensive of their views. Thus, the researcher and informants were from a similar cultural and social environment and could converse openly on the subject of antimicrobial use in pigs. As the researcher had no specialist insight into the pig sector they allowed participants to accelerate their knowledge and immersed themselves in the theories derived from the qualitative studies. However, due to the position as the primary researcher as a practising veterinary surgeon it was inevitable that they had some prior knowledge on antimicrobial use and resistance.

On reflection it was felt that the position of the researcher as a veterinary surgeon placed them as a peer of the participants and as such were regarded with higher credibility than had her background experience not been revealed. Similarly, other co-researchers involved in the collection of qualitative data were either veterinary surgeons or from a livestock farming background placing them in a parallel position with informants to the position of the primary researcher.

Methodological Approach

A focus group is a qualitative approach used to collect data about beliefs and opinions from a small group of participants about an experience, specific concern, service or other reality (Basch, 1987). Although this approach was first described by Bogardus in 1926 its use was not widespread until around 30 years later; its application has been increasingly described in human and veterinary literature (Christley and Perkins, 2010, Britten, 2005). The technique allows the researcher to collect a significant amount of qualitative data in a quick and convenient manner simultaneously from a number of participants. Focus groups revolve around group interaction which allows participants to exchange ideas, share experiences and answer questions; they are particularly useful for exploring beliefs and experiences

(Kitzinger, 1995). Thus, it was an effective method to explore participant experiences of using antimicrobials and perceptions on antimicrobial responsibility and resistance. The focus groups conducted in this thesis (presented in chapter 2) were conducted as a scoping exercise (Ryan et al., 2014) to identify the spectrum of perceptions on antimicrobial resistance and drivers behind antimicrobial use decisions which were evaluated in greater depth in subsequent studies.

Following the focus group study a number of in-depth semi-structured face-to-face interviews were conducted (presented in chapters 3 and 4). The themes identified in the focus groups were used to develop a topic guide such that these perceptions could be explored in greater detail. Qualitative interviews are more widely adopted in research studies when compared to focus groups (Dicicco-Bloom and Crabtree, 2006).
The semi-structured nature of the interview allowed the interviewee to direct the focus of the interview and may have elicited opinions which would have not have been revealed in a group situation. The interviews were used to delve deeply into the social and personal perceptions and behaviours of the individuals (Basch, 1987, Dicicco-Bloom and Crabtree, 2006). This was particularly advantageous for the sensitive research area of antimicrobial use in pigs.

The collective data from the qualitative studies were used to inform the content of a questionnaire study on a wider sample of veterinary surgeons and farmers in order to evaluate the generalisability of theories and themes obtained in the earlier qualitative work. The use of mixed methods in this thesis acted to validate both methodological approaches, gain detailed information on the perceptions of participants and uncover contradictions or sub population differences.. (Bryman, 2012, Greene et al., 1989).

Thematic Analysis

Thematic analysis is commonly utilised across qualitative studies to explore perceptions, behaviours and opinions and to identify common themes in qualitative data. However, it is poorly defined as a methodology with a wide range of different techniques being characterised as thematic analysis (Boyatzis, 1998, Roulston, 2001). It has been used to explore drivers behind antimicrobial use in both human (Charani et al., 2012, Rodrigues et al., 2013) and veterinary medicine (Mateus et al., 2014) and has been employed in studies exploring farmer perceptions on cattle biosecurity (Brennan and Christley, 2013) and sheep health planning (Kaler and Green, 2013). To address the wide-ranging definitions and practical applications of thematic analysis Braun and Clarke (2006) produced detailed guidance on the methodology, which has been widely adopted in the aforementioned qualitative studies in the veterinary field. Thus, this was considered to be the most appropriate approach to thematic analysis to apply in/to the studies published in this thesis.

Following the methodology outlined by Braun and Clarke (2006)), themes are considered to be common patterns of responses or meanings which are developed through a stepwise process. Qualitative data in the form of transcripts from either focus groups or interviews transcribed verbatim are the foundation of the thematic analysis approach. Initially, transcripts were read and re-read to allow the researcher to fully immerse themselves in the data. Initially, the researcher considered key ideas and perceptions in the context of the participant or participants. This process was conducted alongside reflective journals which were completed at the time of qualitative data collection. These included the perceptions of the researcher, such as attitude of the participants to the subject area, and any additional visual cues not captured through interview transcripts. Additional notes and memos were added to the existing reflective journal.

Initial coding was conducted in which areas of interest and patterns within the text were identified as codes. These codes were then given preliminary labels and additional memo notes were added to any codes of particular interest to the researcher or any outlying or unusual concepts. Transcripts were then read reiteratively and initial codes were reviewed. Patterns within these initial codes, common subject areas and linked ideas were then categorised into wider themes. A constant comparison process was employed in which themes were evaluated in relation to the whole data corpus and were then refined, condensed and defined to form distinct themes.

A thematic map was created and themes were re-categorised and condensed to form a final agreed set of themes. This process identified overarching themes which were defined in these studies as major themes which consisted of minor themes reflecting a more specific subject area or common ideal. For example, the major theme of 'Veterinary surgeon-client relationship' consisted of the contrasting themes of 'mutual relationship' and 'client pressure'.

All transcripts were coded initially by the primary researcher (LC). The focus groups were then reviewed in detail alongside a second researcher (SL), with extensive experience in qualitative research methods, and themes were further reviewed and refined. Both of the veterinary surgeon and farmer interview transcripts were analysed by the primary researcher (LC) with a second researcher (SL) independently coding five transcripts from each dataset. The transcripts which were double coded were chosen purposively to reflect the spectrum of opinions and majority ideas captured in the interview process. The independently coded transcripts were compared and the themes were further refined to ensure that each was independently meaningful, distinct from other themes yet overlying and linking concepts were considered (Patton, 2002). This discussion and refinement of the themes ensured that themes were relevant to the research questions (Bryman, 2012).

The two researchers concluded that data saturation has been achieved from the data set when no new descriptive codes or themes were identified in the data (Bryman, 2012, Braun and Clarke, 2006). True data saturation was achieved in the veterinary surgeon and farmer interviews whereby it was agreed between the two researchers (LC and SL) that no novel themes were defined from interview transcripts and thus there was no value in conducting additional interviews.

The themes defined from the qualitative data collected in the studies presented in this thesis were discussed and reviewed by a multidisciplinary team of researchers including clinical veterinary practitioners, veterinary epidemiologists, researchers experienced in qualitative research methodologies and microbiologists. This process included referring to all of the data sources including transcripts, reflective journals and thematic maps.

<u>The use of Computer-Assisted Qualitative Data Analysis Software</u>

The use of computer-assisted qualitative data analysis software has become increasingly popular in qualitative research as it allows the researcher to manage multiple transcripts within one workspace and data fragments to be coded with ease. It has been argued that the use of such software packages allows qualitative research to be more systematic and thus increases trustworthiness of the data (Sinkovics and Alfoldi, 2012). Another major advantage is the ability to review text fragments categorised as parallel themes alongside each other in an external document to the individual transcripts (Bryman, 2012). There has been some concern expressed by researchers that the use of computer software may result in disengagement from the data with the analysist focusing on technique rather than the meaning of the data with themes becoming distant from the transcriptions (St. John and Johnson, 2000, Cope, 2014). Additionally, there is concern that there is a temptation to quantify themes (Catterall and Maclaran, 1997). However, efforts were made to ensure that that the thematic analysis process was focused on the research question in the studies presented in this thesis. The use of computer software meant that the researcher was able to study multiple themes, the relationships between them and conduct in-depth analysis efficiently (St. John and Johnson, 2000).

In the studies presented in this thesis the computer-assisted qualitative data analysis software Atlas.ti 7.7.1. (ATLAS.ti Scientific Software Development) was utilised for coding and categorisation of minor and major themes. In addition, memos reflecting on themes or identifying key quotations were added to the transcripts within the software. This was particularly advantageous for reviewing themes alongside the research team as all of the data are easily available in one workspace. However, the creation of thematic maps was done with paper and pencil and later transferred into Microsoft Powerpoint 2010 (Microsoft Corporation, Redmond, Washington, USA) to produce the maps presented in this thesis.

Thesis Aims and Objectives

Prescribing practices in pigs such as the frequent use of in-feed antimicrobials, the commonality of prophylactic use and the high sales of products authorised for use in pigs has highlighted the species as an area of concern for ensuring that use is optimal and prudent to minimise selection pressures. Decisions relating to antimicrobial use in pigs do not happen in isolation, they occur in an environment where factors intrinsic and extrinsic to both the veterinary surgeon and farmer influence these decisions. This PhD aims to explore the paradigm of behavioural influences behind antimicrobial prescribing and use by veterinary surgeons and farmers within the United Kingdom in order to gain a detailed understanding into the necessity for antimicrobials and identify potential interventions and routes through which use can be optimised and minimised.

The chapters report findings from three studies, two using qualitative methodology and one using a quantitative approach. Chapter 2 describes focus group discussions used to explore veterinary surgeons and farmers perceptions on antimicrobial use decisions in pigs; data were analysed using a thematic approach. The themes generated from the initial enquiry were used to develop a topic guide for in-depth semi-structured interviews. Qualitative in-depth interviews with both veterinary surgeons and farmers were conducted in order to deepen understanding of the themes generated from the focus groups and to explore new ideas and identify any contrasting opinions within the participant population. These are described in chapters 3 and 4.

Finally, themes generated from the qualitative enquiry were used to construct quantitative questionnaires which formed the third study of this PhD thesis (presented in chapters 5 and 6), and was used to assess and investigate the generalisability of key themes, perceptions and attitudes surrounding antimicrobial use in a representative sample of pig veterinary surgeons and farmers.

Chapter 2

Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: A qualitative study

Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: A qualitative study

Background to published paper on focus groups conducted to explore antimicrobial prescribing practices in UK pig veterinary surgeons and farmers

The focus group discussions formed the initial scoping phase of the studies presented in this thesis exploring the drivers and motivators of antimicrobial prescribing practices in UK pig veterinary surgeons and farmers. The themes identified in this study formed the basis for the interview guides for in-depth qualitative interviews which sought to gain more detailed information on the perceptions of veterinary surgeons and farmers.

Development of a focus group topic guide

The focus group studies were conducted as an initial scoping study in order to explore the perceptions of veterinary surgeons and farmers on the subject of antimicrobial use and resistance in pigs. The focus group guide was developed by the research team to be broad but to also cover some specific areas currently relevant to antimicrobial use in the UK pig industry. These were identified by an extensive literature review in animals and humans, discussion with pig and other veterinary surgeons including those in government and reviews of UK and EU policy and initiatives around antimicrobial use in livestock.

Structure and facilitation of focus groups

The focus groups were held across three meetings in three distinct geographical areas. Participants details are outlined in tables 2 and 3, the number coding refers to the meeting number whilst those also coded alphabetically refers to the individual focus groups held in the same meeting.

Meeting 1 consisted of one farmer-only and one veterinary surgeon-only focus group and was in an area of moderate pig density. Meeting 1 was organised through existing contacts and consisted of a veterinary surgeon group where all participants worked at the same veterinary practice; thus, all participants were familiar with each other. Whilst the farmer group were all clients of the same veterinary practice they did not appear to know each other very well.

Meeting 2 consisted of three farmer-only focus groups and was held in place of a regular meeting held by the Agricultural and Horticultural Development Board Pork (AHDB Pork, formerly the British Pig Executive (BPEX)) in an area of high pig density. Farmers were familiar with each other, however most only met through the AHDB Pork meetings. In order to avoid farmers from the same pig units dominating discussion individuals employed by the same farm were placed into different focus groups (Morgan, 1997). In addition, a local veterinary surgeon, AHDB Pork employee and an individual from a pharmaceutical company also attended the meeting. However, as they were merely observers and did not contribute to discussion it was not felt that they had biased or directed discussion. Thus, these participants were not included in the qualitative analysis.

Meeting 3 consisted of only one veterinary surgeon-only focus group and was held in an area of high pig density. This meeting was organised through an existing contact and included both participants from a private pig production company and individuals from two different private veterinary practices.

The initial focus groups were facilitated by members of the supervisory team who were experienced in qualitative research methods. The primary researcher (LC) acted as a non-participatory observer in the initial focus groups conducted in meeting 1 in order to immerse themselves in the qualitative methodology. This role included making detailed notes both during the focus groups and reflective notes on the qualitative methodologies in order to advance understanding and develop qualitative data collection skills (Malterud, 2001). The primary researcher then progressed to co-facilitating a focus group in meeting 2 in order to further develop these skills, and finally progressed to facilitating a focus group in meeting 3 independently.

Analysis of qualitative data from focus groups

The focus groups transcripts were analysed using the thematic analysis technique described in chapter 1 under the section ‘General Introduction to Approach and Methodology in Qualitative Studies’. An inductive approach to coding was taken as the researcher had no pre-existing theories on the drivers behind antimicrobial use in pigs. All transcripts were coded initially by the primary researcher (LC). The focus groups were then reviewed in detail alongside a second researcher (SL) and themes were further reviewed and refined. Themes were discussed and reviewed by a multidisciplinary team of researchers including clinical veterinary practitioners, veterinary epidemiologists, researchers experienced in qualitative research methodologies and microbiologists. This process included referring to all of the data sources including transcripts, reflective journals and thematic maps.

Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: A qualitative study

This chapter is presented as it was published in the Veterinary Record.

Reference:

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Abstract

Increasing awareness of bacterial antimicrobial resistance in human beings and veterinary medicine has raised concerns over the issue of overprescribing and the indiscriminate use of antimicrobials. Their use in food-producing animals is under scrutiny due to the perceived risk from the zoonotic transfer of resistant pathogens from animals to human beings. This study used focus groups to explore the drivers and motivators behind antimicrobial use and prescribing by veterinary surgeons and farmers in the pig industry in the UK. Studies of two veterinary and four farmer focus groups were undertaken, each with between three and six participants, in three geographically distinct regions of low, moderate and high pig density in England. Thematic analysis of the focus group transcriptions revealed convergent themes, both within and across, the veterinary and farmer focus groups. Veterinary opinion was such that ‘external pressures’, such as pressure from clients, legislation and public perception, were considered to strongly influence prescribing behaviour, whereas, farmers considered issues surrounding farming systems and management to be greater drivers towards antimicrobial use. Acquiring such in-depth insight into the antimicrobial prescribing behaviours in veterinary medicine provides more detailed understanding of prescribing practice and will aid the development of interventions to promote the responsible use of antimicrobials.

Introduction

The use of antimicrobials in food producing animals is an emotive subject which has sparked much debate. Pigs currently contribute the largest proportion towards the sale of single species antimicrobial products in food producing animals in the United Kingdom (UK) (Anon, 2013i). This high usage, alongside the common administration of antimicrobials through medicated feedstuffs has highlighted their use in pigs as an area of concern (Anon, 2012e, Levitt, 2011b). The media has implicated the overuse of antimicrobials in pigs as being responsible for antimicrobial resistance in humans (Levitt, 2011a, Harvey, 2013), through the zoonotic transfer of resistant pathogens from animals to humans. However, others contend that there is little evidence to support such transfer being anything but an infrequent event (Bailar and Travers, 2002, McEwen, 2012, Guardabassi, 2013).

The prudent use of antimicrobials is essential to reduce selection pressure and maintain the efficacy of such drugs. Guidelines on their responsible use in animals have been advocated by various UK organisations including the Responsible Use of Medicines in Agriculture (RUMA), the British Veterinary Association (BVA) (Andrews, 2009, Anon, 2013a, g), and more recently the Pig Veterinary Society (Anon, 2014d). Alongside the judicious use of antimicrobials, improvements in the management practices and housing of pigs have been shown to reduce the reliance of some farms on antimicrobials (Dunlop et al., 1998, Stevens et al., 2007, Fels-Klerx et al., 2011). Whilst existing quantitative studies have attempted to investigate and quantify antimicrobial use, and the associations with particular practices (Gibbons et al., 2013, Stevens et al., 2007, Dunlop et al., 1998), there has been little research investigating prescribing behaviours in the UK pig industry.

In this study we investigated the motivations behind the use and prescribing patterns of antimicrobials in the pig industry using qualitative methods that have previously been used to explore human prescribing behaviours (Rodrigues et al., 2013). Our approach was based on focus groups (Barden et al., 1998, Coenen et al., 2000, Walker et al., 2000, Kotwani et al., 2010, Kuehlein et al., 2011a, Vazquez-Lago et al., 2012). The group discussion setting enabled the comparison of the different opinions that are exchanged between participants during sessions (Morgan, 1993, Kitzinger and Barbour, 1999, Bryman, 2012). These methods are emerging as useful tools in assessing behaviours in veterinary medicine (Coe et al., 2007, Gunn et al., 2008, Kaler and Green, 2013, Robinson and Epperson, 2013, Sheehan, 2013).

Through the medium of focus groups, this study aimed to investigate the motivations behind the use and prescribing patterns of antimicrobials in the pig industry.

Materials and Methods

Focus group design and structure

In total, six focus groups, each containing between three and six participants were held to explore open-ended themes surrounding antimicrobial use and prescribing behaviours in pigs. These were conducted over three meetings in three geographically distinct regions; one in an area of moderate pig density and two in areas of high pig density. These regions were chosen based on the demographic density of the UK pig population, the convenience of utilising existing contacts in the pig industry and the ability to organise a focus group at the convenience of participants. Within most of the meetings farmer-only and veterinary surgeon (vet)-only focus groups were conducted as there was concern that the presence of a vet in the farmer group and conversely a farmer in the vet group, may not allow for free discussion of opinions. At the end of each meeting time was allowed for discussion and comparison between the groups.

A purposive sampling technique was used in order to identify a sample population, whereby individuals were chosen with characteristics relevant to the study (Bryman, 2012). The characteristics for inclusion in the sample population were determined by the authors but aimed to include vets and farmers with experience of different pig rearing systems, with differing levels of job responsibility and experience, and from different geographic areas, in an attempt to represent a range of vets and farmers involved in commercial pig production in the UK. The only incentive provided was refreshments.

Approval for the study was granted by the University of Liverpool Research Ethics committee and an information sheet, giving an overview of the project, was provided for all participants prior to their attendance at a focus group. The consent form is shown in Appendix 1, Figure 1.1 and the participant information sheet is shown in Appendix 1, Figure 1.2. Signed consent to participate in the focus groups was gained prior to discussion, with participants being given the option to opt out of having the discussion recorded.

Procedure

The focus groups were conducted using Kreuger's guidelines on 'Designing and Conducting Focus Group Interviews', which use a set of open ended questions to spark discussion (Krueger, 2002). A topic guide was developed by the authors based on these guidelines; questions were clustered under the following topic headings (Table 1):

1. *Perceptions of antimicrobials and their usage.*
2. *Current antimicrobial use.*
3. *Responsibility*
4. *Future options.*

Table 1 - Focus Group Topic Guide

Topic headings	Areas explored
Perceptions of antimicrobials and their usage	• Perceptions of antimicrobial resistance in pigs • Potential impact of the use of antimicrobials in pigs on human health • Opinion on the 2006 EU ban on antimicrobial growth promoters (AGPs)
Current antimicrobial use	• Choice and formulation of antimicrobials, the reasoning behind a decision (eg. treatment or prophylaxis) • Deciding whether to continue or discontinue medication once it is in use • Perceptions on how antimicrobials are used across different farming systems within the UK pig industry
Responsibility	• Who is responsible for the prudent use of antimicrobials in food producing animals? • Trusted sources of information on antibiotics • The potential impact of the proposed 2013 ban on the advertising of antimicrobials directly to farmers
Future options	• Opinion on the possible banning or restriction of antimicrobials considered critical to human medicine (Anon 2011) (fluoroquinolones, third and fourth generation cephalosporins and macrolides) and the impact of such legislation on the UK pig industry • Methods of reducing antimicrobial use in pigs • Any major hurdles to reducing antimicrobial use in the UK pig industry

All participants were provided with a copy of the question set and each focus group was moderated by one of the authors. The moderator's role was to guide the discussion and ensure all areas in the topic guide were covered whilst allowing free conversation to develop. The full topic guide is shown in Appendix 1, Figure 1.3. The moderator took notes of any key points or body language of participants.

Focus group audio recordings were transcribed verbatim and anonymised. Thematic analysis techniques were used to analyse transcripts (Braun and Clarke, 2006). The process of coding was assisted through the use of the qualitative data management tool Atlas.ti 7.7.1. (ATLAS.ti Scientific Software Development). This involved identifying codes that summarised the meaning of text fragments and the iterative reading and re-reading of transcripts, such that codes were reviewed and re-evaluated. Constant comparison methods were used in order to ensure that less common attitudes and opinions were exposed as well as more dominant themes (Braun and Clarke, 2006). Coded sections of the transcripts revealed re-occurring opinions and subject areas which were considered to be minor themes across the focus groups. These minor themes were found to link, and common subject areas were exposed and were categorised as major themes.

Results

Focus Group Participants

Six focus groups with a total of nine vets and seventeen farmers were completed. These focus groups encompassed a range of different individuals within the pig industry including vets working as assistants and partners, from both private practices and pig production companies, farmers from large companies and independent farms, and representatives from the British Pig Executive (BPEX, now the Agricultural and Horticultural Development Board Pork (AHDB Pork)), the Pig Veterinary Society (PVS) and the pharmaceutical industry (Tables 2 and 3). There was a wide age distribution amongst the vets and farmers ranging from approximately early twenties to mid-sixties.

Table 2 – Participants at the vet focus groups

Meeting Number	Focus Group	Number company Vets (all associates)	Number of associates in private practice	Number of partners in private practice	Other participants	Geographic region
1	1A		2 female	1 male	1 male retired partner now a consultant	Moderate pig density
3	3	2 male, 1 female		2 male		High pig density

Table 3 – Participants at the farmer focus groups

Meeting Number	Focus Group	Number of indoor Farmers	Number of Outdoor Farmers	Other Participants	Geographic region
1	1B	2 male	1 male (organic)		Moderate pig density
2	2A	2 male	1 male	1 male mixed practice vet partner	High pig density
2	2B	4 male		1 female BPEX representative, 1 male pharmaceutical representation	High pig density
2	2C	3 male	1 male		High pig density

Themes Identified

Eight major themes emerged which were considered to influence antimicrobial prescribing behaviours. These major themes included ‘Agricultural Factors’, ‘External Pressures’, ‘Vet-Client Relationship’, ‘Drug-related Factors’, ‘Disease Epidemiology and Outcomes’, ‘Responsibility’, ‘Economic Factors’ and ‘Knowledge Base’. A summary of the responses to the focus group questions and some key quotations are shown in Appendix 1, Figures 1.4 (veterinary surgeon focus groups) and Appendix 1, Figures 1.5 (farmer focus groups).

Agricultural Factors

'Agricultural factors' were a commonly recurring theme in the farmer focus groups and were often raised by the vet focus groups. There was a spectrum of opinion as to which rearing systems, be they indoor or outdoor, slatted or straw-based, were beneficial to reducing antimicrobial use by vet and farmer participants. There was, however, agreement between the vet and farmer focus groups that an all-in-all-out pig flow was beneficial to minimising the requirement for antimicrobials over continuous pig flow systems. In the following quote a vet describes a farm which employs a pig flow system whereby pigs are continuously added to pens, and are mixed from different sources or farms, and uses this as an example of a farm with a high antimicrobial requirement.

'…anything that's continuous… anything that mixes pigs… …' (Vet)

There was some conflict of opinion on the relationship between management practices and antimicrobial usage. The subsequent quote, from a vet, reflects the opinion of the majority of vet and farmer participants that management practices could be employed that would reduce the reliance on antimicrobials, but that may have negative economic consequences:

'*...my view is probably we do use too much mass medication... there could be management practices that a lot of clients could put in place to reduce antibiotics that are economically less viable than using the antibiotics...*'(Vet)

Conversely the opinions of a minority of the farmer participants considered that antimicrobial use would not compensate for poor management.

'…*antibiotics are not going to cover bad management...*' (Farmer)

Both the vet and farmer focus groups considered the health status of a herd to be a key factor in the amount of antimicrobials used on farms. A high health status was correlated with the ability to reduce the reliance on antimicrobials when compared to a lower health status.

'We're a high health herd, we get very good performance, we put nothing [no antimicrobials] in-feed …' (Farmer)

External Pressures

A pressure was considered to be any factor that placed a demand on participants and resulted in some level of stress, or a feeling of coercion, into a particular behaviour. Pressures were identified by participants whenever they considered that a request or issue caused them to question and reflect on their personal morals. 'External pressures' considered pressure from politics and legislation, public perception, importation of pig products and pressure from retailers. In the vet focus groups this was a very commonly recurring theme but was less common in the farmer focus groups.

Pressures from politics and legislation were considered to be a major stressor by vets within the focus groups. Vets reflected that legislative decisions are driven by political pressure and are not always supported by scientific evidence; as one participant expressed on the subject of the Europe-wide Antimicrobial Growth Promoter (AGP) ban*:*
'…it was a political decision, it wasn't being driven by the farming community or by the veterinary community…' (Vet)

Vet-Client Relationship

Client pressure was considered to be a major influencer towards antimicrobial prescribing by the vet participants. Vets felt a strong burden of responsibility to ensure that the correct antimicrobial was prescribed as pressure arose from clients when a treatment was unsuccessful.
'*And the client won't accept well, why have you tried three products? They want you to come up with the right answer straight away …'* (Vet)

The farmer focus groups did not observe this pressure and considered their interactions with their vet to be more of a mutual relationship. Farmers considered that prescribing decisions by the vet were made following consultation and discussion with themselves.
'*I rely on them [the vet]… and you build a working relationship… over the years…'.* (Farmer)

In contrast, this theme did not appear in the vet focus groups.

Drug-related factors

'Drug related-factors' considered the characteristics of drugs chosen, such as efficacy, formulation, inherent sensitivity patterns, drug availability, and the withdrawal periods of products. Across the vet and farmer focus groups the majority of participants did not consider that antimicrobial resistance had affected the health and welfare of their livestock and considered this to be more problematic for others, whilst a minority acknowledged the issue had arisen.

'…*there are locations in the UK that have multi-resistance dysentery but… we don't have it*…' (Vet)

This viewpoint was echoed in the farmer focus groups and linked closely with the theme of 'Responsibility'; the sense that participants perceived that some vets and farmers are not using antimicrobials as judiciously as they perhaps should be but that they were not themselves in this category.

The potential banning or restriction of the 'critical antimicrobials' (Collignon et al., 2009) was a point for discussion within the focus groups. Vet and farmer participants generally considered that increased restrictions on the fluoroquinolones and third and fourth generation cephalosporins would restrict antimicrobial options. Independently, both vet focus groups felt that there had been an increased requirement to use the aforementioned classes of antimicrobials due to the 'loss of products':

'Naxcel[1] and Baytril[2] are being used because other products have been taken off the market…' (Vet)

There was greater concern across the focus groups over the potential restriction of macrolide use; with the utmost concern over tylosin. Vets cited it as being the only authorised antimicrobial available as an in-feed formulation for use in pigs near slaughter weight as it has a zero withdrawal period. Farmers were concerned over whether alternative antimicrobials were available for use in these pigs, but considered the task of finding an alternative to be the responsibility of the vet.

Antimicrobial use for prophylaxis, in pigs not exhibiting clinical signs of disease, was considered justifiable and prudent by the vet and farmer focus groups, for conditions which cannot be controlled by other means. It sparked a rather emotive response amongst participants.

'…*you cannot argue welfare and ban antibiotic usage in a preventive way.'* (Vet)

All focus groups considered how difficult the decision can be to withdraw prophylactic antimicrobials, once they are perceived to have a benefit. Participants also considered that the formulation of the drug played a role in this decision; should in-water medication require re-starting, following its withdrawal, there is no time delay in comparison with in-feed formulations where there is often a delay obtaining a feed order.

'*The difficulty is though if you put it [an antimicrobial] in feed, 'it works' in inverted commas, there is a perceived benefit, sometimes you're a bit reluctant to take it out… If you* *take it out, it goes wrong and it's in feed then there is quite a bit of a lag before it goes in again than with water…'* (Farmer)

Disease Epidemiology and Outcomes

Disease was not considered as a static state, in which a pig is either infected or not, it was considered as a dynamic state in which different diseases interact to form a *'stew pot of disease*' and where disease may be sporadic, subclinical or a persistent problem. This opinion was shared by the vet and farmer focus groups.
'I think you've got to differentiate between whether you're dealing with an endemic, chronic, grumbling disease versus an acute outbreak of a disease and the usages of the two are completely different…' (Vet)

This unpredictability led participants to consider disease prevention strategies to be essential with vets and farmers citing vaccination as a possible solution to reduce a farm's reliance on antimicrobials. Diagnostic testing, both in emerging diseases and in endemic infections was considered by all focus groups to influence antimicrobial prescription. Antimicrobial susceptibility testing for bacterial pathogens was considered to influence the decision of which class and formulation of antimicrobial to prescribe.

Responsibility

The theme 'Responsibility' considered the concept of the prudent use of antimicrobials and explored where this responsibility was perceived to lie. There was an overwhelming opinion amongst vets and farmers that they considered themselves to use antimicrobials responsibly, and in the case of the farmers, they considered their respective vets to also be responsible. However, concern was present with some participants that other vets and farmers may be less judicious. In the following quote, the vet expresses concern that a neighbouring practice vet may overprescribe antimicrobials for a particular farm.
'I can think of lots of names… of people [vets] … who've used antibiotics a lot more liberally than we'd ever dream of and in ways we'd want to avoid' (Vet)

Commonly, both vet and farmer focus groups placed the main burden of responsibility for the prudent use of antimicrobials on the vet.

Vets considered compliance to be a factor that drove them to choose a particular formulation of an antimicrobial on a particular farm.

'*…if you know they're not going to jab something for five days then… you can water medicate...'* (Vet)

A shared belief amongst all focus groups was that irresponsible use in human medicine was contributing to the antimicrobial resistance problems in human medicine. A number of participants from the farmer and vet focus groups felt that poor compliance is an issue in human medicine.
'*the pigs actually finish the course whereas the humans don't.*' (Vet)

Economic Factors

The theme of 'Economic Factors' emerged equally commonly in the farmer and vet focus groups. The shared opinion of the majority of vets and farmers was that cost influenced prescribing patterns in some situations.
'[farmers] can't afford to put any antibiotics in without any good reason…' (Farmer)

A small number of vets in Focus Group 1A showed dynamic views on this issue. Initially, one participant took a defensive stance that cost would never drive antimicrobial use:
'*what influences choice… not cost?*' (Vet)

However, later acknowledged that in some circumstances it may influence prescribing behaviours:
'*…responsible use and cost effectiveness….*' (Vet)

Production costs were cited by both the farmer and vet focus groups as being a major factor in antimicrobial usage. Issues such as the high cost of management and an inability to re-invest in buildings were considered to be major hurdles in reducing antimicrobial usage.
'*If farmers could re-invest in new and better buildings. That would drive down antibiotic dependency… there isn't enough profitability to re-invest…'* (Farmer)

Knowledge Base

Farmers considered their vet to be the most trusted source of information on antimicrobials; whilst being sceptical and non-trusting of information gained from advertisements.
'…farmers would be the least trusting of any advert…' (Farmer)

Vets and farmers did not believe that the 2013 ban on such advertisement would have any impact on antimicrobial usage in the pig sector. Vets cited the National Office for Animal Health (NOAH) Compendium, alongside other academic and scientific literature, as the information they trusted most on antimicrobials.

Discussion

The qualitative approach used in this study offered an interactive forum for participants to share and discuss their experiences and opinions on what drives and motivates antimicrobial use in pig production. Many of the themes that emerged were shared between vets and farmers; showing common attitudes and concerns.

The focus group environment enabled participants to clarify their individual opinions on the subject through discussion and knowledge-exchange between participants; a method called the ‘sharing and comparing process’ (Morgan, 1997). This allowed a complex understanding of the subject without the moderator being required to give detailed information or definitions; which may have influenced opinion. An inevitable limitation of the focus group setting is that the presence of one or two more dominant participants may result in data reflecting the opinions of these individuals, rather than the group as a whole, this was minimised by the presence of a moderator to encourage the expression of opinions by all participants (Fern, 1982).

Literature suggests that antimicrobial usage may differ more on an individual farm basis than between different rearing systems as a whole (indoor versus outdoor, slatted versus straw-based systems) (Scott et al., 2006, Scott et al., 2007, Stevens et al., 2007). This trend is mirrored in the diverse opinions elicited from the focus groups with regards to which rearing systems would lead to lower or higher antimicrobial use, and may reflect the inclusion of participants experienced in a range of rearing systems and from a variety of geographic locations.

An inadequate farm environment and a lack of ability to re-invest in the farm infrastructure were a transparent concern in the vet and farmer focus groups. Similarly, Stevens (2007) found that 79 % of UK pig farmers considered ‘improved housing’ as an alternative to antimicrobial use. Participants considered the lack of profitability in the pig industry to limit their ability to improve housing, however, previous work shows that farms, where the farmer felt there was room for improvement in the farm environment, used more in-feed antimicrobials than those who did not (Stevens et al., 2007, Scott et al., 2006, 2007). This would inevitably increase drug costs on these farms. This shows the difficult balance between the relatively short-term cost of antimicrobials and the more long-term cost of environment improvements that were discussed at length by vets and farmers in these discussion groups.

Cost was considered to influence antimicrobial use by the vet and farmer focus groups. Previous work has found that cost motivates antimicrobial prescribing in human medicine (Buusman et al., 2007), cattle practice (Gibbons et al., 2013) and in the pig sector (Sheehan, 2013). It has been proposed that there is a conflict of interest in that the vets' ability to profit from the sale of antimicrobials may be seen to influence prescribing decisions (Anon, 2012g, Rollin, 2006). However, this study and previous work by the VMD revealed that pig vets felt strongly that this did not drive their prescribing decisions (Sheehan, 2013). The strength of opinion on this issue may reflect the pressure on vets from the media's negative portrayal of antimicrobial use in animals (Levitt, 2011a, Harvey, 2013) and the World Health Organisation's (WHO) proposal to 'decouple' antimicrobial sales; which would separate the right to prescribe from the vets' ability to supply antimicrobials (Anon, 2012b).

Vets identified that pressure from clients can be a driver for antimicrobial prescribing, whilst farmers seldom considered this to be the case. Similar pressure has been shown to drive antimicrobial prescribing in human medicine (Cockburn and Pit, 1997, Macfarlane et al., 1997, Coenen et al., 2000, Kumar et al., 2003), and Gibbons and others (2013) identified that cattle practitioners in Ireland were more likely to prescribe antimicrobials if they perceived that farmers expected them. Conversely, farmers considered the mutual relationship between the farmer and the vet to have a greater influence on antimicrobial usage. Such interaction has been shown to influence prescribing practice in human medicine, where maintaining the doctor-patient relationship was considered to influence prescribing behaviours (Butler et al., 1998). The vets in this study did not identify the theme 'Vet-Client Relationship' as influencing antimicrobial usage, possibly reflecting a difference in perceptions. In contrast, 'veterinarian attitude/customer relationship' was identified by the VMD focus groups as driving antimicrobial use in the pig sector (Sheehan, 2013). This discrepancy may reflect differences in the participants purposively sampled for each study.

Despite this perceived close working relationship between the vet and farmer, farmers perceived the responsibility for the prudent use of antimicrobials to lie with vets. This opinion was echoed in work by Stevens and others (2007) who showed that 96 % of pig farmers considered responsibility for '*good practice in the use of antimicrobials'* to lie with vets. Busani (2004) defined a ‘judicious user’ of antimicrobials to be a cattle practitioner who showed an awareness of the problem of antimicrobial resistance and the importance of responsible use; he found that three quarters of cattle vets conformed to this description (Busani et al., 2004). In parallel, the majority of vets and farmers considered that they were prudent antimicrobial users and showed the appropriate awareness to fit Busani’s model of a ‘judicious user’.

The importance of the prudent use of antimicrobials in livestock, which are considered by the WHO to be ‘critical to human health’ (Anon, 2012d), was widely acknowledged by the vet focus groups. A high level of awareness of the importance of only using fluoroquinolones and third and fourth generation cephalosporins, when absolutely necessary, was shown by vets. This consciousness and sparing usage is widely quoted in various publications as being commonplace amongst companion and food producing animal vets (Rantala et al., 2004, Weese, 2006, Williams et al., 2012, De Briyne et al., 2013). There was concern amongst vets and farmers that restrictions on these classes would put increased pressure on themselves and the health and economics of the UK pig herd. However, it was the possibility of increasing restrictions on the macrolide class of antimicrobials that provoked greater concern amongst vets and farmers. This may reflect the frequency of the use of macrolides in pig production globally (Dunlop et al., 1998, Anon, 2007, Jordan et al., 2009).

Antimicrobial use for disease prophylaxis is a recognised practice within the pig industry and was considered by vets and farmers to be a common and justifiable use. This opinion is mirrored in work by Stevens (2012) who found that 62.6 % of pig farmers in the UK considered that disease prophylaxis warranted antimicrobial usage. Antimicrobial use for disease prevention was quoted by vets and farmers as being administered most often through an in-feed formulation, which accounts for this being the most common route of administration for antimicrobials in pigs in the UK (Stevens et al., 2007).

The role of vaccination as an alternative to antimicrobials in disease prevention on pig farms was identified by vets and farmers. Such conclusions are reflected in Stevens and others (2007) findings that 80 % of pig farmers considered vaccination to be an alternative to antimicrobial usage. Once disease was identified the vet and farmer groups recognised that diagnostic testing influenced prescribing behaviour in both routine disease surveillance as well as emerging infections. The VMD focus groups did not consider that ‘routine diagnostic testing’ influenced prescribing habits in the pig sector, however it was acknowledged to be used to investigate novel infections on farms (Sheehan, 2013).

The vet focus groups quoted the NOAH Compendium as being their most trusted source of information on antimicrobials to aid prescribing decisions. This agrees with previous research from across the veterinary sector (Hughes et al., 2013, Hughes et al., 2012, Williams et al., 2012). Farmers considered their vet to be the most trustworthy source of information on antimicrobials as is shown by previous research which confirmed the strong reliance that farmer's place on vets for information (Lathers, 2001, Ruegg, 2006, Friedman et al., 2007). Advertising by pharmaceutical companies was not considered to influence prescribing behaviour by either the vet or farmer focus groups. This contradicted with the VMD prescribing pressures focus groups with vets, where participants within the pig sector felt that it may influence prescribing (Sheehan, 2013).

Overall, vets and farmers felt there was insufficient evidence to prove a decisive link between antimicrobial use in food producing animals and the development of resistance in humans. This contrasted with Stevens and others (2007) findings that 50 % of pig farmers considered that resistance in human beings could be a consequence of antimicrobial use in farm animals. The apparent change to a more defensive stance shown by vets and farmers in this study could reflect increasing media interest, that has attributed blame for antimicrobial resistance in humans on the intensive livestock sector (Levitt, 2011a, Anon, 2013c, Harvey, 2013), or could be a consequence of the participants selected in this study.

Focus groups are considered to be most useful when they are composed of a balance of different individuals, whereby participants share similar cultural, societal and hierarchical roles yet are dissimilar enough to elicit a variety of opinions (Krueger, 1994, Greenbaum, 1998). The purposive sampling employed in this study aimed to achieve this desired diversity by the inclusion of vets and farmers with experience of different pig rearing systems, with differing levels of job responsibility and from different geographic areas, in an attempt to represent the range and extremes of vets and farmers in the UK pig industry. However, bias in selection may result in participants that sit to the extremities of antimicrobial prescribing patterns and may exclude the majority opinion of pig vets and farmers.

Conclusion

In conclusion, this study was able to elicit the motivations and behaviours behind antimicrobial prescribing practices in pig vets and farmers, providing a degree of complexity that is difficult to achieve through quantitative research methods. Convergent themes were generated both within and across the vet and farmer focus groups, although further exploration of these themes is required over a wider population of pig vets and farmers to provide more detailed evaluation of prescribing behaviours. Such studies are important to help provide the evidence and social context on which to build future policy and education and to develop effective interventions against the over or inappropriate use of antimicrobials in pigs.

Generic name, Proprietary Name and Manufacturer of Medicines

1. Ceftiofur; Naxcel; Zoetis UK Limited.

2. Enrofloxacin; Baytril; Bayer plc.

Appendix 1

Appendix to chapter 2: Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: A qualitative study

Appendix 1: Appendix to chapter 2: Understanding antimicrobial use and prescribing behaviours by pig veterinary surgeons and farmers: A qualitative study

Figure 1.1 – Consent form for qualitative focus groups and interviews

UNIVERSITY OF LIVERPOOL

CONSENT FORM

Title of Research Project:	**Motivations and drivers of antimicrobial prescribing practices in pigs**
Researcher(s):	**Lucy Coyne, Dr. Pinchbeck, Dr. Latham, Dr Williams, Prof Dawson, Dr Smith, Richard Pearson**

Please initial box

1. I confirm that I have read and have understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. ☐
3. I consent to my anonymised conversations being recorded and subsequently transcribed. ☐
4. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. ☐
5. I agree to take part in the above study. ☐

Participant Name	Date	Signature
Name of Person taking consent	Date	Signature
Researcher	Date	Signature

The contact details of lead Researcher (Principal Investigator) are:

[Contact: Gina Pinchbeck, Leahurst campus, University of Liverpool, Neston, Wirral, CH64 7TE, telephone: 0151 794 6195, email: ginap@liverpool.ac.uk]

Figure 1.2 - Participant information sheet for focus group discussions

Motivations and drivers for antibiotic use in pigs in the UK

Participant Information Sheet

This project aims to gain a clear understanding of the motivations, practices and attitudes surrounding the prescribing and use of antibiotics in the UK pig industry. Antibiotics are at the forefront of tackling infectious disease both in humans and animals, offering very effective ways of rapidly combating a wide range of pathogens. However the rise in resistance against antibiotics and lack of development of new compounds is of concern to both human and animal health.

The use of antibiotics in animals has come under recent scrutiny and there is controversy over the extent to which animals contribute to resistance in humans (or vice a versa). Use of antibiotics in food-producing animals may involve treatment of large numbers of animals at once In the UK , the Veterinary Medicine Directorate estimate that the largest amount of single species antimicrobial products sold to the farming industry are for use in pigs; most of which are administered orally.

The first phase of this 3-year project is to hold focus groups with pig veterinarians, pig farmers and others in the industry to discuss general issues and opinions regarding antibiotic use. All data gathered during the focus groups will be anonymised and held securely at the University of Liverpool, therefore no comments will be attributable to any named individual. Results will be analysed at the University of Liverpool and presented in future at meetings for vets and farmers.

The study is being led by researchers at Liverpool University (Dr Gina Pinchbeck, Dr Sophia Latham, Dr Nicola Williams, Dr Rob Smith, Prof Susan Dawson and Lucy Coyne) and Mr Richard Pearson, a partner at the George veterinary practice in Wiltshire who specialises in pig work, and is funded by DEFRA. The project team aim to work closely with BPEX and the Pig Veterinary Society amongst other major stakeholders in the UK pig industry and are grateful for the support already given.

For further queries, please contact: s.latham@liv.ac.uk or 0151 794 6195 or Lucy Coyne l.a.coyne@liv.ac.uk

Figure 1.3 – Topic guide for focus group moderators

Project title: Motivations and drivers of antimicrobial prescribing practices in pigs

2012-2015

Focus Group Outline

Introduction (5 mins)

Session 1 (1 hour)

A: Perceptions of antibiotics and their usage

(i) Antibiotics are a useful tool in combating disease in pigs. Do you feel that antibiotic resistance is compromising the health and welfare of your patients/livestock?

- *How common a problem is 'failure of treatment' on an individual farm and how common a problem is it perceived to be in the pig industry?*
- *How often is culture and sensitivity testing carried out?*
- *Consideration – costs herd type eg. Indoor, outdoor and intensity of stock density, health status of the herd, identification of 'failure of treatment' on farm by vet/farmer, how routinely are vet visits, diagnostics, surveillance*

(ii) What are your views on the types of antibiotics used in pigs and the frequency of their use?

- *Are there a reasonable selection of drugs available to treat common disease seen in pigs in the UK?*
- *How much does cost affect the type of antibiotic chosen and the frequency of its use?*
- *Do generics increase the likelihood of a particular drug being used? Have generics made prices more competitive for a particular drug?*
- *Consideration – cost, availability of drugs through Veterinary practice.*

(iii) How much do you think that antibiotic use in pigs has an impact on human health?

- *Do you think that antibiotic resistance is a major problem in human medicine?*
- *Do you think that antibiotic use in food producing animals contributes towards antibiotic resistance in humans? If so, How?*
- *How do you think antibiotic use in pigs compares to the other areas of livestock production?*
- *Considerations – awareness of spread of antibiotic resistance through zoonotic routes or transmission through commensal organisms, role of other areas of farming in antibiotic resistance,*

(iv) In 2006 the use of Antimicrobial Growth Promoters (AGP) was banned in the EU. What is your opinion of this legislation?

- *What were the advantages and disadvantages of the ban?*
- *What economic effects did this have? On individuals farms? For the UK pig industry? For the EU?*

(v) What effect has the AGP ban had on pig farming in the UK?

- *What effect did this have on the use of antibiotics immediately after the ban? Has this changed with time?*
- *What problems if any has the ban caused?*
- *Has the EUs ability to trade been affected?*
- *Do you think that a ban should be considered for other Countries, such as the USA, where antimicrobial growth promoters are still used?*
- *Considerations – economics, opinion amongst different age groups of vets/farmers.*

B: Current antibiotic use

(i) What ways do you administer antibiotics to different groups of pigs? For example, by injection, in-feed or in-water? Why do you use these methods?

- *Are in-feed/in-water more likely to be administered to weaners than sows?*
- *Why do you use one method over another? Does the type of feed fed on farm affect the way in which antibiotics are administered?*
- *Are Sows more likely to be given parenteral than other groups of pigs?*
- *Considerations – differentiate different groups of pigs, ie. Sows more likely to have parenteral, growing pigs more likely to have in-feed. Management considerations and cost. Whether feed is bought-in or mixed on farm is a huge consideration. Whether farms are breeding units or rearing units.*

(ii) What influences your choice of antibiotic?

- *What makes the decision to use a particular antibiotic in a pig/group of pigs for a certain disease presentation?*
- *When are long acting antibiotics used over short acting antibiotics? For example, Naxcel versus Excenel? Long-acting ceftiofur versus short-acting?*
- *How often do you review antibiotic use in a particular group of pigs?*
- *Considerations – cost of one drug over another, how routine vet visits are, easier to give a long-acting shot to a pig than repeated doses,*

(iii) How do you decide to a)start, b) continue, c) withdraw in-feed/in-water medication?

- *How much does meat withdrawal period affect this decision?*
- *Is routine disease surveillance carried out in the form of PMs and culture and sensitivity testing?*

(iv) Do you feel that some production systems are more likely to require antibiotics then others?

- *If so, what types of production systems have high usage ?*
- *How could these production systems be improved in order to reduce antibiotic usage?*
- *How far do you think that antibiotics are used to compensate for outdated housing?*

- *Health status of herd*

(v) Under what circumstances are you most likely to use antibiotics for the treatment of disease?

- *What age of pigs are you most likely to treat disease in?*
- *What diseases most commonly require treatment?*

(vi) Under what circumstances are you most likely to use antibiotics for the prevention of disease?

- *What age of pigs are you most likely to prevent disease in?*
- *What diseases most commonly require prevention?*

Whole Group discussion and break (Either lunch or Tea/Coffee with dinner at end of meeting)

Session 2 (50 mins)

C: Responsibility?

(i) Where does responsibility for the safe use of antibiotics in food-producing animals lie?

- *Farmers, vets, retailers, government, EU?*
- *Should vets be allowed more freedom to decide what antibiotics are appropriate to prescribe? Or do, vets have too much freedom?*
- *Should there be strict guidelines on antibiotic prescribing for food producing animals?*
- *Should pharmaceutical companies and vets be allowed to make a profit out of the sales of antibiotics?*
- *Considerations – Denmark – vets no longer able to dispense so removing the profit margin from prescribing antibiotics, do farmers believe that a vets decision is profit driven or is it considered to be an informed opinion not considered financial gain.*

(ii) Many organisations talk about 'shared responsibility' of antibiotic resistance. Do you see the development of antibiotic resistance in humans as an issue for vets and food producers?

- *Do you think there is a link between antibiotic resistance in humans and antibiotic use in animals?*
- *There is some evidence of a link between antibiotic resistance in humans and antibiotic use in animals. How credible do you think this information is? How trustworthy are the sources?*
- *Who else do you think antibiotic resistance in humans is an issue for?*

(iii) What sources of information, on the subject, do you most use and trust?

- *Advice from vet? Other farmers? Nutritionist?*
- *Media? Farming organisations such as BPEX, NPA? Government? EU? Scientific papers? Veterinary/farming press? Others?*

(iv) From 2013 the government will prohibit the advertising of antibiotics directly to animal keepers, in a bid to reduce antibiotic resistance. What are your views on this?

- *How much does advertising influence your decision to use a particular drug?*
- *Will this alter future decisions?*
- *What effect do you think this will have on the types of antibiotics used?*
- *Do you think this is likely to have a negative effect on pharmaceutical companies?*
- *Do you think this will have a negative effect on farmers?*

D: Future options

"There should be a ban on the use of certain types of antibiotics (quinolones and cephalosporins) in animals, in order to protect their activity in humans".

Chief Medical Officer report, 2008:
h*ttp://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_096231.pdf*

It has been proposed that certain classes of antibiotics, namely fluoroquinolones (Baytril, Marbocyl), and third and fourth generation cephalopsorins (Excenel, Naxcel) should not be available for veterinary use in the UK, in order to preserve their efficiency for human use.

(i) **Please discuss your views on this. How would this affect you?**

- *Would this have a negative effect on pig health and welfare?*
- *Would this have a greater effect on the UK pig industry?*
- *Would it be likely to alter the amount of pig products produced in the UK?*
- *Would it have an effect on the UK export market?*
- *Would a ban be enforceable?*

(ii) **More recently, it has been proposed that the veterinary use of Macrolides (Tylan) should also be considered for restriction. Do you perceive a difference in restricting the use of fluoroquinolones and third and fourth generation cephaloporins compared to macrolides?**

- *Are macrolides used more commonly on farms than fluoroquinolones and third and fourth generation cephaloporins?*
- *Will banning such drugs just mean that alternatives are used and the problem is simply shifted to different groups of antibiotics?*
- *Is it likely to result in more disease outbreaks and to affect the health status of herds?*
- *Is this likely to have a significant impact on the health and welfare of pigs?*

(iii) **In your view could antibiotics be used less frequently and more carefully in pigs?**

- *Do you think that pigs can be managed in a satisfactory manner with using fewer antibiotics?*
- *Is reducing antibiotic usage likely to have a negative effect on health and welfare?*
- *How do you think that antibiotics could be used more carefully?*

(iv) **What are the current limitations on reducing antibiotic usage in pigs?**

- *Outdated housing, poor meat price, high cost of feed, high cost of straw, intensification of production to meet demand, poor health status*

(v) **Are there any other major issues around antibiotic prescribing at present and have these changed over time?**

- *Are there more/fewer antibiotics licensed now in comparison to the past?*
- *Has the role of the vet on the farm changed over time?*
- *Are more diagnostics carried out on farm now than a few years ago?*

Whole Group discussion and wrap up

Figure 1.4 - Reflections from veterinary surgeon focus groups

Focus Group 1

1. Veterinary surgeons were very defensive when discussing antimicrobial use and the term ‘responsible’ was repeatedly used to describe their own prescribing practices.
2. Overall, the participants did not feel that there was a need to discuss antimicrobial use in pigs and that the research was not valuable.
3. There was strong agreement that straw-based finishing systems were higher antimicrobial users than indoor slatted systems.
4. Very emotive parallels to human disease were used to describe pig diseases and justify opinion.

Focus Group 3

1. Antimicrobial prescribing in pigs has probably been too high and irresponsible by some veterinary surgeons.
2. The Antimicrobial Growth Promoter ban was positive in terms of forcing the pig industry to evaluate its antimicrobial use.
3. Overall, discussion was very positive with participants actively engaged and enthusiastic about the subject of antimicrobial use in pigs.
4. The focus group included veterinary surgeons from a number of private and company veterinary practices and showed a very proactive and harmonised approach to tackling disease surveillance and antimicrobial use.

Figure 1.5 - Reflections from farmer focus groups

Focus Group 1

1. Perception that antimicrobial use is much more responsible now than it has been in previous years.
2. High reliance on the veterinary surgeon for advice on antimicrobial use.
3. Participants did not feel they had sufficient knowledge to comment on critically important antimicrobials.
4. There was a slight sense of complacency as the farmers felt that their farms were in a much lower pig dense area than other units and therefore many of the diseases being discussed were less of a threat to their units than for others.

Focus Group 2A

1. Antimicrobial use in pigs must be at minimal levels as it would not be economically viable to use too many antimicrobials on a farm.
2. Participants identified a blame culture whereby doctors blame veterinary surgeons for antimicrobial resistance whilst veterinary surgeons place blame at the feet of physicians.
3. Farmers heavily rely on their veterinary surgeon for advice on antimicrobial use.
4. Participants felt strongly that prudent use of antimicrobials lies primarily with the veterinary surgeon and it is his/her responsibility to ensure that farmers are full informed on antimicrobial use.

Focus Group 2B

1. It is more responsible to use antimicrobials for disease prevention than reactively to treat disease as it avoids pigs from suffering the effects of disease.

2. There is concern that legislation is based on political opinion and is not evidence-based.
3. There is considerable pressure from poor public perception on antimicrobial use in pigs however, public opinion is inaccurate and does not reflect actual antimicrobial use practices.
4. The lack of ability to re-invest in improving housing and facilities are a major hurdle to reducing antimicrobial use on farms.

Focus Group 2C

1. Antimicrobial use in pigs is responsible and the spotlight should be on use in humans which is not responsible.
2. The participants were very proactive in considering alternative ways to prevent disease to antimicrobials with lively discussion over biosecurity and management measures.
3. There is room to reduce the amount of antimicrobials used in the UK pig herd by focusing on improving pig health.
4. This focus group independently identified that they felt that benchmarking antimicrobial use between farms would be positive in reducing antimicrobial use (this was identified without any input from the facilitator).

Chapter 3

Understanding the culture of antimicrobial prescribing in agriculture: A qualitative study of UK pig veterinary surgeons

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Understanding the culture of antimicrobial prescribing in agriculture: A qualitative study of UK pig veterinary surgeons

Background to published paper on semi-structured in-depth qualitative interviews conducted to explore antimicrobial prescribing practices in UK pig veterinary surgeons

The qualitative interviews with UK pig veterinary surgeons presented in this chapter explored the themes generated from focus group discussions on antimicrobial use in pigs in greater detail in the form of a face-to-face in-depth interview. The perceptions of veterinary surgeons and themes identified from analysis of these qualitative interviews guided the content of the questionnaire study presented in chapter 5.

<u>The structure and facilitation of the in-depth interviews</u>

In total 22 qualitative in-depth interviews of a semi-structured nature were conducted with veterinary surgeons across England and Scotland. It was considered to be essential that all of the interviews were undertaken in person to ensure that social cues such as voice, intonation and body language could be captured (Raymond, 2006). The harmonisation of the data collection also allowed for comparison between transcripts as well as providing additional reflective notes relating to social cues. Detailed reflective notes were made after each interview in order to capture the researcher's thoughts and feelings of the interview and additional social cues which would not have been captured through audio recordings.

Two pilot interviews were conducted with both the primary researcher (LC) and a secondary researcher experienced in qualitative data collection (SL) present. In these pilot interviews SL acted as the interviewer with LC taking an observer role. This allowed LC to focus on the content and conduct of the interview and to develop further knowledge on qualitative interview techniques. The two subsequent interviews were also conducted with both researchers present however; LC took the role of interviewer with SL acting as an observer. This allowed the researchers to reflect on the role of facilitator and acted to train LC in the necessary skills of facilitating qualitative interviews. The remaining interviews described in this chapter were all conducted with only LC present. However, both researchers reviewed reflective notes alongside interview recordings in order to further evaluate and develop the qualitative interview technique.

The first 10 interview recordings were transcribed verbatim by the primary researcher. This was considered to be advantageous in ensuring that the researcher was fully immersed in the qualitative data. Subsequent interviews were transcribed verbatim by external transcribers. However, all audio recordings were reviewed alongside the transcripts in order to ensure that they were true accounts of the interviews. Additional social cues and reflections were added as additional memos on to the interview transcripts.

Analysis of qualitative data

The interview transcripts were analysed using the thematic analysis technique described in chapter 1 under the section 'General Introduction to Approach and Methodology in Qualitative Studies'. The approach taken was not truly inductive as the content of the interview guide was directed by the earlier focus group study (chapter 2). Thus, a theoretical approach to thematic analysis was taken in which coding was informed and motivated by the researcher's prior findings.

Initially transcripts were not coded using the pre-existing framework and were coded independently. However, the identification of parallel codes and overarching themes to the focus groups resulted in themes being defined under the pre-existing coding framework generated from the focus group study (chapter 2). Thus, coding was deductive and acted to test and explore theories in greater detail which were outlined from the focus group study.

All transcripts were coded initially by the primary researcher (LC) with a second researcher (SL) independently coding 5 transcripts from each dataset. The transcripts which were double coded were chosen purposively to reflect the spectrum of opinions and majority ideas captured in the interview process. The independently coded transcripts were compared and the themes were further refined. Themes were discussed, reviewed and further refined by a multidisciplinary team of researchers alongside reflective notes and thematic maps.

Understanding the culture of antimicrobial prescribing in agriculture: A qualitative study of UK pig veterinary surgeons

This chapter is presented as it was published in the Journal of Antimicrobial Chemotherapy.

Reference:

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Abstract

Objectives: The use of antimicrobials in food producing animals has been linked with the emergence of antimicrobial resistance in bacterial populations, with consequences for animal and public health. This study explored the underpinning drivers, motivators and reasoning behind prescribing decisions made by veterinary surgeons working in the UK pig industry.

Methods: A qualitative interview study was conducted with 22 veterinary surgeons purposively selected from all UK pig veterinary surgeons. Thematic analysis was used to analyse transcripts.

Results: Ensuring optimum pig health and welfare was described as a driver for antimicrobial use by many veterinary surgeons and was considered a professional and moral obligation. Veterinary surgeons also exhibited a strong sense of social responsibility over the need to ensure that antimicrobial use was responsible. A close relationship between management practices, health and economics was evident, with improvements in management commonly identified as being potential routes to reduce antimicrobial usage, however these were not always considered economically viable. The relationship with clients was identified as being a source of professional stress for practitioners due to pressure from farmers requesting antimicrobial prescriptions, and concern over poor compliance of antimicrobial administration by some farmers.

Conclusions: The drivers behind prescribing decisions by veterinary surgeons were complex and diverse. A combination of education, improving communication between veterinary surgeons and farmers, and changes in regulations, in farm management and in consumer/retailer demands may all be needed to ensure that antimicrobial prescribing is optimal and to achieve significant reductions in use.

Introduction

Indiscriminate prescribing practices and the overuse of antimicrobials in food producing animals has been implicated with the emergence of antimicrobial resistance in bacterial populations; with consequences for both animal and public health (Valentin et al., 2014, Van Loo et al., 2007). The emergence of resistance infections in animal populations can impact health and productivity (van Duijkeren, 2014). Additionally there is concern over the potential for the zoonotic transfer of resistant bacteria and resistance genes or plasmids, from livestock species to humans; a phenomenon which has been recognised as a potential threat to human health through the use of antimicrobials in pigs (Burow et al., 2014). Whilst isolated incidents of such transfer are described in the literature (Agersø et al., 2012, Taylor et al., 2008, Lewis et al., 2008), it is impossible to quantify or assess the level of the risk at present (2015). Thus it is essential that prudent antimicrobial practices are adopted in veterinary as well as in human medicine to minimise selection pressures with the aim of slowing the emergence of resistant bacteria (Llor and Bjerrum, 2014, Aarestrup, 2005).

Antimicrobial use in pigs has been highlighted as an area of particular concern in the UK and Europe with the formation of working groups and research initiatives striving to ensure that use is responsible (Grave et al., 2014, Smith, 2015, Anon, 2011b, Borriello et al., 2015). Veterinary prescribing practices in the pig sector, such as the use of antimicrobials for disease prophylaxis (Grave et al., 2014, Callens et al., 2012), the commonality of the administration of in-feed antimicrobials (Grave et al., 2014) and the relatively high sales of antimicrobial products authorised for use solely in pigs (Borriello et al., 2015) have highlighted pigs as a priority species in the UK and Europe for gaining a better understanding of prescribing and use (Grave et al., 2014, Visschers et al., 2016).

Following the 2006 European Union (EU) ban on the use of antimicrobials for growth promotion, they are only permitted to be used for therapeutic or prophylactic indications. Veterinary surgeons are the only professionals able to prescribe antimicrobials for veterinary use in the UK. A thorough understanding of veterinary surgeons' current prescribing behaviours relating to antimicrobial regulation has been identified as being essential to the development of strategies to ensure that veterinary use is responsible (Speksnijder et al., 2015b, Guardabassi and Prescott, 2015, Visschers et al., 2016).

Antimicrobial prescribing does not happen in isolation, but takes place within an environment where factors both intrinsic and extrinsic to the prescriber influence decisions. In human medicine, factors intrinsic to the prescriber relate to their personal confidence in prescribing decisions, concern over the consequences of such decisions and attitudes surrounding a sense of responsibility to patients, whilst extrinsic factors are those external to and beyond the control of the prescriber; such as pressure from patients, other healthcare professionals and institutional policy (Rodrigues et al., 2013). Whilst parallel intrinsic drivers have been identified in veterinary medicine (Busani et al., 2004, Gibbons et al., 2013, Mateus et al., 2014), extrinsic pressures such as the financial viability and the influence of husbandry practices on prescribing decisions are unique to the role of livestock as food producing animals (Speksnijder et al., 2015b). Therefore, it is necessary to understand how antimicrobial prescribing sits amongst other factors that might drive antimicrobial use.

There are a number of methodological approaches that can be taken to understand the relationship between behaviour, prescribing and antimicrobial use. Whilst some provide more structured empirical data, qualitative approaches are more appropriate in broad exploratory contexts such as antimicrobial resistance and veterinary prescribing (Al-Busaidi, 2008). In this study we used in-depth qualitative interviews to explore the attitudes, motivations and reasoning behind prescribing decisions by pig veterinary surgeons. This is the only large-scale study of this type to be undertaken in the UK and provides novel insights into UK prescribing practices which have potentially wide-ranging implications for the control of antimicrobial resistance and the economic landscape for pig farming.

Methods

Selection of Participants

All veterinary practices listed as conducting pig work on the Royal College of Veterinary Surgeons (RCVS) veterinary practice database in England, Wales and Scotland (Anon, 2015i) were contacted by phone. Practices were asked to confirm that they still undertook some commercial pig work and if so the names of veterinary surgeons that treated pigs were requested. A final confirmed list of 261 veterinary surgeons and their 104 respective practices was made; this was believed to represent all practices that conducted commercial pig work. Data on the veterinary surgeons, such as gender and year and place of graduation was obtained from the RCVS Veterinary Surgeon Registers. Participants were recruited using a purposive sampling technique which aimed to obtain a sample population that contained a spectrum of veterinary surgeons working within the UK pig industry and thus included both male and female, partner and assistant, private practice and company practitioners with a range of levels of experience. Veterinary surgeons that had previously attended a focus group from a previous study on prescribing practice in pigs (Coyne et al., 2014) were excluded from the selection process.

All the interviewees were approached directly by telephone or email to request participation and arrange a suitable time and location.

Data Collection

Qualitative in-depth interviews of a semi-structured nature were conducted. An interview guide was developed by the authors based on a review of the literature, current issues surrounding antimicrobial use and results from a previous focus group study exploring antimicrobial prescribing behaviours in pig veterinary surgeons and farmers (Coyne et al., 2014). The interview guide (Appendix 2, Figure 2.1) consisted of open questions designed to encourage free and detailed discussion around influences on prescribing decisions and the use of antimicrobials in pigs and included the following key areas:

- Views on the current debate over antibiotic use and antibiotic resistance
- Drivers and motivators of antibiotic prescribing and dispensing decisions
- The licensing and legislation of antibiotics
- Husbandry practices and antibiotic use
- Antibiotic usage in the UK, EU and the rest of the world
- Barriers to reducing antibiotic use for both prophylaxis and treatment
- The future of pig farming

All interviews were undertaken by the author (LC) with an additional author (SL) also present for a number of interviews. Flexibility was allowed in the order and conduct of the interview and questions were phrased in an attempt to encourage participants to express their views and recount their stories. Further questions that arose during the interviews were phrased carefully in order to avoid leading the discussion.

Two pilot interviews were conducted and the interview guide was reviewed and revised by the authors. Transcripts from the pilot interviews were reviewed in detail by three of the authors and were considered to be of acceptable quality to include in the overall analysis.

Interviews were conducted at a place and time convenient to the participant. Interviewees were given a participant information sheet that provided an overview of the project. Permission to record the interviews was sought over the telephone when recruiting participants as it was considered a vital component of the qualitative interview process to facilitate the subsequent data analysis. All participants signed a consent form prior to the interview (Appendix 1, Figure 1.1, the consent form was the same for all of the qualitative studies). Ethical approval for the interviews was gained from the University of Liverpool Veterinary Science Research Ethics Committee and the Department for Environment, Food and Rural Affairs (Defra) survey control unit prior to commencing the study interviews.

Thematic Data Analysis

The interview audio recordings were transcribed verbatim and anonymised. The transcripts were transferred into Atlas.ti V.7.7.1 (Atlas.to Scientific Software Development) for data management using a thematic approach. Despite being widely used in qualitative research, thematic analysis is poorly defined as a methodology, with approaches taken being diverse and sometimes variable (Braun and Clarke, 2006, Boyatzis, 1998, Holloway and Todres, 2003). Thus, to ensure consistency of data analysis the six phase approach to thematic analysis described by Braun and Clarke (2006) was adopted (Braun and Clarke, 2006). This approach has been widely used and accepted as being robust across a wide range of disciplines including human health research (Braun and Clarke, 2014).

A theoretical approach to thematic analysis was used in which the coding of the transcript was motivated by the authors' pre-existing coding frame from an earlier focus group study (Coyne et al., 2014). Reiterative reading of the transcripts by two of the authors (LC and SL) was used to transform ideas generated into a set of codes to identify a feature of the data of interest to the researcher. These initial codes were then categorised into potential themes and coded data extracts within identified themes were reviewed and collated to form the minor themes. The two researchers conducting the data analysis concluded that data saturation was reached from the data set when no new descriptive codes or themes were identified from additional interview transcripts and therefore no further interviews were conducted once this had been achieved.

Themes were discussed and reviewed by a multidisciplinary team including epidemiologists, veterinary surgeons and a researcher experienced in qualitative research methods in order to reflect on the relevance of the themes to the research questions (Bryman, 2012). These themes were then refined to ensure that each was meaningful and clear but distinct from other themes (Patton, 2002). A thematic map was constructed in order to review the relationships between these minor themes. Minor themes that were linked by a common subject area or which related to an overall topic were grouped together, given a unique theme title and considered as major themes. A reflective journal account of the interviews was written immediately following each interview and a summary of these notes are shown in Appendix 2, Figure 2.2.

Results

A total of 24 veterinary surgeons were contacted and 21 interviews were completed and included in the study; 3 practitioners were willing to take part in the study but it was not possible to arrange interviews due to geographic and time constraints. Table 2.1 in Appendix 2 gives an overview of the demographics of the sample population. All of the interviews were conducted by one or both of authors (LC and SL) and lasted between forty-five and ninety minutes.

Thematic analysis revealed eight major themes consisting of seventy six minor themes that were identified as influencing antimicrobial prescribing behaviours. The thematic map is shown in Figure 1 and a table of themes is shown in Appendix 2, Table 2.2.

Disease Epidemiology and Outcomes

In its most simplistic form, disease was considered to be a driver for antimicrobial prescription. Amongst interviewees definitions of disease were diverse; on one hand, participants' defined disease in terms of distinct bacterial pathogens, such as *Salmonella species*, *Streptococcus suis* and *Brachyspira hyodysenteriae,* whilst on the other hand, individuals proposed that disease syndromes consisted of multiple pathogens.

'…we're very often not treating singular pathogens. You're feeding a disease syndrome with multiple potential effects.'

Whilst theoretically only bacterial disease should influence prescribing behaviours, most veterinary surgeons identified that this perception was too basic and perceived that viral disease played a role in prescribing behaviours. For example, when influenza virus infects a herd antimicrobials may be used to treat the impact of secondary bacterial diseases.

'I think at finisher level [fattening pig near slaughter weight] the main antibiotics we would use for respiratory disease are used to control secondary bacterial infections… Flu is a massive issue. We all know you don't give antibiotics for flu. However, if you don't put in a course of CTC [Chlortetracycline] or something, pigs will then get something else and then you'll start seeing pigs die'.

Disease was categorised as either chronic or acute by interviewees; with contrasting approaches to antimicrobial use and diagnostic testing in the two states. Routine diagnostic testing to monitor endemic and chronic disease levels was seldom cited as being the norm on most pig units. However, performing diagnostic testing when acute clinical signs were first seen was described as a common behaviour by participants; particularly when a novel pathogen or more severe form of an endemic disease was suspected. In order to ensure that pig welfare is not adversely affected an antimicrobial must be selected based on a presumed diagnosis, observed on either clinical or post mortem examination before being able to confirm the choice through susceptibility profiles. This time delay in attaining results from antimicrobial susceptibility testing (AST) was acknowledged as being problematic by veterinary surgeons. In parallel, the direct consequences of disease, morbidity and mortality, were considered to drive the use of antimicrobials for both therapeutic and prophylactic reasons.

'If you have animals that are acutely ill and are in the process of dying… you need to get antibiotics into them as quickly and as effectively as you can…'

'That's why we always do culture and sensitivity on everything really. The very first day, if it's a severe disease, it would be a best guess on post-mortem as to what was causing the problem.'

Some participants felt that endemic disease levels amongst the UK pig herd were high and that antimicrobials were used to reduce the impact of disease on production. Thus antimicrobial use in these situations was considered to be aimed at managing disease levels on farms rather than on producing a clinical cure.

'The national herd is not very clean, and if you took antibiotics out tomorrow, bacterial disease would avalanche through the herd and the pig farm would become non-viable.'

Vaccination was proposed by interviewees as an alternative method to antimicrobial use to prevent disease. The following quote bridged the major themes of 'disease epidemiology and outcomes' and 'agricultural factors' as it considers vaccination, health status and the facilities and management of a farm to be pivotal in minimising the antimicrobial requirements of a farm.

'If you can get decent buildings, a decent stockman, decent health status, and you've got a reasonable vaccination programme in place to control any underlying health, then a lot of farms [would] manage with very little in-feed [antimicrobials medications?]…'

Agricultural factors

The sample population held a wide spectrum of opinions on which farming systems would be defined as higher and lower antimicrobial users. Farming systems considered included indoor units when compared with outdoor rearing and slatted-based pig accommodation in comparison to straw-based housing. Although opinions were diverse there were a few dominant ideas. For instance, some participants identified that slatted systems were advantageous in their ability to minimise enteric disease on pig units; as pigs did not come into direct contact with faecal matter. A specific example given by some was that levels of *Salmonella species* were higher amongst straw-based pig units when compared with those that utilised slatted flooring.

'… we invented slatted systems so that we could separate the pig from its urine and its faeces. As soon as you separate a pig from its urine and faeces, they are infinitely healthier than before.'

'Salmonella isolates from slaughter pigs… the solid floor finisher houses are the ones that have given us the biggest…'

The majority of veterinary surgeons considered the quality of the unit management to be the most significant factor in avoiding the overuse of antimicrobials; a *'well managed'* pig unit was thought to require fewer antimicrobials than one that was perceived to be managed poorly. Interviewees felt that having highly skilled stock people was pivotal to this with a few individuals making a direct link between having highly skilled staff and a minimal antimicrobial requirement on a unit, through early recognition of clinical disease signs and prompt therapeutic intervention.

'…the system absolutely influences diseases and therefore the use of antibiotics. Lower ones are always the ones that are well managed… if it is badly managed you can end up with problems and diseases so the management of each system is the key really.'

'I think stockmanships massive, it's seeing it, it's seeing a problem before it develops and getting in there because you may need less antibiotic use because we've caught something early.'

Some management practices were considered to be limiting factors in reducing antimicrobial use on many farms. Participants linked the practice of mixing pigs from multiples sources, a continuous pig flow system and low health status herds with high disease burdens on pig units when compared with sourcing pigs from a single source, an all-in/all-out pig movement system and herds with a high health status. Additionally, interviewees also linked farm environment with antimicrobial use and considered old buildings with poorly maintained facilities to be higher antimicrobial users.

'The higher users [of antimicrobials]… would tend to be the older farms, longer established units, lower health status, continuous flow, poor hygiene, dubious management practices, and yes, a lack of attention to detail and management. Lower use would be high health units, perhaps more extensive, all-in, all-out by department or by batch, things like that.'

External Pressures

Veterinary surgeons commonly cited poor public perception as a pressure on their professional lives. Two contrasting opinions were found amongst participants as to how the public perceived that pigs were produced. On one hand, some participants proposed that the general public thought that a significant amount of antimicrobials were used in the pig industry and cited inaccurate media reporting as the grounding of this public opinion. Conversely, others held the opinion that the general public were unaware of the intensity of pig production and had an idealised image of smaller scale extensive agricultural systems with low antimicrobial use.

'I think in terms of food production… there is a perception that again pigs and poultry do get a lot of antibiotics. They'll believe what's on the front page of the tabloid papers and take it away, whether there's any proof or not.'

'There is a complete disconnect… the general public has this vision of sort of utopian agriculture where a nineteen fifties Darling Buds of May farm with three pigs and ten chickens against the world, there is a complete disconnect between the two, the reality is cheap food on the shelves, intensive farming.'

Veterinary surgeons voiced opinions on antimicrobial use in pigs overseas, in other veterinary sectors, and in human medicine. The majority opinion amongst participants was that the pig veterinary sector was more responsible in its use of antimicrobials when compared with other species sectors. This view was more common amongst the specialist pig practitioners compared with individuals who worked in mixed species practice.

'I think that if you're looking for irresponsible use of antibiotics… you're probably looking at the wrong industry… the cattle guys and the sheep guys are much more difficult to get under control than the pig guys…'

Many interviewees held the opinion that overprescribing is an issue in human medicine and some linked this to resistance in humans. Participants shared the opinion that issues of antimicrobial resistance in human medicine were predominantly driven by prescribing practices in humans and that any influence on human resistance profiles, from veterinary use, was negligible. Some participants expressed concern that the medical profession implicated the veterinary sector in resistance issues; this was identified as a pressure on prescribers.

'We know that medics have traditionally just dished out antibiotics to anybody.'

'Personally, I suspect, and from things that I've read and seen, I suspect it's probably more the use of antibiotics in human medicine that has driven antibiotic resistance in the human bugs… rather than transfer from animals.'

'…it's [antimicrobial resistance] obviously an issue in human medicine, which I think they're probably using us as the scape goats for. At the moment I think we've just got to be seen to conform or to reduce our usages to take the party line.'

When compared on a global scale interviewees considered that the UK pig industry was a low antimicrobial user compared to many other countries. Many interviewees felt that antimicrobials were used in a greater volume and less responsibly overseas; this linked closely with the minor themes of importation pressure and retailer pressure. Participants felt that farmers were under pressure from retailers due to the high price of producing pig meat in the UK and the constant threat from supermarkets sourcing pig meat from abroad; where antimicrobial use is greater and prescribers face fewer regulations over prescribing.

'Go to America, go to Brazil, go to Thailand, all big players in moving multiple amounts of meat around the world and they are huge users of antimicrobials.'

'There's no point at all in trying to hammer the UK farmer into using no antibiotic, for his product to become too expensive on the marketplace for the supermarkets to buy, and for the supermarkets then to buy in from countries that are still quite happy to dish out the antibiotic.'

Veterinary Surgeon-Client Relationship

Client pressure was perceived to be a potential driver towards antimicrobial prescribing by veterinary prescribers. Most clients were considered to respect the decision of a veterinary surgeon, as to whether an antimicrobial was necessary or not, however, participants recognised a minority of *'bullying clients'* that desired antimicrobials and applied pressure on veterinary surgeons to prescribe. The potential for blame should an antimicrobial not be prescribed, and later prove to be necessary, was identified by some interviewees as a specific

factor in client pressure. An awareness of the potential for litigation under such circumstances was identified by a few participants as a possible driver for antimicrobial use.
'There are 75% of rational clients that you can discuss things with and reason as to why they don't need to use that antibiotic. And there is the 25% of damaging clients who will simply insist… that they have that...'

'…there are some things that probably don't need antibiotics – almost certainly don't need antibiotics. But I think you're laying yourself open to litigation if you don't use them.'

In contrast to the perception of client pressure a minority view identified a relationship in which the veterinary surgeon and farmer worked together in a mutual partnership. This view was most commonly held by practitioners who were either partners or in a senior role within their respective practices. Participants generally placed the burden of responsibility for the prudent use of antimicrobials in pigs, on themselves, as the prescriber. However some interpreted that the relationship between the veterinary surgeon and the farmer, resulted in a shared responsibility between both parties. These participants tended to acknowledge this mutual relationship much more commonly than those who considered the responsibility for prudent use to lie solely with the veterinary surgeon.
'With the vet and the doctor who's prescribing. They are the professionals, they should be able to see the bigger picture and it's their responsibility.'

'*…the farmer and the vet, together… working as a team... You can't pin it on one or the other; it's got to be both. Both need to be aware and willing to take it on board.'*

Drug-related Factors

Veterinary surgeons considered a complex interaction between different disease characteristics and the number of animals affected when deciding which formulation of antimicrobial to prescribe. In general, participants considered injectable antimicrobials were most commonly used in smaller groups of pigs whilst in-feed or in-water formulations were more appropriate for larger group sizes. Overall, interviewees preferred in-water medications in acute disease situations, as they are able to be administered more promptly than in-feed preparations. Conversely in more chronic or *'endemic'* disease situations the in-feed route was considered to be acceptable as it offered the *'cheapest'* and *'easiest'* route of administration for farmers, when compared with in-water formulations.
'The sorts of thoughts that I would be thinking about would be… the number of pigs that you actually need to treat. Obviously you can't inject everything if it's a big group.'

'[The] majority of the situations that you are dealing with would be that pigs would need immediate medication which you can only do with water because the feed cannot get there on time…'

A general consensus across the interviews was that the use of in-feed antimicrobials for disease prevention was both commonplace and justifiable. The decision to continue or discontinue prophylactic in-feed antimicrobials was identified as problematic by many as there was concern that withdrawal may adversely affect pig welfare in situations where management improvements are either not economically viable or practically feasible. In addition, participants felt a sense of pressure from the reluctance of farmers to withdraw an antimicrobial perceived to be effective due to the high economic costs involved in discontinuing an antimicrobial and then being required to re-introduce it.
'I do believe in prophylactic treatments because there are too many times where you try and not use antibiotics and then you end up with a bad mortality [rate]…'

'Some farmers are quite reluctant, I suppose, to pull out a lot of preventative medicines because if everything does go wrong it does cost them quite a bit.'

The World Health Organisation categorised fluoroquinolones, third and fourth generation cephalosporins and macrolides as critically important antimicrobials of the highest priority for risk management in their use; to maintain efficacy for human use (Anon, 2012d). Thus, the veterinary use of these highest priority critically important antimicrobials was an area for discussion in the interviews. Veterinary surgeons showed a great sense of awareness of this issue and recognised that the use of fluoroquinolones and third and fourth generation cephalosporins should be confined to clinical situations where no alternative antimicrobial is available. However many described clinical examples of use, for example the use of a fluoroquinolone as a first line treatment in neonatal scour. Participants justified this use due to the widespread resistance in diarrhoea pathogens to other antimicrobial classes and as alternative antimicrobial classes, that have been used historically, are either no longer marketed in the UK or no longer available.
'…the major use of fluoroquinolones is in piglet scours. If there was an alternative there then obviously, yes, we would use it… We just don't have something that's effective enough.'

'…we lost neomycin and we were using neomycin quite a lot, so you know then we had to move on to something else, and that pushed us nearer to having to use fluoroquinolones than we'd like to go…'

The majority of veterinary surgeons did not feel that resistant infections in pigs had a major impact on their clinical work despite commonly stating that neonatal scour pathogens frequently exhibited resistance on historic ASTs to multiple antimicrobial classes. Furthermore the observation of treatment failures following the administration of an antimicrobial, and the need to change to a different antimicrobial after initial treatment was a common theme yet participants' seldom linked with antimicrobial resistance. Interviewees felt that it was difficult to identify a direct cause for these treatment failures; reasons commonly proposed included underlying viral disease challenge and incorrect or inefficient administration of antimicrobials.

'...sometimes it's difficult to know whether the treatment failure has been because of resistance to the antibiotic. Or whether it has been that the medicine hasn't been either administered or taken in by the animal correctly… If that's the case, you then try a different antibiotic, for the same problem, and you get a much better response.'

The interviews gauged veterinary opinion on the potential impact should a restriction on the veterinary use of the critically important antimicrobials be implemented. There was a general consensus that the loss of the third and fourth generation cephalosporins would have a minimal impact on the pig industry, however there would be a negative impact should the fluoroquinolones be restricted, and a greater effect should the macrolides be included in a restricted list. Debate over the potential restriction of the macrolides sparked strong views amongst veterinary surgeons; there was concern that a ban would have a major economic impact on the pig industry and would negatively affect pig welfare. A common example cited by interviewees was that if tylosin was no longer available for the treatment and control of *Lawsonia intracellularis,* which causes ileitis in pigs, then the cost of production would increase.

'…in terms of the fourth generation cephalosporin, I, as a veterinarian, try to avoid it like the plague…. The Fluoroquinolones... I think we would probably cope, but there are times when that's the only thing that will do, according to my diagnostics.'

'Ileitis, while it's not a big problem in terms of mortality, does affect an awful lot of piglets …. I think the cost of production would increase as a result. We would also have more welfare issues; we'd have more tail bites; we'd have more agitation in pigs.'

The meat withdrawal period on a product, which ensures that antimicrobial residues do not enter the human food chain, was identified as a driver in antimicrobial choice decisions by veterinary surgeons and was of particular importance when medicating pigs near slaughter.

For example, an oral formulation of tylosin, a macrolide, was cited as being used frequently in pigs near slaughter due to its nil meat withhold.

'Tylosin is still an interesting antibiotic, because it has the nil withdrawal on it, which means it's the only thing that, if there is a lot of late onset pneumonia, you can actually put in, into pigs. But that's maybe more of an issue, that you could probably reduce the usage of Tylosin overnight by sticking a ten day withdrawal on it.'

Responsibility

Ensuring that optimum pig health and welfare is maintained was described as a driver for antimicrobial use by many veterinary surgeons and was considered a professional and moral obligation. There was a general consensus across the interviews that having a disease was the most important cause of poor welfare in pigs.

'People talk about welfare, they talk about how many pigs are in a pen or whether they've got something to play with in the early hours of the morning. Well actually, no, the most significant cause of any welfare problem to pigs is any disease that they may have.'

'If I can just take one example. If we didn't use antibiotics in this one large… unit - I don't think we could continue, I really don't… The pigs' welfare would be shot at as well. So although I know that it's the system, that's what we've got to work with. So therefore, they need the antibiotics.'

In general, participants held the opinion that they considered themselves to use antimicrobials in a responsible manner, and that in general they would consider the pig sector to be similarly responsible. However, a minority of mixed species veterinary surgeons did not share this opinion. Issues raised by these participants included concern that there may be *'overprescribing'* of antimicrobials within the pig sector and that the use of long courses of in-feed antimicrobials, for disease prevention, may not be prudent and are used as *'management tools'*.

'There are some that just really like to use – they want to throw everything at a problem. You wonder what you're writing the prescriptions out for. Antibiotics which have a little bit of food in or food which has a little bit of antibiotics in.'

'I think the one [prescribing practice] that we as pig veterinarians are weak on are the habitual repeat users. It's the repeated in feed prescription that's the issue, isn't it? I'm as guilty as the next man of that.'

Participants described conflict between their desire to limit the use of critically important antimicrobials as first-line choices and the desire to maximise farmer compliance. Some stated that they have used a critically important antimicrobial, due to the longer duration of action, in order to improve compliance and therefore ensure that the pig received the correct dose of antimicrobial. These participants identified that a long duration of activity would influence the choice of an antimicrobial as it would ensure higher compliance rates when compared with drugs which require repeat injections.

'… it's a conflict of interest between using the fourth generation, third generation cephalosporin as a second line treatment, which is ideal… with [using] a considered less important antibiotic for human health and the animal is not completing the course then…'

'Certainly clients aren't keen to multi-jab. Yes, compliance is improved if you can say a single jab.'

A minor theme that was infrequently encountered yet which sparked a very strong and passionate response was the notion that antimicrobials are still used, on occasion, for their beneficial effects on growth rates despite the 2006 EU ban on the use of antimicrobials for growth promotion. This minority opinion was held by mixed species practitioners rather than specialist pig practitioners. In the following quote the veterinary surgeon proposed that the macrolide tylosin is used for its growth promotional properties rather than the prescribed indication, for the prevention of *Lawsonia intracellularis*:

'Tylan (tylosin) is a growth promoter. It is used as a growth promoter. There are thousands and thousands of tons of Tylan (tylosin) going in at relatively low rates. Whether you say it's against lawsonia, or whatever you call it, or whether you say it's growth… Ultimately, it's almost below a therapeutic… dose.'

Economic Factors

Veterinary surgeons reported an awareness of the financial pressure that farmers were under and felt that this influenced antimicrobial prescribing decisions. Many participants felt driven to try to *'reduce the cost'* of antimicrobials for farmers and did not feel that the profit margin on an antimicrobial would motivate prescribing behaviours. Thus the majority felt that the 'decoupling' of antimicrobial sales; whereby veterinary surgeons are no longer able to dispense drugs directly to clients would not affect the total amount of antimicrobials used in pigs.

'There is a margin on antimicrobials, and from the outside you can actually see that- it's rather bizarre, that this chap prescribes it and…supplies it. Is there a conflict? It genuinely doesn't enter into my prescribing decisions.'

A minority felt that cost may motivate which antimicrobial a farmer requests from their veterinary surgeon and therefore proposed that increasing the price of critically important antimicrobials may result in fewer farmers requesting these drug classes.
'I've got a way to stop them using Fluoroquinolones, I actually make them expensive sometimes.'

Antimicrobial use was considered by veterinary surgeons to be a short-term and less expensive solution to a disease problem in contrast to the higher cost of investing in upgrading the farm environment and improving the management to produce a long-term solution. This concept linked closely with the major theme of 'agricultural factors', as management systems were thought to impact on the antimicrobial requirements of farms.
'Farmers probably have to accept that medication will not rectify poor husbandry or poor management… Also, yes, antibiotics might be a quick and relatively cheap option to solve a problem on a farm – in terms of cost. But actually, should we be doing something that's a bit more expensive and a bit more long-term? We're sort of depending on short-term, relatively cheaper options.'

Knowledge Base
Whilst participants showed an awareness of guidelines on the responsible use of antimicrobials in pigs these were seldom cited as being adopted by veterinary practices. Individual practitioners and practices tended to work independently of these and sought information from their own experience, the history of the farm and colleagues when information beyond an individuals' experience was required. Mixed species practitioners consulted a wider variety of information sources on antimicrobials and were more likely to seek information from colleagues compared with practitioners working within specialist pig practices.
'I mean there already are some guidelines like RUMA, and things like that. But… The trouble is that practices tend to work quite independently… having their individual ways of doing things.'

'We have a practice protocol which would be agreed between the clinicians in the pig department, of which there is now four of us, which would be based on our experience in the past… bearing in mind that there's three of us here with, I don't know, seventy years of experience probably combined of pig practice.'

Whilst the majority of participants felt that the experience of colleagues was a trusted source of information on antimicrobials, a minority acknowledged that there can be an issue with senior colleagues applying pressure on more junior practitioners, which was often in order to maintain good relationships between long-term clients and practices. This minority opinion was shared by both junior veterinary surgeons, who identified the pressure, and senior veterinary surgeons who admitted to applying such pressure.

'me being a grumpy old partner would have been upset that my young vet cheesed off one of my good old clients…'

Discussion

The decision whether to prescribe an antimicrobial, and which antimicrobial to prescribe is influenced by a number of complex factors in the context of pig veterinary medicine. Antimicrobial stewardship initiatives to encourage responsible prescribing behaviours are increasingly common in veterinary medicine, with various UK organisations producing national guidelines on responsible use in companion and livestock species (Andrews, 2009, Anon, 2013g, 2014d, e). However, disease specific protocols are only published for small animal species (Anon, 2012f) and veterinary guidance is not available at a regional level. Similarly, in human medicine national prescribing guidelines are widely adopted (Dixon and Duncan, 2014) however, in contrast, primary care trusts produce and advocate their own local level guidance (Anon, 2015e) targeting specific disease conditions and bacterial pathogens (Ali, 2006). Consequently, whilst the decision whether or not to prescribe an antimicrobial is an individual choice, those working within a human medicine environment have a greater number of targeted information sources to guide such decision-making when compared with veterinary prescribers. Thus, the potential for greater variation between individual prescribing practices by veterinary surgeons, when compared with physicians, highlights this as an area where greater understanding of behavioural influences is needed.

Interviewees highlighted concern over antimicrobial resistance within veterinary and human medicine. Similar concerns and views have been expressed by both companion and farm animal veterinary surgeons (Busani et al., 2004, De Briyne et al., 2013, Speksnijder et al., 2015b). Whilst some participants identified that they had encountered resistance in their clinical pig work, many shared the opinion that resistance was an issue faced by other pig practitioners, in other geographic regions and other species sectors. A review of the human literature revealed a widespread awareness by physicians of the issue of antimicrobial resistance in human medicine (McCullough et al., 2015). However, in parallel with findings in this study, this concern was often accompanied by a belief that the responsibility for the generation of such resistance lies with other professionals and in other medical establishments (Rodrigues et al., 2013, Simpson et al., 2007).

At present there is no integrated collection of data on resistance in zoonotic bacteria within the UK, with human data relying on voluntary laboratory submissions to a national database whilst, veterinary data are obtained through voluntary submissions to the Animal and Plant Health Agency (APHA) and EU-harmonised monitoring surveillance of isolates from healthy animals (Borriello et al., 2015).

Whilst the transfer of resistance genes between bacteria from animals to those seen in humans is an accepted phenomenon, the frequency with which this occurs, and the level of threat it poses to public health, remains unknown (Garcia-Alvarez et al., 2012, Chang et al., 2015). The predominant opinion amongst participants was that this was a sporadic event and that any threat was minimal. Whilst opinions from human prescribers have implicated the overuse of antimicrobials in livestock in human resistance profiles (McCullough et al., 2015), it seems veterinary opinion is divided (Speksnijder et al., 2015b, Cattaneo et al., 2009, Visschers et al., 2016). However, there was a shared opinion amongst the study population that antimicrobial resistance in human medicine was mainly driven by use in humans; an opinion echoed in the literature (Beović, 2006, Anon, 2013n, Huttner, 2013).

The desire of the prescriber to maximise compliance has been recognised previously as influencing prescribing decisions by doctors (Curatolo, 2011, Faure et al., 2014) and veterinary surgeons (Speksnijder et al., 2015b, Gibbons et al., 2013), and was commonly used to justify the choice of a particular antimicrobial by interviewees. Some interviewees described that in some clinical situations they may have chosen a long acting preparation of a critically important antimicrobial as a first-line option due to concern that a farmer was unlikely to be able to administer repeat injections of an alternative short-acting antimicrobial. Similarly, the benefits of long acting antimicrobial preparations for improving farmer compliance has been identified as crucial in livestock species whereby repeat administration of injectable antimicrobials can be practically difficult (Sheehan, 2013, Gibbons et al., 2013). Educational initiatives for producers on the importance of completing a course of antimicrobials, including practical solutions and training for administering repeat injections, may reduce the use of longer acting critically important antimicrobials.

Disease prevention through antimicrobial prophylaxis is perceived to be prudent by human (Bratzler, 2013, Enzler, 2011) and veterinary prescribers (Borriello et al., 2015, Visschers, 2016), although is a much more common phenomena in production animal medicine

(Callens et al., 2012). Interview participants described an ethical conflict between responsible prescribing and ensuring that the health and welfare of the pig is maintained. This has been recognised as an issue in the veterinary sector (Morley et al., 2005) and in human medicine (Simpson et al., 2007, Wood et al., 2007). Veterinary surgeons acknowledged that deciding to withdraw prophylactic antimicrobials on individual farms was problematic due to farmer reluctance to do so and concern by the veterinary surgeon that signs of disease may return on withdrawal, a concern shared by practitioners attending a Veterinary Medicines Directorate focus group on prescribing pressures who identified the difficulty of preventing certain diseases on farms where infections are endemic (Sheehan, 2013). Further research to investigate feasible alternative methods of preventing disease to the use of antimicrobials for a typical commercial UK pig unit may allow farmers to reduce such use.

The participants described complex and varying relationships between the veterinary surgeon and the farmer. In some situations participants felt pressure that farmers expected an antimicrobial prescription and in some instances they faced overt demands from farmers for particular antimicrobials. Client pressure has been identified as an influence on prescribing behaviours in human medicine (Cockburn and Pit, 1997, Lewis and Tully, 2011, Petursson, 2005), and others have shown that client expectation can influence prescribing behaviour in farm animal medicine (Gibbons et al., 2013, Speksnijder et al., 2015b). In contrast, some participants defined a mutual relationship between the veterinary surgeon and the farmer; whereby prescribing decisions were shared between both parties. In human medicine the importance of maintaining the doctor-patient relationship has been found to have a positive influence on prescribing behaviours (Kumar, 2003, Butler, 1998) whilst Visschers and others showed the value that pig farmers' placed on their veterinary surgeon for information on antimicrobials, the risks associated with use and alternatives to such use (Visschers et al., 2015). These results suggest that effective communication and improved veterinary surgeon-client relationships may be beneficial in increasing farmer awareness of the issues surrounding antimicrobial use and may reduce the issue of client pressure described by some participants.

Fears of being blamed should antimicrobials not be prescribed and later prove to be necessary, and the potential litigation resulting from such a situation, were cited as concerns by veterinary surgeons. Similar fears and pressures have been found to influence prescribing decisions in human medicine (Petursson, 2005, Butler, 1998, Broom, 2014) and veterinary prescription behaviours in livestock species (Gibbons et al., 2013, Speksnijder et al., 2015b). Another concern identified by some of the junior level veterinary surgeons was pressure to prescribe from senior colleagues; also a concept identified in human medicine (Charani et al., 2013). The ability to mitigate veterinary surgeons fear of diagnostic uncertainty is complex due to the unpredictability of which animals may suffer negative consequences should antimicrobials not be prescribed and then later be required. Greater educational opportunities for veterinary surgeons on the importance of using an evidence-based medicine approach, diagnostic testing to support clinical decisions and the negative consequences from unnecessary prescribing, may alleviate some of these pressures from practitioners. The wider adoption of practice protocols based on collective veterinary surgeon experience, disease profiles from diagnostics and existing national guidelines on antimicrobial use in pigs, may build confidence and guide more junior veterinary surgeons to make independent prescribing decisions. Participants identified that antimicrobial use often targeted disease syndromes potentially consisting of multiple viral and bacterial pathogens. Similarly, such disease syndromes have been recognised as a potential motivation for antimicrobial prescribing in human (Smith, 2002) and veterinary medicine (Glass-Kaastra et al., 2013, McEwen and Fedorka-Cray, 2002). In human medicine it has been shown that co-infection with bacteria in acute viral respiratory disease could worsen the disease clinical signs (Obasi et al., 2014). Similarly, participants identified that secondary bacterial infections would result in more advanced clinical signs in pigs if antimicrobials were not used. Thus, controlling and preventing viral disease on pig units is vital to minimising antimicrobial use.

In chronic disease situations, where a prolonged antimicrobial course is indicated, interviewees expressed a preference for in-feed antimicrobials with the lower cost considered a motivation. A minority of the sample population proposed that the use of in-feed antimicrobials for disease prevention may, in some circumstances, be used for their beneficial effects on growth rates. Therefore, there was conflict in what participants defined as prudent use, with some considering the use of tylosin to prevent ileitis, caused by *Lawsonia intracellularis*, as being responsible use, and others considering this practice to be, in reality, for its growth promotion properties and thus such use was not justified

Routine diagnostic testing to determine the disease status in a herd was seldom cited by the interviewees. Similarly, it has been found to be infrequently conducted in farm animal veterinary practice (Sheehan, 2013, De Briyne et al., 2013) and is considered to be an underutilised tool by physicians (Okeke et al., 2011, Lance and Axel, 2004). Veterinary surgeons recognised the merits of AST in new disease outbreaks, however, they highlighted concerns over the time lag in obtaining results if immediate treatment was required. Such concerns are highlighted in this study and are echoed in the human (Dunne and van Belkum,

2014) and veterinary literature (Speksnijder et al., 2015b, De Briyne et al., 2013). The availability of ‘pen side’ and rapid diagnostic tests, to identify both pathogens and antimicrobial susceptibility profiles, would allow more targeted antimicrobial use and avoid the requirement to change antimicrobials following susceptibility results. In addition, more structured surveillance data on bacterial isolates and susceptibility profiles in animal disease would allow practitioners to make more informed prescribing decisions in the absence of AST results.

Participants described a social responsibility to reserve the use of critically important antimicrobials for cases where these classes are the only therapeutic option; this has also been shown to influence antimicrobial use by human (Wood et al., 2007, Simpson et al., 2007) and veterinary prescribers (De Briyne et al., 2013). However, contradiction was observed within the study as whilst participants described an ideology where fluoroquinolones are a second line therapeutic choice, their use was commonly cited as being a primary therapeutic in the treatment of piglet scour. This inconsistency between the desired behaviour, to ensure that antimicrobial use is responsible, and the actual prescribing decision is shown by Busani and others where 54 % of veterinary surgeons chose a fluoroquinolone as a first line choice in a calf scour scenario despite showing a high awareness of judicious antimicrobial use practices (Busani et al., 2004). Justifications amongst participants for the use of fluoroquinolones in piglet scour were high resistance levels to other antimicrobials in neonatal bacterial diarrhoea and a lack of availability of non-critically important antimicrobials for these cases. In parallel, fluoroquinolones were shown to be used in 12 % of diarrhoeal conditions in pigs in Europe (De Briyne et al., 2014), and the lack of availability of some antimicrobials was also identified in a veterinary focus group discussion on prescribing pressures in UK pigs (Sheehan, 2013). It is essential that veterinary surgeons regularly perform AST in order to monitor resistance profiles and ensure that treatment choices for neonatal scour are appropriate and justified. However, this effort needs to be coupled with further research into methods through which neonatal diarrhoea can be prevented and managed within pig units.

Discussion over potential restrictions on the veterinary use of critically important antimicrobials sparked unease amongst participants. Greatest concern in terms of pig health lay with the potential restriction of the macrolides, followed by the fluoroquinolones and the least concern was reported over the third and fourth generation cephalosporins. A study examining the frequency of antimicrobial use in European pigs showed that 10.8 % of prescriptions were macrolides, 7.2 % were fluoroquinolones and 2.3 % were third and fourth generation cephalosporins (De Briyne et al., 2014).

Maximum residue limits (MRLs) for veterinary medicinal products are solely based on pharmacological data with no consideration of the potential influence on antimicrobial use (Anon, 2010b). The importance of choosing a product with a suitable withdrawal period was highlighted by interviewees and is an economic factor unique to the food animal sector. For example, the nil withhold period on in-feed tylosin formulations was described as a motivation towards its use in pigs near slaughter. As a key driver towards prescribing behaviours (Sheehan, 2013, Speksnijder et al., 2015b, Lubbers and Turnidge, 2014) the introduction of longer MRLs on tylosin may be beneficial in reducing prescribing in livestock near slaughter weight; this may be a potential intervention to drive more targeted and responsible use of the highest priority critically important antimicrobials. However, this perceived benefit would have to be judged against the background of possible health, welfare and productivity impacts that may occur.

Veterinary surgeons' ability to profit from the sale of antimicrobials has been highlighted as a potential conflict of interest (Anon, 2012g, Rollin, 2006). In reaction to this concern, the European Parliament has debated the possibility of 'decoupling' antimicrobial sales to eliminate the potential that profit may drive prescribing behaviours (Anon, 2012b). However, the impact of such policy in other European countries shows diverse results from countries hence the impact appears unclear and may be complex and influenced by other factors. A study examining pig farmer perceptions in Switzerland showed that there was a neutral opinion on such policy (Visschers et al., 2014), whilst study participants expressed widespread concern that such a move would have a negative impact on the financial stability of practices and on the health and welfare of patients; views shared by the UK and European veterinary professions (Anon, 2012g, 2013l).

Despite agreement that environment and good management were important influences on antimicrobial use, participants presented a wide range of views, with no consensual opinion, on which farming systems related to high or low quantity of antimicrobial used. Such diversity of opinion is shown in the literature when the interaction of farming systems, with the health and welfare of pigs, is deliberated (Guy et al., 2002, Scott et al., 2007, Lyons et al., 1995, Johnson et al., 2001, Stevens et al., 2007). One distinct viewpoint presented by some interviewees was that straw-based solid flooring was linked with greater quantity of *Salmonella species* than slatted systems. The literature does not support this proposal as a similar prevalence of *Salmonella species* has been reported in slaughter pigs raised in both slatted and straw-based systems (Berriman et al., 2013). Thus, further research is needed on the association between different housing, flooring and management systems on the incidence of disease, resistance and the use of antimicrobials to identify optimum housing and management to reduce and prevent clinical disease and thus reduce the clinical need for antimicrobials.

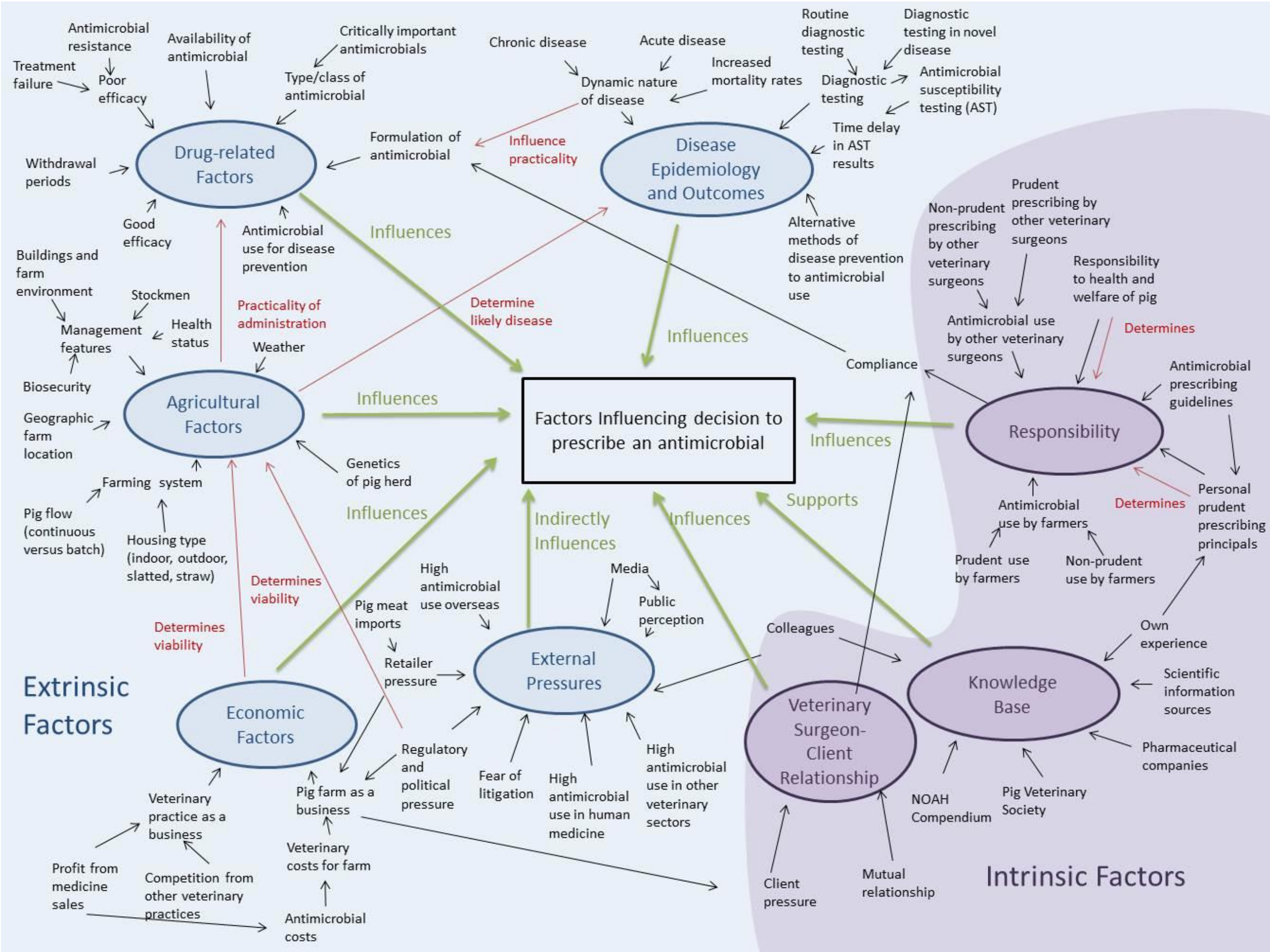
Participants identified that having highly skilled staff was essential in ensuring that a unit is well managed; a concept echoed in the literature (Coleman et al., 1998). In addition, interviewees identified vaccination as an highly desirable alternative to antimicrobial use for pig disease prophylaxis, as reflected in other studies (Anon, 2015d, Postma et al., 2015b, Visschers et al., 2016). Further evidence of the most efficient systems in terms of reducing antimicrobial use and resistance, whilst maintaining productivity and providing economic return, are not currently available.

Seeking alternatives to antimicrobial use in pigs using an integrated approach that considered the pig within its herd and environment was a concept defined by participants. Ensuring that pigs have an optimal farm environment with high quality hygiene, biosecurity and management practices has been associated with low antimicrobial use (Laanen et al., 2013, Stevens et al., 2007). In parallel with the literature veterinary surgeons identified that in some cases improved biosecurity, and environmental management have been considered as viable alternatives to prescribing by reducing the need for treatment (Postma et al., 2015b, Anon, 2015d). However, participants felt that the costs of such improvements may be considered prohibitive and reinvestments in farming systems are feasible due to the high costs involved; an opinion echoed in the literature (Speksnijder et al., 2015b, Alarcon et al., 2014, Postma et al., 2015b). In parallel, whilst the economic and health benefits of MRSA control programs in human hospitals are clear, human medicine faced similar financial hurdles in implementing effective disease prevention and control programs in tertiary care settings (Gould, 2006). A comprehensive cost-benefit analysis of improving management practices and facilities, and reducing antimicrobial use, in typical UK pig production systems may be beneficial in providing evidence for methods that will optimise the use of antimicrobials.

Conclusions and implications

This study offers in-depth insights into the complex influences behind antimicrobial prescribing decisions by UK pig veterinary surgeons. Veterinary surgeons were very aware of antimicrobial resistance and identified a social responsibility for prudent use. However, there was a failure to perceive it as relevant to their own situation. Antimicrobial resistance was not considered a major problem for the health of pigs in the UK, despite the identification of treatment failures and pathogens that were resistant to some classes of antimicrobials. This combined with other influences such as a strong responsibility to ensure animal health and welfare, pressure from clients to prescribe and a lack of alternative and economically viable strategies, such as management improvements or investment in new facilities, may all lead to inappropiate prescribing in some contexts. Interventions to optimise or reduce antimicrobial use on farms will need to consider these multiple factors if they are to be successful across the pig industry.

Figure 1 – Thematic map



Appendix 2

Appendix to chapter 3

Understanding the culture of antimicrobial prescribing in agriculture: a qualitative study of UK pig veterinary surgeons

Appendix 2: Appendix to chapter 3: Understanding the culture of antimicrobial prescribing in agriculture: a qualitative study of UK pig veterinary surgeons

Table 2.1 - Demographic data for participants

Demographic information	Category	n
Gender	Female	4
	Male	17
Company or Practice	Practice	19
	Company	2
Pig density of geographic location	High	11
	Moderate	7
	Low	1
	UK-wide[2]	2
Type of work	Farm only	2
	Mixed	9
	Pig only	10
	Assistant	6
Position in practice	Partner	13
	Consultant[1]	2
Years since graduation	0-5 years	3
	6-10 years	1
	11-15 years	0
	16-20 years	3
	21-25 years	3
	>26 years	11
Postgraduate study	DBR	1
	DipECPHM	1
	CertPM	3
Breeding sows under care of the veterinary surgeon	Less than 999	4
	1000-5000	8
	5001-10,000	3
	More than 10,001	2
	No information	4
Finishing pigs under the care of the veterinary surgeon[3]	Less than 50,000	8
	50,001-100,000	1
	100,001-200,000	1
	More than 200,001	2
	No information	9
Caseload - indoor/outdoor split	All indoor	9
	Majority indoor	6
	Majority outdoor	5
	No information	1

[1] - Consultant – Advisory role, does not prescribe drugs
[2] - Consultant works throughout the UK
[3] – If respondent stated the number of finishing pigs was progeny from breeding sows on a breeding to finishing farm an estimate of the number of finishing pigs was calculated based on the UK average of 25.8 pigs finished per breeding sows per year (Source - AHDB Pork)
**Cert PM – Certificate in Pig Medicine, DipECPHM - European Diploma from the European College of Porcine Health Management (ECPHM)*

Figure 2.1 – Veterinary Surgeon In-depth Interview Topic Guide

When arranging the interview on the phone the following information will be sought about the vet prior to the interview:
Amount of time spent working with pigs; number of breeding sows and fattening pigs under care; different types of systems under care – for example, indoor, outdoor, farm assured or not, organic; number of years working with the pig industry; position within practice e.g. partner or associate; year and place of graduation; professional memberships or membership of any committees.

'Thank you for agreeing to take part in the interview today. I am Lucy Coyne and am a PhD student at the University of Liverpool. The interview is part of a Defra funded project exploring the use of antibiotics and the issues surrounding antibiotic resistance. The project is seeking to gain real insight into the views and beliefs of vets and farmers involved in the UK pig industry.'

1. Views on the current debate over antibiotic use and antibiotic resistance
   What are your views on the issue of antibiotic resistance?
   Do you think that antibiotic use in pigs has an effect on human health?
   Where do you think the duty for the responsible use of antibiotics lies?

2. Drivers and motivators of antibiotic prescribing and dispensing decisions
   Describe the events and thought processes behind a decision to prescribe or dispense an antibiotic, and the choice of the type and formulation of antibiotic which.
   Consider:
   - ✓ *Protocols followed (practice, personal, pharmaceutical company)*
   - ✓ *Injectable, in-feed or in- water formulations*
   - ✓ *First line, second line choices, cephalosporins , fluoroquinolones*
   - ✓ *Farmer influence /pressure*
   - ✓ *Practice discussion*
   - ✓ *The decision to start, continue and withdraw*

   Who do you go to for advice and information on antibiotic choice?
   Which information sources do you trust?
   In some other European countries vets are no longer able to dispense antibiotics. What are your views on this? What effect would such regulations have on the UK?
   Do you think vets should do more to encourage a positive attitude towards responsible antibiotic usage, for example, through self-regulation of antibiotic use as a profession?
   Do you think your practice prescribes antibiotics responsibly?

3. The licensing and legislation of antibiotics
   What are your views on the licensing of antibiotics?
   What are your views on the legislation surrounding antibiotic use?
   What effect would the possible banning or restriction of fluoroquinolones and third and fourth generation cephalosporins have? What effect would adding macrolides to this list have?
   What are your views on the ban on advertising of antibiotics directly to farmers?

4. Husbandry practices and antibiotic use
   What effect do you think antibiotics have on the health and welfare of pigs?
   Do you think that there is variation in the antibiotic requirements of different husbandry practices or farming systems?

5. Antibiotic usage in the UK, EU and the rest of the world
   In your view, how does antibiotic usage in the UK pig industry compare with the EU and the rest of the world?

6. Limitations to reducing antibiotic use for both prophylaxis and treatment
   What is going to limit the ability to reduce antibiotic use in pigs?
   Is health status a significant factor and if so what are the limitations of improving health status?

7. The future of pig farming
   What does the future hold for pig farming?

Table 2.2 - Intrinsic and extrinsic factors identified as influencing antimicrobial prescribing behaviours through in-depth qualitative interviews with 21 veterinary surgeons working in pig practice in the UK.

Factors intrinsic to the prescribing veterinary surgeon	**Factors extrinsic to the prescribing veterinary surgeon**
Knowledge Base a) Colleagues b) NOAH Compendium c) Own experience d) Pharmaceutical companies e) Pig Veterinary Society f) Scientific information sources **Responsibility** a) Personal prudent prescribing principals b) Prudent prescribing by other veterinary surgeons c) Non-prudent prescribing by other veterinary surgeons d) Prudent antimicrobial use by farmers e) Non-prudent antimicrobial use by farmers f) Professional responsibility to health and welfare of pig g) Compliance **Veterinary Surgeon-Client Relationship** a) Mutual relationship b) Client pressure	**Agricultural Factors** a) Farming system - Pig flow (all-in-all-out, continuous) - Housing type (indoor, outdoor, slatted, straw) b) Management of unit c) Biosecurity d) Health status e) Farm environment f) Quality of stockmanship g) Geographic farm location h) Genetics of pig herd i) Weather **Disease Epidemiology and Outcomes** a) Dynamic nature of disease - Acute disease - Chronic disease b) Increased mortality rates c) Diagnostic testing - Routine diagnostic testing - Diagnostic testing in a novel disease situation d) National disease surveillance e) Alternative methods of disease prevention to antimicrobial use **Drug-related Factors** a) Availability of antimicrobial b) Good efficacy c) Poor efficacy - Antimicrobial resistance - Treatment failure d) Withdrawal periods e) Type/class of antimicrobial f) 'Critical' antimicrobials g) Formulation of antimicrobial h) Antimicrobial use for disease prevention **Economic Factors** a) Veterinary practice as a business b) Profit from medicine sales for veterinary practices c) Competition from neighbouring veterinary practices d) Pig farm as a business e) Veterinary costs for farm **External Pressures** a) Media pressure b) Public perception pressure c) Fear of litigation d) Regulatory and political pressure e) Retailer pressure f) Importation pressure g) High antimicrobial use abroad h) High antimicrobial use in other veterinary sectors i) High antimicrobial use in human medicine

Figure 2.2 – Reflections from veterinary surgeon qualitative interviews

Interview V001

1. Defensive stance that driving income from medicine sales does not affect prescribing behaviour.
2. Interviewee has a major concern over pressure from clients who expect antibiotics.
3. Business pressure as a Partner in a practice to keep clients who will seek an alternative vet if their demands are not met.
4. The veterinary profession needs to take a forward move in order to promote and encourage prudent use of antibiotics.

Interview V002

1. Very pro-active and forward thinking way of looking at veterinary medicine, focusing on prevention of disease rather than simply treating disease.
2. The role of the interviewee as a vet within a large company is reflected in the opinions expressed in the interview in that the interviewee does not sympathise with farmers struggling financially but simply states that they need to compete within the market to make a profit.
3. Optimistic opinion of the future of pig farming for the UK.
4. Exchange of ideas between vets in neighbouring practices is likely to be beneficial for disease control and the exchange of ideas between vets.

Interview V003

1. The interviewee believes that the major limitation to reducing antimicrobial usage in pigs in poor stockmanship and lack of training with issues such as poor compliance and an inability to recognise a problem.
2. Takes a very defensive position on behalf of farmers when it comes to criticism of farmers over using too many antibiotics.
3. A high level of awareness of the stigma and issues surrounding the use of antibiotics considered to be 'Critical antibiotics to human health'.
4. An unusual opinion on the usefulness of de-populating and re-stocking as the interviewee believes that it can make the situation worse as the re-stocked pigs are naive to pathogens and any future disease outbreaks are devastating.

Interview V004

1. The interviewee gives the sense that they have extensive experience in the pig industry as they are in a position whereby they can answer the questions quickly and concisely from experience.
2. In general the opinions given are very cynical particularly in relation to political decisions and organisations.

3. The interviewee has a very negative perception of antimicrobial use in human medicine and uses this to justify opinion on a number of occasions.
4. The interviewee acknowledges the use of antibiotics as a management tool on some farms and does not defend the farmers use of them.

Interview V005

1. Strong sense that the interviewee has a strong interest in the issue of antibiotic use in pigs.
2. Evidence is quoted by the interviewee to justify opinion. This evidence quoted appears to be from a narrow range of sources and selected as examples to support a very biased viewpoint.
3. There is a sense that the interviewee considers their opinion to represent that of veterinary surgeons in general.
4. The in-depth interview transcript resembles a narrative interview in sections whereby the role of the interviewer is much more minor and the interview is led by the interviewee.

Interview V006

1. The general opinion of the interviewee is that antibiotics are used responsibly by herself at an individual level, practice level and in terms of the UK pig industry.
2. General positive opinions on working as a pig vet in the UK. Does not consider many factors to be a hurdle.
3. Family background in pig farming does not appear to affect opinion as does not feel a need to defend farmers actions, she remains impartial.
4. Very proactive opinion towards management changes and vaccination protocols as disease prevention measures.

Interview V007

1. Use of the pronoun ‘we’ throughout appears to be used to represent both at different points in the interview the opinion of the veterinary practice and the opinion of the Pig Veterinary Society.
2. Interviewee considers his opinion to represent that of all of the vets at the practice.
3. Balanced opinion on the future sees the potential for optimism as well as pessimism.
4. Due to vested interest as PVS treasurer some of the opinions given may be biased?

Interview V008

1. Very cynical opinion that antibiotics are overused by pig farmers as they are cheap and readily available.
2. Very sceptical opinion that there is no incentive for farmers to reduce antibiotic use in pigs.

3. A strong opinion that pigs finished by companies commonly receive blanket medication across all farms at certain stages of production and units are not approached at an individual level.
4. Vets are under immense pressure from clients to prescribe antibiotics that the farmer perceives are required.

Interview V009

1. Sceptical opinion over whether antibiotics are used responsibly in the pig industry as considers it to be used as a management tool.
2. The concept that associates have no control over the running of the practice and no influence on it.
3. Issue of writing prescriptions on behalf of another vet, presumably working as a veterinary consultant, who only carries out quarterly visits.
4. Considers prophylactic medication to be the most common use of antibiotics in commercial pig herds.

Interview V010

1. As a veterinary consultant working for a number of practices with no dispensing rights the interviewee has a balanced opinion with few vested interests.
2. There is generally little concern from the interviewee over the system of licensing of antibiotics in the UK.
3. The interviewee seems to have a very broad spectrum view of the various management systems in the UK pig industry having working with various systems across the country.
4. The interviewee is very forward-thinking and is accepting of potential future legislation whether they directly agree with it or not.

Interview V011

1. Having only worked within the pig sector the interviewee does not draw on experience from other species in a veterinary context.
2. The lack of emotional attachment in prescribing decisions for livestock in comparison to domestic pets is a point recognised by the interviewee.
3. The interviewee is very aware of the competitive nature of veterinary practices and has concerns over the affect this may have on self promotion of the pig veterinary profession.
4. Detachment of the public from production systems has resulted in poor consumer knowledge and understanding of the production of British pork products.

Interview V013

1. A very cynical viewpoint that antibiotics in pigs are generally misused and overprescribed in the UK.
2. Common theme identified is the notion that antibiotics are used as a ‘prop’ for farms to compensate for a lack of improvements in management to reduce reliance on antibiotics.

3. As interview progresses interviewee contradicts earlier cynical opinions and actually states that antibiotic misuse has been more of a problem in the past and that now there are more responsible pig producers.
4. Interviewee has major concerns that other vets and neighbouring practices are not using antibiotics responsibly.

Interview V014

1. The interviewee's opinion is only based on working in one pig company in the UK and has never worked in mixed practice; consequently, they have limited experience of private practice or other species in the UK.
2. There is a lot of concern over antibiotic resistance and the potential impact that prescribing vets can have on this.
3. The interviewee considers resistance when prescribing antibiotics and is very aware of the importance of responsible use.
4. Although it was considered the interviewee does not ponder economics as strongly as some other participants. This may reflect their status within a company supplying to one retailer.

Interview V015

1. The interviewee's extensive experience of pig farming in the UK and Spain from the agricultural and veterinary perspective allows them to have balanced and sometimes critical opinions.
2. The interviewee considers that vets that have qualified more recently are more responsible with antibiotic use than older vets who qualified a greater number of years ago.
3. Cost of antibiotics and diagnostic tests is a consideration for vets in the diagnosis and treatment of disease.
4. A poor health status and the lack of eradication programs for disease is a likely hurdle in reducing antibiotic use in pigs in the UK when compared to elsewhere in Europe.

Interview V016

1. The interviewee holds the controversial opinion that antibiotic resistance is only a major threat to the elderly and those who are immunosuppressed, and is less of a concern in the general population.
2. There is a strong opinion that the use of antibiotics for disease prophylaxis is considered a responsible use of antibiotics in pigs.
3. The pig industry is likely to face more legislation and pressure from Politicians on antibiotic use from the EU in spite of what vets do.
4. Interviewee appears to hold the opinion that antibiotics are essential to pig production in the UK and that improving management would not alter use.

Interview V017

1. Interviewee appears to present very honest opinions and admits limitations in their knowledge and expertise.

2. Vets are under a lot of pressure from farmers not to discontinue the use of preventative in-feed antibiotics.
3. The interviewee holds the controversial opinion that antibiotics are still used for growth promotional purposes in pigs under the direction of vets.
4. The interviewee generally holds quite a cynical opinion that antibiotics are abused in the UK pig industry and has a pessimistic opinion of the future of the industry.

Interview V018

1. The interviewee has a defensive stance. They almost seem to present opinion as if they are arguing a viewpoint with an individual of a contrasting opinion.
2. The interviewee is constantly clarifying questions with the interviewer as if they are concerned that the questions are looking for a more complicated response.
3. The interviewee appears very certain in their opinion that their use of antibiotics is responsible.
4. The interviewee expressed a strong opinion that cost was a factor is antibiotic use but this was conflicting. They suggested both that high cost reduced use but also that using antibiotics for disease elimination cost less when compared to other methods not using antibiotics.

Interview V019

1. The interviewee draws on their extensive knowledge and experience of pig work when considering antibiotic use.
2. The interviewee appears to be very pro-active towards looking at disease prevention.
3. A trusting relationship between the farmer and vet is vital in effective herd health management.
4. The interviewee has a very natural demeanour that is neither defensive or submissive giving the interviewer the impression that the opinions given are very honest.

Interview V020

1. Due to the vet working within a company they gain no financial benefit from prescribing or dispensing antibiotics; as such profit from medicine sales does not influence their opinion.
2. The interviewee does not really consider the relationship between the vet and the farmer very extensively which perhaps reflects the structure of the company.
3. The interviewee has a negative opinion of outdoor production in terms of biosecurity and antibiotic use, yet outdoor production makes up the bulk of their work.
4. The interviewee has a negative opinion of UK retailers and has empathy for the pressure they place on farmers.

Interview V021

1. The competition between veterinary practices in the geographic region of the interviewee means that there is no discussion between practices on pig health and welfare in the region.
2. The interviewee has a very balanced view in terms of understanding the financial constraints of farmers but being aware that they may be using antibiotics prudently where management changes could be implemented.
3. Antibiotics are used as a management tool on some farms.
4. As the interviewee is the only vet in the practice who does pig work they may have a narrow viewpoint as they are not influenced by the opinions of colleagues.

Interview V022

1. The interviewee admits to facing pressure from clients and to sometimes being intimidating by them when trying to withdraw in-feed antibiotics.
2. The interviewee appears to lack confidence in their answers to some of the questions and often asks rhetorical questions.
3. The interviewee is very aware of what they consider to be responsible use and openly admit that they sometimes question whether the prescribing of other vets is prudent, both within their practice and at other practices.
4. Pressure from pig farmers wanting to use antibiotics is the biggest hurdle to reducing use across the UK.

Chapter 4

Factors related to antimicrobial use decisions by UK pig farmers: A qualitative study

Factors related to antimicrobial use decisions by UK pig farmers: A qualitative study

Introduction

Pig production systems commonly utilise antimicrobials for both disease treatment and prevention in the UK and across the European Union (Callens et al., 2012, Sjölund et al., 2015, Stevens et al., 2007, Schwarz et al., 2001). Due to concerns over the potential public health implications from the use of antimicrobials in livestock, there have been a number of initiatives that seek to ensure that antimicrobial use is prudent and justifiable (Andrews, 2009, Anon, 2014d, e). In the UK these have included species level guidance on responsible use in pigs aimed at both prescribing in veterinary surgeons and antimicrobial use by producers (Anon, 2013g, 2014d).

Antimicrobial resistance in production animals has not been shown to be a major concern of farmers in Europe or Canada with little unease expressed over potential public health consequences from their use (Moreno, 2014, Marvin et al., 2010, Visschers et al., 2016). Additionally, quantitative studies have identified that non-clinical factors relating to economics and legislation are more commonly perceived as pressures on the pig industry by pig farmers when compared with clinical factors relating to antimicrobial use and resistance (Visschers et al., 2015, Visschers et al., 2014). Studies from human medicine have shown that improving the knowledge of the general public on the association between indiscriminate prescribing and resistance, as the end-user of antimicrobials, positively influences patient and parental demand for antimicrobials (Eng et al., 2003, Belongia et al., 2003, Seppälä et al., 1997, Trepka et al., 2001).

In order to seek effective interventions to ensure that antimicrobial use in pigs is minimal and targeted it is essential to gain a comprehensive understanding of the behavioural influences behind antimicrobial use decisions by farmers and to assess what factors may act as a barrier to reducing use at a farm level. In order to gain detailed information on the drivers behind antimicrobial use decisions by UK pig farmers a qualitative approach was taken through the use of in-depth semi-structured interviews.

Methods

Data Collection

Qualitative in-depth semi-structured interviews were conducted face to face. An interview guide was developed based on a review of the literature, current issues surrounding antimicrobial use and results from focus groups conducted previously (Coyne et al., 2014). The interview guide was constructed based on Lofland and Lofland's guide to preparing a qualitative interview which seeks the answer to the question; 'just what about this is puzzling me?'(Lofland, 1995). Key questions were listed under the topic areas which could be used to prompt or guide discussion. Open questions were used to encourage farmers to express their views and recount their stories around antimicrobial use in pigs and included the following key areas:

- Views on the current debate over antibiotic use and antibiotic resistance
- Drivers and motivators behind administering antibiotics on farm or consulting with the vet over the requirement to use antibiotics
- The licensing and regulation of antibiotics
- Husbandry practices and antibiotics
- The limitations to reducing antibiotic use for both prevention and treatment
- How the UK pig industry and antibiotic usage within it compares with the EU and the rest of the world
- The future of pig farming

The interview guide is shown in Appendix 3, Figure 3.1. The interview guide was used to lead the direction of the discussion whilst allowing for free conversation with the participant so long as the dialogue was relevant to the subject matter. Therefore this allowed for flexibility in the interview but with scope to guide conversation back to the topic guide should the discussion move too far away from the research question. A reflective journal account of the interviews was written immediately following each interview and a summary of these notes are shown in Appendix 3, Figure 3.2.

Initially three interviews were conducted as pilots, with two of the team present, to test the key questions and ideas. Transcripts from these initial pilot interviews were reviewed in detail. The data collated from these and the nature of the interviews was considered to be of acceptable quality to include in the overall analysis.

All interviews were undertaken by the author (LC) with an additional author (SL) also present for a number of interviews. Interviews were conducted at a place and time convenient to the participant. Interviewees were given a participant information sheet that provided an overview of the project, prior to participation in an interview. Permission to record the interviews was sought over the telephone when recruiting participants as it was considered a vital component of the qualitative interview process in order to facilitate the subsequent data analysis. All participants signed a consent form prior to the interview (Appendix 1, Figure 1.1). Ethical approval for the interviews was gained from the University of Liverpool Veterinary Science Research Ethics Committee and Department for Environment, Food and Rural Affairs (Defra) survey control unit prior to commencing the study interviews.

Thematic Data Analysis

The qualitative analysis of the interviews was conducted using a thematic analysis methodology. This approach sought to identify, examine and record patterns, or 'themes', within the data. These themes described complex ideas and topics within the interviews which related to the underlying research question which sought to explore the behaviours and motivations behind antimicrobial use decisions, perceptions on the social context of antimicrobial use in pigs and awareness of antimicrobial resistance in the UK pig sector. The same methodological steps to the thematic analysis were taken as are described in chapter 3.

A second researcher (SL) analysed five interview transcripts independently. Themes and codes were examined in detail in relation to the coded data extracts and were discussed with the primary researcher (LC). In addition, SL re-read all of the transcribed interviews, and reviewed the generated codes and thematic maps; any revisions to the codes or themes were made in discussion with LC. The two authors conducting the data analysis concluded that data saturation was reached from the data set as no new descriptive codes or themes were identified within the data.

Participant Sample Population

The geographical scope of the study was to seek perceptions from farmers across England, Scotland and Wales. A review of the regional breakdown of the breeding herd revealed that 93 percent of this population was located in England, with 6 %

in Scotland and under 1 percent of the breeding sows located in Wales (2013). Thus, with a target of 20 qualitative interviews the study aimed to conduct 18 interviews within England and 2 in Scotland in order to gauge opinion across the study area. Due to the small number of commercial pig units in Wales, Wales was excluded from this qualitative study.

For England a list of 150 farmers was selected from the Defra June Survey of Agriculture and Horticulture, 2011 using a stratified random sampling methodology. The sample was selected based upon the type of farm here defined as: i) holdings with both female breeding sows and fattening pigs, ii) female breeding sows only and iii) fattening pigs only, and on the size of farm represented by the number of breeding sows or fattening pigs on the farm. The size of farm data were based on the size groupings provided in the Defra ‘Size band crop areas/livestock numbers/holding counts in England: 2005 - 2011’ data set) (Anon, 2013d). Any farms with less than 5 breeding sows or less than 50 fattening pigs were excluded from the data selection process. In England 50% of the farms had both female breeding sows and fattening pigs, 10% had breeding sows only and 40% had fattening pigs-only and consequently a sample population consisting of 75 (50%) with female breeding sows and fattening pigs, 60 (40%) fattening only holdings and 15 (10%) breeding sows only holdings was selected. For Scotland existing contacts within the pig industry were used in order to recruit farmers.

Within each farm type holdings were then randomly selected based on the number of breeding sows or fattening pigs. Sampling was proportional to the total number of pigs represented by that farm size group (such that large farms that represent the majority of pig numbers in UK were not underrepresented) (Table 1). For example, for fattening pigs the largest farm size (1000 pigs or over) represents 80% of all fattening pigs in the UK therefore 80% (48) of the fattening pig only farms selected were in this size band.

Approval was granted from the Defra Survey Control Unit and a confidentiality agreement was signed. To meet confidentiality laws, contact telephone numbers could not be supplied until farmers had the option to decline participation in the project. Consequently, a letter was sent to each farmer inviting them to opt out of having their telephone numbers shared with the study. This letter outlined the aims of the study, the voluntary nature and estimated interview duration. Farmers were allowed nineteen days to respond and opt out; a return address and email address were supplied in the letter.

Farmers were recruited from those which did not opt out using a purposive sampling approach which aimed to include a spectrum of farmers working within the UK pig industry and thus included participants from farms which bred and finished pigs, breeding-only farms, and fattening-only, indoor and outdoor units, and from independent and company farms.

Table 1 - Sampling frame for the interview study based on the relative percentage of holdings from each size category for holdings with female breeding and fattening pigs, fattening pigs only and breeding sows only.

Holdings with both female breeding sows and fattening pigs			
	The number of sows on farms		
Type of farm	**5-24 female pig breeding herd**	**25-99 female pig breeding herd**	**100 and over female pig breeding herd**
Holdings with both female breeding and fattening pigs	3	6	66
Holdings with fattening pigs only			
	The number of fattening pigs on the fattening only farms:		
Type of farm	**50-299 fattening pigs**	**300-999 fattening pigs**	**1000 and over fattening pigs**
Holdings with fattening pigs and no female breeding pigs	2	10	48
Holdings with breeding sows only			
	The number of sows on farms		
Type of farm	**5-24 female pig breeding herd**	**25 to 99 female pig breeding herd**	**100 and over female pig breeding herd**
Holdings with female breeding pigs and no fattening pigs	1	1	13

Results

Interview Participants

Of the 115 farmers contacted by mail 45 chose to opt out. Attempts were made to contact 97 of the remaining 105 farmers by telephone, however 32 were excluded as they were not able to be contacted on three separate occasions, seven participants could not be contacted as the telephone number was no longer active and 15 participants were omitted as they no longer kept pigs. Of the 43 participants that were invited to take part in the interviews 21 declined to be included in the study; reasons given included low staffing levels, a lack of time and harvest time. Therefore, 20 interviews were arranged within England using the database and a further two interviews were conducted in Scotland. Both of the farmers contacted in Scotland agreed to take part in the study. Hence a total of 22 qualitative interviews were completed.

Participants had a wide range of levels of experience and either worked as managers on independent and company farms or owned and managed their own independent units. There was a wide variation in the size of the pig units represented, from one individual being responsible for only nine breeding sows through to another participant being responsible for twenty two thousand sows (Table 2).

Table 2 - Demographic data for farmer interview participants

Demographic information	Category	N
Gender	Female	0
	Male	22
Independent or company farm	Independent	14
	Company	8
Pig density of geographic location	High	10
	Moderate	10
	Low	2
Farm type -farrow-to-finish, breeding only, finishing only	Farrow-to-finish	12
	Farrow-to-finish with multi-site production	3
	Breeding only	4
	Feeding only	3
Housing type	Outdoor	3
	Outdoor breeding, indoor straw feeding	5
	Indoor slatted	8
	Indoor straw	6
Herd status	Open herd	5
	Closed herd	17
Breeding sows on farm	No breeding sows	3
	1-99 breeding sows	3
	100-499 breeding sows	6
	500- 999 breeding sows	1
	More than 1000 breeding sows	9
Feeding pigs on farm	No feeding pigs	4
	Progeny from breeding sows	15
	1-499 feeding pigs	0
	500-999 feeding pigs	1
	1000-4999 feeding pigs	0
	More than 5000 feeding pigs	2
Assurance scheme membership	Red Tractor Farm Assurance	20
	RSPCA Assured	10
	QMS Assurance	1
	Soil Association	2

Eight major themes consisting of seventy six minor themes were identified which related to antimicrobial use behaviours. The major themes were classified as either intrinsic, which were directly linked to the farmer, or extrinsic which were external and beyond the influence of the farmer. Extrinsic themes were ‘Agricultural Factors’, ‘Disease Epidemiology and Outcomes’, ‘Drug-related Factors’, ‘External Pressures’ and ‘Economic Factors’, whilst ‘Responsibility’, ‘Veterinary surgeon-client Relationship’ and ‘Knowledge Base’ were categorised as intrinsic themes. A comprehensive list of themes can be found in Appendix 3 Table 3.1 and a thematic map is shown in Figure 1.

Extrinsic Themes

Agricultural Factors

Agricultural factors referred to all features relating to the farming system employed such as management practices, farm facilities and biosecurity measures. This theme was the most commonly discussed across the farmer interviews and was identified as being the most important factor which decided the total amount of antimicrobials required on a farm. Additionally, agricultural factors were found to be related and linked with all of the major themes defined from the interview transcripts. Farmers expressed very strong and diverse opinions as to how farming, management and housing systems related to the health and welfare of pigs and consequently, antimicrobial use. There was no agreement on what they would consider to be advantageous for the health of pigs; indoor or outdoor housing; slatted or straw-based pig accommodation. The majority noted that there were limitations and advantages to all production systems and that these contrasts were likely to result in a diverse range of disease conditions; with specific bacteria and viruses prevailing in some systems and being absent from others.
'I think every system's got its strengths and its weaknesses, and every system exposes or isolates an animal from certain bacteria or virus[es]...' (F004)

There was a tendency for farmers to express opinions on farming systems that they had experience of working in. One opinion, held predominantly by producers with experience of outdoor production, expressed that outdoor breeding herds were likely to have lower antimicrobial use when compared to herds housed indoors. These individuals often described the outdoor environment as a more natural system for the sow, which had a positive impact on their health and welfare. In contrast, a perception held solely by indoor producers expressed that sows and piglets on outdoor units may suffer negative health and welfare implications due to the extreme temperatures experienced.
'I would say outdoor breeding is certainly a very, very low user of antibiotics… outdoors is a very natural system. The animal takes care of itself...' (F018)

'… an outdoor pig, is not very happy in February. It's not covered by fur or feather. And it's not very happy in the summer when it's 80 degrees...' (F005)

'When you look at the weather we've had the last two winters, pigs have frozen to death outside in farrowing huts and drowned in farrowing huts.' (F006)

An association between farming systems and economics was identified by farmers. For example, whilst outdoor production was perceived as being beneficial in minimising antimicrobial requirements, farmers noted that the scope for outdoor production was limited as it was deemed less efficient when compared with indoor systems; in terms of pigs produced per sow. Farmers expressed the opinion that intensive agriculture was necessary in order to produce enough meat to satisfy consumer demand.

'I started off with outdoor pigs, and it works well, but you can't produce the number of pigs from an outdoor system as you can from a well-run indoor system.' (F022)

'The outdoor bred British pig isn't going to feed the world; in all honesty… it will be from intensive people.' (F007)

The housing of feeding pigs on slatted floor systems sparked two opposing views amongst interviewees. On one hand slats were considered to be advantageous for pig health as they separated the animal from faeces and urine. Conversely, the concept of the pig being in an environment above a slurry pit was not believed to be healthy for the pigs. In the following two examples participants used examples from human public health to justify their contrasting opinion.

'The Victorians were the ones who back in the 19th century separated the humans from muck, and brought sanitation, and that saw a huge reduction in disease… It's healthy for the pigs. It's more economical. One of the reasons it's more economical is the fact that we have to use less medicines, any in-feed/water, whatever.' (F001)

'The worst thing a pig does is get stuck in a confined area, with a fan environment, the standard way. They are sitting above a sewer. They sit on the slats above sewerage. Well yes, that's a very healthy way to live isn't it? Look at the trouble we had in London, in the early part of the century, with the Black Death and the plague and all the rest of it.' (F008)

The majority of participants identified that a low stocking density was associated with a minimal need for antimicrobials when compared with a farm with high

stocking densities. In addition, many farmers described that achieving and maintaining a high health status herd was associated with a low antimicrobial requirement and disease burden. However, additionally a minority had concerns that a high health status herd may be vulnerable to novel disease due to immunological naivety to new pathogens.
'If you want to reduce the drug usage in any livestock sector, reduce the stocking density, whether it is indoors or outdoors.' (F010)

'I think if you keep the health status up… it does cut your use of antibiotics markedly.' (F014)

'Health status… there is the potential… that everything is then that clean that you have had no pressure to a bug, and when something does come around, it knocks everything sideways.' (F020)

There was general agreement amongst farmers that the quality of the management of a system had more impact on the amount of antimicrobials required than the type of farming system employed. Improving management practices was considered to be pivotal in reducing the antimicrobial requirements on a farm. Subsequently, farmers identified a minority subset of farmers that used antimicrobials in some circumstances as a *'management tool'* to compensate for a lack of re-investment in buildings and facilities. In these situations respondents felt that there may be improvements in husbandry and management systems that could replace the requirement for long-term antimicrobial use, however, these changes are less economical than the use of medicated feed. This long-term or 'habitual' use of antimicrobials was commonly cited by participants as an example of irresponsible use, which was also coded for as a minor theme in the interview transcripts under the major theme of responsibility. A minority of farmers proposed that an outlying population of irresponsible farmers may in some cases use long-term in-feed antimicrobials for their beneficial effects on growth rates in pig herds.
'I think as management and the environment improves, the use of antibiotics will reduce.' (F016)

'Any system can be badly managed. Half of the people that keep animals shouldn't be allowed; they should have a license to keep 'bloody' animals. Sorry, I get very cross about it… Management is a huge thing with managing antibiotic use.' (F005)

'Because some farmers use antibiotics all the way through the finishers… It becomes a habit, I think, to use it. It becomes a crook… management-wise…' (F011)

'Antibiotics has become a prop for poor buildings and bad practice.' (F016)

'…a poorly managed farm, the chances are you will use more antibiotics than a well-managed farm. Of course there are always differences, you will get some guy who is very switched on, very well managed, and will use drugs as a growth promoter…' (F017)

The concept of animal welfare was discussed extensively by farmers but the definitions and interpretations were diverse. Positive welfare was most commonly defined as the absence of disease, with the presence of disease being a negative welfare concern. For the latter definition antimicrobials were described as the route through which this state of negative welfare could be corrected. Conversely, for some, welfare was a much more complex subject than simply considering the disease status of an animal; these individuals considered welfare to involve the physical and mental wellbeing of a pig. These farmers identified that whilst a pig may be in an optimal environment to grow and achieve the farmers' desired production parameters they may have poor welfare overall without mental stimulation. Such opinions were most commonly expressed by farmers familiar with outdoor production. However, the importance of mental stimulation to promote positive welfare was also identified by individuals experienced in indoor production.

'We believe health is very, very important, both for the production and for the health and welfare of the pigs.' (F001)

'…medication is required, we can't leave an animal to suffer, we do have to treat it where required.' (F008)

'I've seen pigs really, really happy - not mentally, but happy as in health wise - when they're indoors. They've got the perfect temperature, perfect amount of light, perfect food. Yes, they're bored out of their brains, and the welfare is awful, but they are happy in terms of their diet and their gut.' (F003)

'...the psychology of that sow. The one that performs and produces the 18 or 16 pigs is actually happy in that system, or happier than the one that produces 10...' (F002)

Having highly skilled staff was identified as being integral to a well-managed pig unit. Farmers described the ability of stock people at recognising disease problems early as an essential quality and exemplified good management practice. Some participants directly linked the quality of staff with antimicrobial use; poorly skilled staff were considered to be a limitation in reducing use on some units and employees who are disinterested and lack enthusiasm in their work may use antimicrobials as a short-term solution to a longer term problem. In contrast, farmers defined good stock people as those with an innate skill and an ability to detect any discomfort in the pig herd before it became a major problem. Participants identified the recruitment and retention of highly qualified staff as problematic; they identified that a lack of availability of highly motivated staff as a pressure on the pig industry.

'*So the sharper the stock man, the more effective you can deal with issues before it gets out of hand, and make decisions fast in terms of segregation or that sort of thing.'* (F013)

'Good stockmen are worth their weight in gold... If you're not interested and you're not bothered, what's easier than chucking a load of antibiotic food in? It makes it right for the short term, doesn't it?' (F006)

'...stockmanship, usually, you cannot teach. People are either good stockmen or they are not. It is having a stockman's eye... Stockmanship is crucial. It is very difficult to put your finger on it... But you can see it in somebody.' (F011)

'The biggest problem we have as an industry is finding good staff... everybody I talk to is struggling to find people, who want to actually spend time with animals, let alone, are happy to work seven days a week, you know. But that's what animals have to have, a seven day a week commitment.' (F008)

Alongside the discussion over staff skills many farmers expressed opinions on the ability of pig producers as business owners, and the role they play in the future of pig farming. There was shared opinion amongst farmers that individuals that have remained in the pig industry have done so through hard work and dedication; these individuals commonly identified that their own devotion to the pig industry was due to a genuine affection for pigs. Many participants independently introduced the concept of *'professional pig keepers'* who are highly skilled in managing herd health and run highly productive pig units. This linked closely with the major theme of responsibility whereby such keepers were considered to be responsible in their use of antimicrobials.

'I have been so totally involved… with the welfare and love of the animals, I thought somebody has got to be 'bloody' crackers to go through what we have been through. You actually have to love animals to do it, don't you?' (F005)

'You could say, within the shrinking pig industry, there's what I would describe as professional pig keepers and amateur pig keepers… there are fewer of those amateurs, and there are more professionals. The one thing that professional pig producers are very savvy at is managing health, because they realise that health is almost the number one criteria.' (F001)

Disease Epidemiology and Outcomes

Disease was considered by farmers to be a major influence on antimicrobial use behaviours; its unpredictability and dynamic nature were factors that were identified by many. A few participants described a concept that the disease burden on a farm is in a state of equilibrium, with the introduction of a novel disease, or changes in the environment, directing the balance in favour of increased disease levels; with the solution to this high disease burden being antimicrobial use. Interviewees identified that bacterial disease motivated antimicrobial use directly in the form of treating discrete primary bacterial pathogens, such as *Salmonella* and *E.coli species*, whilst viral disease was considered to result in a need for antimicrobial use due to secondary bacterial disease.

'It's a fine balance with a pig unit. You have got a disease load in there and it will be sat there balanced. But anything can tip it over the edge. It can be to do with environment; it can be to do with other diseases coming in or anything like that. Then you might just need a little bit of antibiotic input at times just to get you over a problem.' (F011)

'We do have Apralan (apramycin) in our creep ration against any scour problems. If there's an E.coli that we aren't vaccinating against, or even like a salmonella.' (F007)

'To me, we are trying to get away from antibiotics in pigs… It seems to me that you use a lot of antibiotics to treat secondary things.' (F016)

'…pneumonia in pigs, in young pigs, because we've got various viruses we're having to deal with as well… it's a question of diagnosing a pneumonia accurately… So generally we do a temperature check to identify that they've got a fever first before we'll go down the route of an antibiotic in a pig.' (F013)

Disease was categorised as either chronic or acute by farmers, with the use of antimicrobials contrasting in both circumstances. Chronic disease on a unit was not always considered to drive antimicrobial use directly. Some participants considered that underlying or endemic diseases were generally tolerated in a pig herd as long as other variables that may influence disease levels remained stable; such as avoiding introducing stock with an unknown health status. More specifically some participants proposed that endemic disease enabled pigs to build up a level of immunity. In contrast, acute disease situations were considered by farmers to directly drive antimicrobial treatment. In these circumstances participants described the short-term therapeutic use of antimicrobials to cure disease and with no longer term need for antimicrobials.

'…generally the diseases that we often have to navigate around is low level endemic PRRS on the unit, low level endemic enzootic pneumonia on the unit… we would normally keep that in check. Because this is a stable herd, i.e. the diseases are in there, animals are acclimatised accordingly when they come in, we wouldn't expect to have to put in a huge amount of antibiotics [in-feed].' (F009)

'As a policy, we would never have a blanket treatment in… Let's say you have got a respiratory problem in a finishing house, you don't want to keep putting it in all the time if you can get away with it because the animal is creating a degree of immunity to it…' (F010)

'We had one lot of abattoir returns where the CCIR information showed a lot more pneumonia-type lesions in the lungs… by the time we had got through to the following Monday, we were getting a lot of coughing in the unit as well… We blitzed everything for a matter of weeks, and then we took all the medication out of feed and water, and we haven't seen a problem. We got on top of it and cleared up the symptoms at the time. Then, those pigs have come through okay.' (F022)

Whilst, many farmers described this concept of chronic disease only requiring antimicrobials when an external factor affects the normal status quo on the unit and results in disease signs, the use of antimicrobials for disease prevention was commonly described by farmers. Such practices were considered to be a prudent use of antimicrobials if alternative methods of preventing disease were either not effective or viable. Farmers felt strongly that preventing disease through antimicrobial use is a more responsible behaviour than treating disease once clinical signs appear; this was used as a justification for the use of prophylactic antimicrobials. These individuals identified that antimicrobial use for disease prevention resulted in healthier pigs and a reduced requirement for antimicrobials for therapeutic reasons.

'…if we get a strep suis problem. The vaccine is quite difficult to use, it's not overly effective in my experience. So you are then relying on medication and constantly putting medication in throughout the growing period.' (F018)

'The breeding herds; we put a bit of in-feed medication through to get them over the initial hit; a couple of months… It tends to be an insurance policy. You know something's wrong. Bang it in to try and hold things at bay really. To make sure it doesn't get any worse.' (F012)

'The important thing is prevention rather than the cure, isn't it? What this boils down to is preventing. The healthier the pigs are, the less you have to use an antibiotic.' (F010)

'we're reasonably high health here so we don't use in-feed medication, apart from we do sows twice a year for eight days. We pulse them twice a year, spring and autumn on the advice of our vets, because it keeps any of the niggling problems down. Metritis and Lepto, if there is a bit of a problem with that, it will just keep it... down there… We don't have to treat the sows at any other time apart from odds and sods that we inject them with. So, generally, it works quite well.' (F006)

The decision whether or not to withdraw prophylactic antimicrobials was acknowledged by farmers as being problematic. Participants identified a fine balance between the economic cost of disease and the antimicrobial cost; with the decision to discontinue medication being a compromise between the two. Many also highlighted reluctance amongst some farmers to withdraw such antimicrobials. Farmers felt that the use of antimicrobials for disease prevention should be

reviewed on a regular basis; it was suggested that this should be reviewed quarterly and could coincide with Farm Assurance veterinary visits.
'…the cost of disease on any commercial unit… is huge. It comes down to what's your attitude in terms of risk and everything else? Sometimes the risk of breakdowns in health is such that… people are really, really reluctant to actually take it [in-feed antimicrobials] out.' (F009)

'Routinely on vet visits, on quarterly vet visits, one of the things we will look to do is those units that have medication, can we withdraw it? It's a quarterly discussion that we have.' (F001)

Diagnostic testing was considered by many farmers to influence antimicrobial use practices with a contrasting approach taken in chronic and acute disease situations. Farmers placed a higher importance on antimicrobial susceptibility testing in an acute disease outbreak to identify the specific pathogen responsible for disease. Test results were not identified as directly driving the initial antimicrobial use decisions but as a tool to confirm whether the correct antimicrobial has been prescribed, or whether an alternative may be required. Farmers described how antimicrobial courses were initiated prior to obtaining results as the time delay in obtaining results may result in greater morbidity in the affected herd. Routine diagnostic testing to monitor herd disease status was considered to be carried out less frequently; this most commonly involved testing for Enzootic pneumonia (EP) and Porcine Reproductive and Respiratory Syndrome (PRRS) at quarterly farm assurance visits. Farmers commonly cited the importance of the government veterinary laboratories in such diagnostics.
'…we had a unit which broke down with scour four or five weeks ago, on piglets. About a third of them had the scour… So we then take samples to the VLA (UK Government laboratory) and try to get that, to find out what is actually causing it, and then see what it is sensitive to.' (F019)

'I would always say to our production manager stick some CTC (Chlortetracycline) in now because… if you wait for the results to come from the lab, quite often you'll have ten times the problem if you hadn't done anything.' (F002)

'We do bloods every veterinary visit, so once a quarter… we blood test the ones prior to a PRRS vaccination… We will also look for EP. At the moment we are looking harder at flu, because there seems to be quite a bit of flu about.' (F018)

Vaccination was identified as an alternative and preferential method of disease prevention to antimicrobial use by farmers. Many valued the role of vaccinations against viral disease challenges in preventing the requirement for antimicrobials for secondary bacterial pathogens. Farmers identified two key advantages to vaccinations. Firstly, increased availability of vaccinations was correlated with a reduction in the use of antimicrobials on pig units and secondly, vaccinations were considered to be beneficial in improving pig production parameters. However, some participants also outlined that it was not feasible to use vaccinations to prevent some diseases due to the poor efficacy of available vaccinations. For example, the *Steptococcus suis* meningitis vaccination was considered to be ineffective and therefore it was not considered to be a viable option to prevent disease.

'…in a lot of ways we're able to control certain viruses with a vaccine. But if you're stopping a virus attack, you're also stopping a whole load of secondaries which are bacterial usually.'

'As far as looking at our own herd here is concerned, our antibiotic use has actually reduced enormously with the advent of no end of different vaccines.' (F004)

'I think vaccines, especially for pneumonia… When you think, they grow 10 days faster when you vaccinate them really. Although we never used to blanket-treat for it, it was obviously an underlying issue that was there. It never really got clinical in any way, but it was underlying. The vaccines have obviously improved health no end, really.' (F015)

'…we went along vaccinating sows and pigs for meningitis. The vaccine didn't work, but because it was a meningitis vaccine we were forced, and forced and forced to medicate with this bloody vaccine. In the end I got one batch, not vaccinated. When you actually looked at the cost, and the mortality, it was better not to vaccinate.' (F017)

Farmers considered the avoidance of mortality and morbidity as a significant motivation towards the use of antimicrobials. Discussion on high mortality rates sparked an emotive response from farmers and was commonly used as a justification for antimicrobial use. These concepts linked closely with the definitions and interpretation of negative welfare considered under the major theme of agricultural factors.

'…on day one, you have got think, "Right, I can't wait until all the pigs have died before I decide what I am going to use, I am going to have to do something." So… if they still scour, do we then go in with something like the basic scour drug that we have, which is Norodine (oxytetracycline)…' (F019)

'We can't leave an animal to suffer, we do have to treat it where required.' (F008)

Drug-related Factors

The efficacy and availability of antimicrobials affected farmers' antimicrobial use decisions. Participants seldom expressed a preference for particular types of antimicrobials as long as they were efficacious; antimicrobials belonging to the penicillin and tetracycline classes were the most commonly cited examples and were generally considered to be effective. Overall, the majority felt that the range of antimicrobials available was sufficient for their needs.

'I'm saying, the drug we use and rely on at the moment, Betamox; broad spectrum, penicillin-based antibiotic is still working and still effective.' (F012)

'We have always stuck to the simple… things which have been either Penicillin or Terramycin (tetracycline) based.' (F005)

'The problems that we see, the medications that we have at our disposal, generally speaking, work well and will control the problems.' (F018)

Antimicrobial resistance in both human and veterinary medicine was a shared concern amongst farmers. Resistance in human medicine was considered to be mainly as a result of indiscriminate use in humans and that any selection pressure from use in livestock was minimal. However, the majority of farmers acknowledged that even though this risk was small there was a potential for public health implications from antimicrobial use in pigs. Treatment failure where a first choice of antimicrobial has been ineffective was described by farmers as a relatively frequent occurrence and farmers usually associated this with antimicrobial resistance. Another opinion on antimicrobial resistance in pigs was that the practice of periodically changing the type of antimicrobial used on a farm reduced the chances of resistance developing.

‘‘The more we use antibiotics, the more opportunity [they] have to mutate and get round it. It's getting critical. It's getting bad in human health, but even in animals, there are so many drugs now that don't work.’ (F003)

‘My opinion, personally, is that if the doctors and the human health control was more under control, we would probably get less resistance.’ (F008)

‘You select these bacteria or whatever in the pig population, and then they come over to the human population with antibiotic resistance… It is the fact that using it in the pig selects the organism, which then goes on to infect the humans. With the focus on the livestock industry, whether it is deserved or not: I would say that focusing on the human side of things is probably more important.’ (F010)

‘You asked that question earlier about resistance. “Do you think you’ve seen any resistance?” Well, yes, I suppose there have been times where we’ve decided, “CTC is not working very well. What are the alternatives?”’ (F001)

‘…I am a great believer in withdrawing certain drugs. Not having them on a unit for four or five years, because when you bring them back, by God they work.’(F017)

Critically important antimicrobials as defined by the WHO are those that are considered to be of high importance in human medicine (Anon, 2012d). Farmers showed awareness of the concerns over their veterinary use and felt strongly that it was essential that their use was prudent. For the purposes of the interview discussions the WHO highest priority critically important antimicrobial classes (fluoroquinolones, third and fourth generation cephalosporins and macrolides) were used to define the critically important antimicrobials. Interviewee opinion was sought on the effect should a ban be placed on their use. In general, farmers considered that a ban on a certain class of critically important antimicrobials would not be an issue if alternative antimicrobials were available for use in these clinical situations; they considered that it was the responsibility of the veterinary surgeon to identify alternative antimicrobials. Farmers expressed a strong opinion that any such legislation to restrict or ban certain classes of antimicrobial should be founded on reliable scientific evidence.

'There are several medicines that are not necessarily banned on-farm, are they, but they're restricted use because of the effect that that has had on human medicine, from what I understand.' (F012)

'I can see that they will put restrictions on these classes because someone will wake up one day and say, "There is too close a link between the two."' (F021)

'Providing there are alternative strategies, there are other things that you can use, then it's not a problem. But, essentially those sort of decisions we would always refer to a vet rather than actually try and deal with ourselves.' (F009)

'I have not seen the evidence, so the first thing is that I would hate it to happen if there was not clear scientific evidence that it was the right thing to do. If evidence is there, then, I think generally, it would increase costs for the pig industry.' (F014)

When participants were asked to consider the effects of a ban on individual classes of antimicrobials there was generally the least concern over restrictions to the use of the third and fourth generation cephalosporins; it was seldom described as being used on farms. There was more concern over a potential ban on the use of the fluoroquinolones, whose use was commonly described in the treatment of scour in piglets; Farmers felt that it would result in high mortality rates. Greatest concern was felt over a ban on the veterinary use of the macrolides; in particular in-feed formulations of tylosin. Farmers described that tylosin was frequently used in pigs near slaughter weight due to its nil meat withdrawal period and interviewees were concerned that there may not be an alternative product with no meat withdrawal period. The withdrawal period on a product was a drug characteristic that all farmers identified as a consideration when choosing an antimicrobial.

'Well Baytril (enrofloxaxin) is particularly used for piglet scours, E. coli, that kind of thing. I've not met many farmers that have used Naxcel (ceftiofur)… Naxcel is occasionally used for strep series type infections but it doesn't seem to be very common.' (F013)

'…well if you look at the Marbocyls (marbofloxacin) and the Forcyls (marbofloxacin), I am not sure what else is out there, that would or could replace that. I think obviously, if that was removed, we would certainly have more

problems with – certainly an increase in mortality and more issues from controlling a scour type problem or a mastitis type problem.' (F018)

'Tylan (tylosin) is used quite widely by an awful lot of pig farmers…' (F015)

'The beauty of Tylan (tylosin) – correct me if I'm wrong – but I think there's no withdrawal… I think, in food, it's nil. So yes. Well, that does have a place within my thinking, certainly within the industry.' (F012)

'…some of the very long withdrawal periods are a problem for us and actually they can prevent the use of various things because they're so long.' (F013)

The ease of administration of antimicrobials was identified by farmers as a factor in antimicrobial use decisions. Injectable formulations were identified as being limited to individual animals whilst in-feed and in-water antimicrobials could be easily administered to large groups of animals. Farmers expressed a preference for in-water formulations in acute disease situations and in-feed for more chronic and endemic disease. In-water formulations were considered advantageous in ensuring that pigs receive the right quantity of antimicrobial at the correct time and were considered to be effective if pigs are inappetant; where in-feed formulations are not appropriate. In contrast, farmers showed a preference towards in-feed formulations in more chronic long-term disease situations. Farmers cited the ease of administration to large groups of pigs and the economics of it being the *'cheaper option'* as benefits of in-feed formulations over in-water. However, farmers identified that a limitation of in-feed can be the delay in obtaining the feed order and therefore the delay in initiating treatment when compared with in-water medication.

'…the injectables are for individual animals… But the in feed thing or the in water thing is much more of a batch thing or a herd thing…' (F004)

'I suppose in-feed – we'll have that in there for a certain length of time. But I suppose the water, it's more, if you've got a problem, you can get it in there as quickly as possible. That's certainly the best way of getting antibiotic into a pig. If they're ill they'll drink water still, whereas they won't be eating food.' (F007)

'I'd rather use water based antibiotics, if we're going to use any, than feed ones. For two reasons, number one, usually if you have a problem you want something

sorting there and then as a consequence, if you have feed in a bin then it may be three or four days before that food is used and the medication stuff comes through.' (F002)

External Pressures

The majority of farmers identified poor public perception of pig production as an external pressure; they felt that this was rooted in the public being misinformed on agricultural practice. These participants perceived that public opinion reflected that too many antimicrobials are used in pigs and that drugs are used in an indiscriminate manner. In contrast, some farmers described a more complex relationship between the general public and agriculture; they proposed a detachment between the reported beliefs and subsequent actions of the public. For example, whilst individuals may state that they support British pig production farmers felt that the role of economics in consumer decisions outweighed the moral decision to purchase British meat. Farmers commonly implicated non-governmental stakeholder groups and the media as motivating this poor public perception. Media pressure was identified as a major pressure on the pig industry; this was considered to be grounded in inaccurate and misinformed media reporting. For example, some farmers accused the media of reporting that antimicrobial growth promoters are used in pig production despite the 2006 EU ban on such use. *'I think the industry probably does get a bad name because people see farmers are using antibiotics… There's a lot of ignorance out there I think, but the farmer is the one who is the bottom of the stack and he can get kicked and trampled on, and very often that happens.'* (F004)

'Public disconnect - You do the supermarket surveys. "We want responsibly-sourced and wholesomely-produced." "Can we look at your shopping basket when you come out?" "Yes, fine." "Why have you got that?" "That is cheap."… "Do you know where they come from?"

"No. I don't care. It is cheap." That is the battle, and actually making people realise that food comes from fields and you don't just sit there on the train and the countryside is going by and there is nothing out there. It is doing stuff. It is our factory space.' (F020)

'I think our situation in agriculture is far better than what the public think. I think there's sometimes some scare stories, probably generated by certain lobby groups, that livestock species [are] full of antibiotics and growth-promoters. Well, we're not allowed to use any growth-promoters.' (F009)

'…in this day of a hysterical media, where they go, "Do you know that your pigmeat is laced with growth promoters because pig farmers can't [be] bothered to do x, y and z?"… it only takes one stupid reporter to say the wrong thing at the wrong time and the whole lot all just flares up and we are all left picking up the pieces.' (F021)

Farmers acknowledged that they felt pressure from legislation and politics; there was a perception that political decisions were made with little thought or support for the pig industry. One issue which was raised by a few farmers was concern over potential legislation that would restrict the use of in-feed antimicrobial prescriptions in pigs. Some participants felt that such political pressure had driven veterinary surgeons to be proactive in prescribing decisions and to discontinue the use of in-feed antimicrobials in pigs in anticipation of such policy; they expressed grave concern due to the increased mortality rates experienced.

'I think we as an industry do feel vulnerable to knee jerk government reactions… I'm not saying that there shouldn't be control over the use of antibiotics and the use of all sorts of things, I agree that any responsible government should act responsibly with anything like that. But I think there is a danger of uninformed pressure…' (F004)

'The common one is, "We are going to stop having in-feed medication in Europe." They have been talking about that for 12 years. We as a company, keep preparing ourselves for it and refusing to use in-feed medication, and it results in more death.' (F017)

Farmers commonly coupled the retailer pressure described previously with pressure from the importation of pig meat. They described that lower purchase costs for imported meats have resulted in supermarkets demanding UK products at competitive prices. The majority of farmers expressed concern that antimicrobial use in these importation countries was greater and poorly regulated in comparison to the UK. Countries commonly given as examples were the United States of America, Russia and China. In contrast, a minority of farmers identified that the

UK was under pressure from countries that were more responsible in their use of antimicrobials. For example, these farmers considered Denmark and the Netherlands to be responsible users of antimicrobials, and to have lower use when compared with the UK.

'Again, it comes down to our lovely friends in the supermarkets, doesn't it? They are the dictators of it all… It is all down to the supermarkets: what they can shift, and what they can import, because it is 2p a kilo cheaper from Denmark or wherever. We are very much at the mercy of them. It is all down to producing cheap food.' (F021)

'I think we have probably got one of the most regulated antibiotic usages in the industry, and probably in the world… The UK is not self-sufficient in food production, so we need to import. What the UK is doing is correct, without a shadow of a doubt, but you just wish that some of the other competitors from elsewhere in the EU, especially in Eastern Europe, or elsewhere in the world would be of the same standard.' (F021)

'China, Russia, I think there will be a high reliance on using medication....' (F009)

'I know from what I've been told that they've got a big use of antibiotics in America… You would probably think that what you perceive about the Dutch and the Danes that they're not heavy users of it…' (F006)

Antimicrobial use in human medicine was identified as a pressure by farmers. Many felt that agriculture came under an unfounded and disproportionate amount of pressure in relation to reducing antimicrobial use, when compared with human medicine. These participants proposed that antimicrobials were overprescribed in human medicine and that use was sometimes non-prudent. For example, physicians indiscriminately prescribing antimicrobials and bowing to patient demands for antimicrobials and patients not completing prescribed courses of antimicrobials.

'There's been MRSA detected in the UK since 1961, which is the year I was born, that I'm aware of and we still haven't got it in pigs. It's still in humans. Should we be saying we shouldn't be letting humans have antibiotics? In terms of why are we so hell bent on stopping animals when it's the humans themselves in some respects that are causing all their own problems?' (F002)

'That in human health, I'm aware that there are people that go to the GP and if they don't get a course of antibiotics they feel as if that doctor has not treated them properly. Despite the fact they've got a perfectly good immune system and their body was more than capable of actually fighting off what they'd got.' (F009)

'As far as I can gather from what they say, the biggest problem with antibiotics is people not taking the full course.' (F006)

Economic Factors

The high financial costs involved in pig production alongside the difficulty in making a living were identified by farmers as limiting the scope for improvements in accommodation and facilities which reduce the antimicrobial requirements on farms. Farmers expressed a desire to minimise the economic burden from disease. Interviewees associated the absence of disease with minimal requirements for antimicrobials and therefore reduced veterinary costs. This concept echoes the importance placed by farmers on management and housing under the theme of agricultural factors for minimising antimicrobial use.
'…you cannot run a pig farm profitably with high levels of endemic disease.' (F009)

'…accommodation is a key part of improving health, we then need to be able to be reinvesting in quality finishing accommodation. And you need a desire to be able to reinvest the money. So you need some profit to start with.' (F001)

'…you cannot run a pig farm profitably with high levels of endemic disease.' (F009)

'If you can stabilise health and you can manage that health, then, you certainly will be using a lot less reactive-type drugs if you can have good health plans, and have good vaccination programmes with preventative use of those drugs. Then, you should be using less and you should have a more profitable unit, without doubt.' (F022)

Farmers considered that the high cost of antimicrobials was a motivation towards ensuring that their use was minimal on farms. Many identified that high veterinary costs acted as an incentive to seek alternative therapeutic and prophylactic methods. For example, the introduction of a vaccination protocol to prevent disease and achieving and maintaining a high health status could minimise the costs of antimicrobials and offer farmers the potential for making more profit out of herds. Farmers' described that this desire to minimise the costs of antimicrobials was rooted in the substantial economic pressure on the pig industry to produce pigs at a low cost to the consumer. The majority identified this as a long-term pressure from retailers. Discussion over retailer pressure was emotional and sparked passionate opinions.

'At the end of the day we are really pressurising them [stock people] to reduce costs, so we don't want to use medication unless we have to. We would rather do the testing, we would rather use vaccines.' (F018)

'If you can stabilise health and you can manage that health, then, you certainly will be using a lot less reactive-type drugs if you can have good health plans, and have good vaccination programmes with preventative use of those drugs. Then, you should be using less and you should have a more profitable unit, without doubt.' (F022)

'…there are huge cost implications with antibiotics… So we're obviously all the while looking to see, "Do we need that in the feed, that antibiotic?" But then equally you look and say, "Well if we don't have it in there, what's the cost of that going to be?... at the end of the day, we're running a business here trying to produce meat for people to eat.' (F004)

'Continual supermarket pressure in terms of not paying the right price for the product. Also the feed costs have been ridiculous these last few years… the financial pressure on pig farmers has been extraordinary.' (F013)

The overall economics in pig production were the basis for the majority opinion on the potential future of the UK pig industry; many participants stated cautious opinions on the future stability of the industry. Whilst farmers considered that pig production had the potential to produce meat at sustainable costs compared with other livestock sectors they expressed concerns that the high production costs and low prices paid by retailers were hurdles to the profitability of businesses. Some participants depicted a cyclical economic landscape in pig production whereby the industry continued going through phases of both growth and decline. However, farmer opinion was divided between those optimistic and those pessimistic as to whether the future would be towards the financial rewards phase of the cycle. Most participants considered that the retailers and associated customer demands would dictate the future.

'We are back to the supermarket actually putting their money where their mouth is by continuing to source UK pigs, and because of our regulation, it costs more.' (F020)

'*I have a mildly optimistic view, mainly because I think the levels it's at the moment are, historically, as low as they've ever been since we developed a pig industry... We've never been self-sufficient pig meat. I just think the potential's there…Beef and sheep are going to be too expensive. Pig meat can still be produced economically, so I think it has brilliant potential. The rest of Europe eats twice as much as we do.'* (F012)

'The pig industry, in its cycle, is always moving from – I'd like to say boom to bust, but we don't have much boom, and it's generally bust.' (F001)

<u>Intrinsic Factors</u>

Responsibility

Farmers expressed confidence that they themselves were responsible in their antimicrobial use behaviours. Participants cited factors such as ensuring that antimicrobials were only used when necessary and an awareness of the issue of antimicrobial resistance to exemplify this prudent use. Whilst participants believed that they, as individuals, were responsible users of antimicrobials, many felt that other farmers may be less responsible in their use. Some participants proposed that in some cases the use of in-feed antimicrobials may not be targeted or justifiable; a few highlighted ethical and moral issues surrounding such practices by farmers. One example given by some farmers was of swine dysentery which sparked great concern due to the high economic losses should the disease be introduced on to a farm. These individuals proposed that some irresponsible farmers did not approach the disease as a threat to the health of the whole UK pig herd and only considered the impact of the disease on their own individual farm. Thus, these irresponsible farmers did not consider the risk of disease spread to neighbouring pig units and the potential for the disease to spread far within a region. Another example of irresponsible behaviours cited by a few participants was that antimicrobials are still used, on occasion, for their beneficial effects on growth rates.

'…we only use antibiotics in the herd where we need to use them. We're very well aware of the advantages of the antibiotics, but also the dangers and the drawbacks….There's always an issue obviously about the resistance… but we're all the while striving to bring down to the minimum that we can survive with…' (F004)

'I know that every time that we will use any medicines at all, it will be on a needs must basis.' (F001)

'Our biggest concern is some of our customer herds where they're in areas where there is swine dysentery circulating, particularly if the swine dysentery is in a pool where you have a hobby or smallholder farmer who the economic impact for him having it is not particularly huge. Therefore there's not much incentive for him to actually tie it up.' (F010)

'Dysentery really is a real nasty that we wanted to get rid of. We developed the dysentery charter, things like that, so that at least there was a little bit of communication between producers… Now, there are one or two pig businesses up here who… The standard thing then is, "Well, let's not bother testing about that looseness. Let's just put some Denagard (Chlortetracycline) in."… Now, they won't know then whether they've got any dysentery or not, because that will mask it… Now, that's where I think the producer should have more responsibility, more ethics.' (F001)

'…a poorly managed farm, the chances are you will use more antibiotics than a well managed farm. Of course there are always differences, you will get some guy who is very switched on, very well managed, and will use drugs as a growth promoter…' (F017)

The majority of participants reported having confidence that their respective veterinary surgeon was responsible in their prescribing practice. Farmers reflected that it was the professional responsibility of a veterinary surgeon to ensure that antimicrobial use was prudent and justified. Moreover, most farmers placed a considerable responsibility for the prudent use of antimicrobials on the veterinary surgeon as the prescriber. In contrast, a few farmers proposed that a minority of veterinary surgeons may be irresponsible in some of their prescribing practices. Some participants implicated the willingness of some veterinary surgeons to prescribe antimicrobials on a long-term and continual basis as a non-justified and irresponsible behaviour, which may be used to compensate for bad management practices. This was linked with economic factors by a few farmers who considered the ability of veterinary surgeons to profit from the sale of antimicrobial products may influence the decisions of some to prescribe antimicrobials. Farmers were asked to consider what the effects of 'decoupling' prescribing and dispensing, so that veterinary surgeons are no longer able to sell antimicrobials, would have on prescribing. Whilst the majority felt that this would have little effect on overall antimicrobial use, as they were confident that their veterinary surgeons were prudent in their antimicrobial use decisions, a minority felt that this may reduce use in irresponsible veterinary surgeons who may be driven to prescribe by the ability to profit from antimicrobial sales.

'…my perception of the vets is generally that they're pretty careful, pretty responsible and actually see the thing from all sides.' (F004)

'…the veterinary surgeon would have the overall say on what we use and what he prescribes, so he is ultimately responsible.' (F018)

'I could see why in the market, there could be an incentive for them to over-prescribe because there was a profit incentive. I would like to think that the vets are responsible enough not to do that, but I could see why, potentially, it could be an issue, and I could see why some countries have split the different services.' (F014)

Veterinary surgeon-Client Relationship

Interviewees explored the interactions between farmers and their respective veterinary surgeon and described a dynamic and sometimes contrasting relationship. The most commonly described relationship between the veterinary surgeon and the farmer was of a positive nature and of a mutual '*partnership'.* Within this mutual relationship farmers proposed that there was a shared goal to ensure that antimicrobial use was responsible. This theme echoed the confidence shown by farmers in theirs and their respective veterinary surgeons' prudent use of antimicrobials and a mutual desire to ensure that use was minimal and targeted. In this mutual partnership farmers identified that they had a role in informing and

guiding the veterinary surgeon on the current herd health and disease issues in order to give the veterinary surgeon confidence in their prescribing decisions.
'I just think it's important to have a good vet on farm as well who you can get on with. I think a lot of the vets I've come in contact with are real sensible people… it's a partnership…' (F006)

'We operate a policy with our vets in which they are very much part of the management team... We remunerate them on the basis that we want healthy animals, which don't require high medicine input.' (F001)

'…you are reliant on your veterinary advice a lot of the time, but the vets have got to make a decision based on something, and the more information that you can give them, then, it gives them far more power to be able to make a confident decision on whether you should use an antibiotic…' (F022)

Farmers also described a different relationship whereby they are reliant on their veterinary surgeon as a prescriber. In this scenario there was an element of necessity in having a positive relationship with their veterinary surgeon as the only route by which they could obtain antimicrobials. In contrast to this mutual relationship and reliance on the veterinary surgeon a few farmers identified that a minority of farmers may place pressure on veterinary surgeons to prescribe antimicrobials; these participants considered this behaviour to exemplify irresponsible antimicrobial use by some farmers.
'we don't do anything, can't do anything without the vet anyway…I think the thing about the vet is you can speak your opinion... you can bounce a thing around and you can look for a way forward…' (F004)

'The vets have to be involved [in prescribing decisions], because I don't prescribe. I have never been a vet, I didn't want to be a vet. My job is to point out problems to the vets. Now they cover that, they make decisions on whatever medication we use.' (F008)

'Pig farmers then have to avoid putting undue pressure back to the vet… you hear stories of undue pressure brought to bear on vets and very few of them are in a position where they'd say, "Well if you're not prepared to take my advice, you can look elsewhere."' (F012)

Knowledge Base

Farmers cited that they consulted their respective veterinary surgeon more commonly than any other sources of information on antimicrobials. The majority considered that their veterinary surgeon would be the most trusted source of information on antimicrobials and most valued their experience. Additionally, some participants valued their own experience in pig production and considered this to be a credible information source on antimicrobial use and disease control. Other information sources considered less commonly by some participants included the internet, scientific literature, the farming press and advice from colleagues.

'…if you wanted advice about antibiotics or whatever, you would go to the vet.' (F016)

'The vet would always be the… the ultimate source… who you trust and who knows what's what… The vet would always be the first call.' (F016)

'There is a local bunch of pig farmers within a 30-mile radius that meet quite regularly. You might chat and get ideas, but you would always go back through the vet. The vet would always be … the ultimate source… who you trust…' (F016)

'I will come up with my own opinions, through using different antibiotics on 70,000 different animals.' (F017)

Discussion

A spectrum of agricultural factors were deemed important in influencing antimicrobial use decisions however, in parallel with the literature there was no consensual opinion amongst farmers as to which housing systems, indoors or outdoors, straw or slatted flooring, were beneficial in minimising antimicrobial use and maximising health in pigs (Etterlin et al., 2014, Guy et al., 2002, Scott et al., 2006, Stevens et al., 2007). However, there was some level of agreement on breeding systems with a significant proportion of participants reflecting that outdoor breeding systems necessitated lower antimicrobial requirements than indoor systems. This concept was mirrored in a study by Stevens and others (2007) where UK farmers reported significantly lower overall antimicrobial costs in outdoor breeding systems than their colleagues who bred pigs indoors.

The importance of outdoor production in the UK, with approximately 40 % of the breeding herd outdoors, is unique globally as elsewhere in the developed world indoor housing of the breeding herd is the dominant system with outdoor extensive systems being a niche for specialised markets (Honeyman, 2005, Anon, 2015g). The farmer perception that outdoor breeding systems were low antimicrobial users was coupled with concern that outdoor production systems were not a sustainable option to meet global demand for pork; a concern shared and demonstrated by agricultural economists (Tilman et al., 2002, Rask and Rask, 2011, Thornton, 2010) and shown by the worldwide trend towards indoor intensive systems (Honeyman, 2005). Further research to quantify antimicrobial use for different housing systems and management practices commonly employed in the UK would offer guidance on optimal farming systems and methods of minimising antimicrobial use on farms.

The quality of the management of a pig unit was considered to be essential in minimising the antimicrobial requirements of a unit with farmers describing the importance of an optimal environment for pigs (Anon, 2015d, Fertner et al., 2015, Stevens et al., 2007, Laanen et al., 2013). Many identified that a lack of economic certainty had resulted in the inability of many farmers to reinvest in the housing and management improvements needed to reduce their reliance on antimicrobials. Such conflicts are recognised in other studies with Stevens and others (2007) reporting that farmers who felt that their farm environment could be improved used more in-feed antimicrobials compared to those that did not perceive that improvements were necessary, whilst Alarcon and others (2014) highlighted that farmers recognised a need to balance the high cost of disease with augmenting production costs..

Farmers cited the unpredictable and downward price trends from retailers as being responsible for the economic instability they described. This pressure from retailers has been acknowledged as a concern for farmers and veterinary surgeons in the pig sector (Sheehan, 2013, Alarcon et al., 2014). However in contrast to pressure, retailers have been identified as being actors in promoting minimal and responsible antimicrobial use behaviours in pig producers (Anon, 2015d). Long-term, sustainable and economically stable relationships between retailers and farmers may allow farmers to make necessary investments in improving management and housing in order to reduce antimicrobial use. For example, offering economic rewards for low use may incentivise farmers to engage in seeking alternatives to antimicrobials and to optimise use.

Highly skilled stockpeople were perceived by farmers to be an essential component of a well-managed pig unit and enabled early disease recognition and prompt antimicrobial treatment. Similarly, farmers in a study by Fertner and others reported that highly skilled staff were better able to identify disease signs early, however, the study reported that veterinary surgeons did not necessarily correlate this with low antimicrobial use. This study also highlighted the importance of spending sufficient hours observing the pigs in order to recognise any issues in a herd (Fertner et al., 2015). In other studies the presence of highly-skilled stock people, who show empathy for pigs under their care, has been correlated with positive health, welfare and productivity parameters in pigs (Jaaskelainen et al., 2014, Hemsworth et al., 1994, Coleman et al., 1998).

The prophylactic use of antimicrobials at group level has been identified as a common behaviour in European pig production (Chauvin et al., 2002, Timmerman et al., 2006, Stevens et al., 2007, Speksnijder et al., 2015b), in spite of a move by the European Parliament to seek to ban the practice (Anon, 2011a). In light of recent pressure there has been a move to evaluate alternative methods of preventing disease to antimicrobial use (Postma et al., 2015b, Anon, 2015d, Postma et al., 2015a, Visschers et al., 2015); a concept described and favoured by participants. However, in-line with the opinion of veterinary surgeons (Speksnijder et al., 2015b) and farmers (Stevens et al., 2007, Callens et al., 2012) in the literature, interviewees felt that the use of antimicrobials for disease prophylaxis was justified and prudent in some circumstances. However, some farmers expressed concern that a minority of irresponsible pig producers may use antimicrobials as a long-term ‘management tool’ in place of husbandry improvements. Similarly, other studies have identified that such habitual use behaviours are a factor in prophylactic antimicrobial use by some pig farmers (Visschers et al., 2014, Buller et al., 2015).

A few farmers took an extreme view and described a minority subset of irresponsible veterinary surgeons and farmers who utilise antimicrobials for their beneficial effects on growth; in spite of a ban on such practices (Soulsby, 2007). The literature supports this proposal with Buller and others identifying that the use of antimicrobials to improve productivity levels is still a common practice in the UK (Buller et al., 2015), and Moreno and others showed that the majority of Spanish pig producers felt that antimicrobials would improve their farm performance parameters (Moreno, 2014).

It has been proposed that the ability to profit from the sale of antimicrobials may act to incentivise overprescribing in veterinary surgeons (Anon, 2001, Rollin, 2006). Whilst the majority of farmers felt that this would not motivate prescribing by most veterinary surgeons a few felt that there may be a minority of irresponsible veterinary surgeons in which the ability to profit from antimicrobials may drive antimicrobial use behaviours. Similarly in agreement with the majority, Visschers and others found that farmers perceived that ‘decoupling’ would have little importance in reducing antimicrobial use in pigs (Visschers et al., 2014).

The decision over whether to continue or withdraw prophylactic medication was described as being problematic by farmers due to the unpredictable nature of disease and the potential negative economic consequences; a common concern amongst pig veterinary surgeons and farmers (Buller et al., 2015, Anon, 2015b, Sheehan, 2013). The importance farmers placed on the cost-effectiveness of these decisions is also shown in a study by Alarcon and others that showed that in disease control decisions economic considerations were key drivers in the decision making process (Alarcon et al., 2014). Interviewees felt that it was most appropriate to review the use of prophylactic antimicrobials at quarterly farm assurance visits in accordance with the current recommendations by the PVS (Anon, 2015b). Garforth and others acknowledged the importance that farmers place on these visits in assessing health issues and any alternations to health plans (Garforth et al., 2013).

Farmers recognised that the dynamic and unpredictable nature of disease motivated antimicrobial use and described a phenomenon where viral disease often necessitated antimicrobial treatment for secondary bacterial pathogens. This multi-factorial nature of disease, and the relationship between viral pathogens and secondary bacterial challenge, is frequently recognised as a feature of pig disease syndromes (Alarcon et al., 2014, Wills et al., 2000, McEwen and Fedorka-Cray, 2002). Alarcon and others found that farmers identified the impact of pig disease to consist of the observation of sick pigs, reduced production parameters and increased mortality rates (Alarcon et al., 2014); such conclusions were mirrored in discussion through the study interviews. The emphasis that participants placed on morbidity and mortality rates has been shown to be a major concern of farmers in pig and other livestock sectors (Alarcon et al., 2014, Fertner et al., 2015, Buller et al., 2015, Visschers et al., 2015).

The importance farmers placed on vaccination as an alternative to antimicrobials for disease prevention has been demonstrated by others (Postma et al., 2015b, Sjölund and Wallgren, 2010, Anon, 2015d, Bak and Rathkjen, 2009, Buller et al., 2015). However, farmers expressed concerns over the efficacy of certain vaccinations; with the inefficacy of *Streptococcus suis* vaccination a common concern. Research into the application of the commercial *streptococcus suis* vaccinations in pigs shows that whilst mortality is reduced the overall efficacy against disease morbidity can be poor; the existence of numerous serotypes and poor cross-protection of current vaccinations are cited as potential reasons for the poor vaccination response observed (Torremorell and Trego, 1997, Goyette-Desjardins et al., 2014, Smith et al., 2001).

Increasing public pressure on the food animal sector, with regards to antimicrobial use, is widely recognised by farmers and veterinary surgeons (Derks et al., 2012, Speksnijder et al., 2015b, Morris et al., 2016). Interviewees identified such pressure and commonly implicated misleading and exaggerated media coverage as the likely source of such public opinion (Morris et al., 2016). Farmers also perceived that there was pressure from human medicine who implicated the overuse of antimicrobials in livestock in antimicrobial resistance in humans (McCullough et al., 2015). Predominant opinion across the interviews reflected that resistance in human medicine was mainly due to indiscriminate prescribing by physicians; a perception echoed in the literature (Morley et al., 2005). Whilst many farmers acknowledged the potential for public health implications from the use of antimicrobials in pigs this was considered to be a sporadic event with minimal negative effects for human medicine. Other studies show that pig producers identify moderate to low public health effects from the use of antimicrobials in pigs (Moreno, 2014, Visschers et al., 2015, Visschers et al., 2016, Visschers et al., 2014).

Previous studies have shown that pig farmers have little knowledge of the threat of antimicrobial resistance in production animals (Visschers et al., 2014, Visschers et al., 2015, Visschers et al., 2016, Moreno, 2014, Marvin et al., 2010). In contrast, pig farmers in this study showed awareness of the issue of antimicrobial resistance and many associated incidents of treatment failures with potential resistance issues. In parallel, other studies report that farmers perceive that treatment failures are a growing issue in livestock (Moreno, 2014, Green et al., 2010, Buller et al., 2015). A few farmers discussed the notion that rotating antimicrobials may slow or prevent the development of this resistance. Such a strategy has been proposed in human medicine to tackle resistance (Erwin and Dilip, 2005) however, there are few studies that provide credible evidence of its worth for controlling the development of bacterial resistance (Brown and Nathwani, 2005, Bergstrom et al., 2004, van Loon et al., 2005, Chang-Ro et al., 2013, Erwin and Dilip, 2005). This practice was once widely recommended for anthelmintics in livestock in an attempt to minimise the development of resistance, however resistance to multiple anthelmintics has developed (Leathwick et al., 2015).

Farmers reflected that diagnostic testing was a frequent behaviour in novel and acute disease outbreaks however routine testing was reported as being rarely carried out; similar concepts have been described by veterinary surgeons (Sheehan, 2013, De Briyne et al., 2013). The time delay in obtaining results from antimicrobial susceptibility testing was a concern amongst farmers with potential negative welfare implications should antimicrobial treatment be withheld until after diagnostic results. This was also a concern of farm animal veterinary surgeons in other sectors (De Briyne et al., 2013, Sheehan, 2013, Speksnijder et al., 2015b). The value that participants placed on the Animal and Plant Health Agency (APHA) (Formerly the Animal Health and Veterinary Laboratories Agency (AHVLA)) as a resource for diagnostics is echoed in work by Alarcon and others that identified a positive perception by pig farmers of the services offered by government laboratories (Alarcon et al., 2014). The availability of rapid, efficient and economically viable diagnostic testing has been identified as an essential component in minimising antimicrobial use on pig units (Anon, 2015d). Therefore, improved availability of cost-effective, and practically feasible diagnostic tests, would allow farmers to acquire a detailed knowledge of the current disease situation on their farm and seek sustainable ways to improve health, manage disease, and to minimise the requirement for antimicrobials.

Antimicrobial use in pigs is most commonly in the form of an injectable formulation in individual animals whilst in-water and in-feed administration is usually reserved for use in groups of animals (Stevens et al., 2007, Rajic et al., 2006). Farmers cited similar usage preferences due to the ease of administering antimicrobials through feed or water for large numbers of animals. The higher cost involved in administering in-water formulations compared with in-feed was considered by farmers to drive the preference for in-feed formulations for chronic disease conditions and prophylaxis. These drivers may account for the commonality of the use of in-feed antimicrobials on pig units (Stevens et al., 2007, Chauvin et al., 2002, Rajic et al., 2006).

Farmer opinion on the potential effects of a ban on the use of the critically important antimicrobials expressed that concern was greatest over the macrolides, followed by the fluoroquinolones and the least concern was associated with the third and fourth generation cephalosporins. A study on the frequency of use of antimicrobial classes in European pigs showed a parallel hierarchy of use; with 10.8 % of prescriptions for macrolides, 7.2 % for fluoroquinolones and 2.3 % for third and fourth generation cephalosporins (De Briyne et al., 2014). Farmers described the zero meat withdrawal period on the in-feed macrolide tylosin as an incentive for choosing this antimicrobial for pigs near slaughter weight. Such behaviours are shown in other studies due to the high reliance placed on macrolides to control enteric and respiratory disease (Pyörälä et al., 2014, De Briyne et al., 2014). Similarly, it has been described as an influence on antimicrobial prescribing behaviours in veterinary surgeons (Speksnijder et al., 2015b, Sheehan, 2013, Lubbers and Turnidge, 2014, Gibbons et al., 2013).

Overwhelmingly farmers considered that veterinary surgeons were the most credible source of information on antimicrobials. This confidence that farmers have in veterinary surgeons for advice on antimicrobials and disease control is mirrored in previous research (Ruegg, 2006, Friedman et al., 2007, Alarcon et al., 2014, Garforth et al., 2013, Buller et al., 2015, Visschers et al., 2015). The literature shows the reliance that farmers place on their veterinary surgeon for advice and guidance on feasible alternatives to antimicrobial use (Visschers et al., 2015, Visschers et al., 2014). Similarly interviewees felt that it would be their veterinary surgeons’ responsibility to find alternative methods of treating or preventing disease should certain antimicrobial classes become unavailable or their use be restricted.

Farmers perceived a positive mutual relationship with their veterinary surgeon in which decisions are made jointly. A similar model is defined in human medicine whereby the importance of maintaining a positive doctor-patient relationship has been shown to influence antimicrobial use (Kumar, 2003, Butler, 1998, Coenen, 2013). Similarly, Alarcon and others defined a relationship between the pig farmer and veterinary surgeon that was based on trust (Alarcon et al., 2014). However, interview participants described a certain need to build and maintain a positive relationship with their veterinary surgeon due to their reliance on them as the only source for antimicrobial prescriptions; a concept also described in the literature (Visschers et al., 2014).

Farmers firmly placed the responsibility for the prudent use of antimicrobials with their veterinary surgeon. This is in-line with other studies into pig and cattle farmers’ perceptions (Stevens et al., 2007, Friedman et al., 2007). Farmers showed personal confidence that their own antimicrobial use decisions were responsible and were guided by their veterinary surgeon. However, it has been reported that a veterinary surgeons’ desired prescribing behaviour may conflict with their actual prescribing practice. For example, veterinary surgeons report an aspiration to limit their use of group treatments (Speksnijder et al., 2015b), however this desired behaviour may be limited as the injection of individual animals may be not feasible and thus, the need to maximise farmer compliance is a driver for group treatments (Sheehan, 2013, Gibbons et al., 2013). Thus, there may be examples where there is miscommunication between farmers and veterinary surgeons on what defines responsible antimicrobial use behaviours and there is potential for improved communication, definition and guidance on prudent practices. Second to their veterinary surgeon many interview participants valued their own experience and the knowledge of farming colleagues on antimicrobials. Similarly, the value pig farmers placed on their own experience and information from colleagues has been shown to influence biosecurity (Garforth et al., 2013) and disease control decisions in UK pig farmers (Alarcon et al., 2014).

The qualitative approach used in this study allowed the researcher to gain a detailed understanding of perceptions on antimicrobial use in pigs and to answer questions which could not be explored in as much depth using quantitative methodologies. The use of the semi-structured interview was advantageous due to its flexible nature and the way in which it allowed the researcher to explore new subject areas generated by the participant and therefore produced rich and detailed data (Al-Busaidi, 2008). In addition, the qualitative interviews elicited individual views and descriptions which uncovered concerns and perceptions that were not foreseen by the researcher (Pope, 2007, Al-Busaidi, 2008). For example, the concept that antimicrobials may be used by some individuals for their beneficial effects on growth was generated from the interviews and was not a pre-determined question on the interview topic guide. The interview setting allowed for a degree of trust and rapport to build between the informant and the interviewer; the creation of a safe and comfortable environment allowed interviewees to share their personal attitudes and experiences (DiCicco-Bloom and Crabtree, 2006).

The position of the primary researcher as a veterinary surgeon with experience of farm animal practice resulted in the interviewer and interviewee being from a similar social and cultural environment and therefore may have allowed the interviewee to discuss and converse on the subject of antimicrobial use openly. This may minimise the hierarchy between the interviewer and informant which can otherwise result in bias in qualitative interviews; in which the participant may offer opinions which they perceive to be socially correct rather than reporting actual beliefs (DiCicco-Bloom and Crabtree, 2006 Coar and Sim, 2006). For example, there may be limitations in self-reported behaviours in which participants may respond to questions and discussion in a way or manner which they perceive that the authors expect them to rather than reporting actual practices (Bowling, 2005).

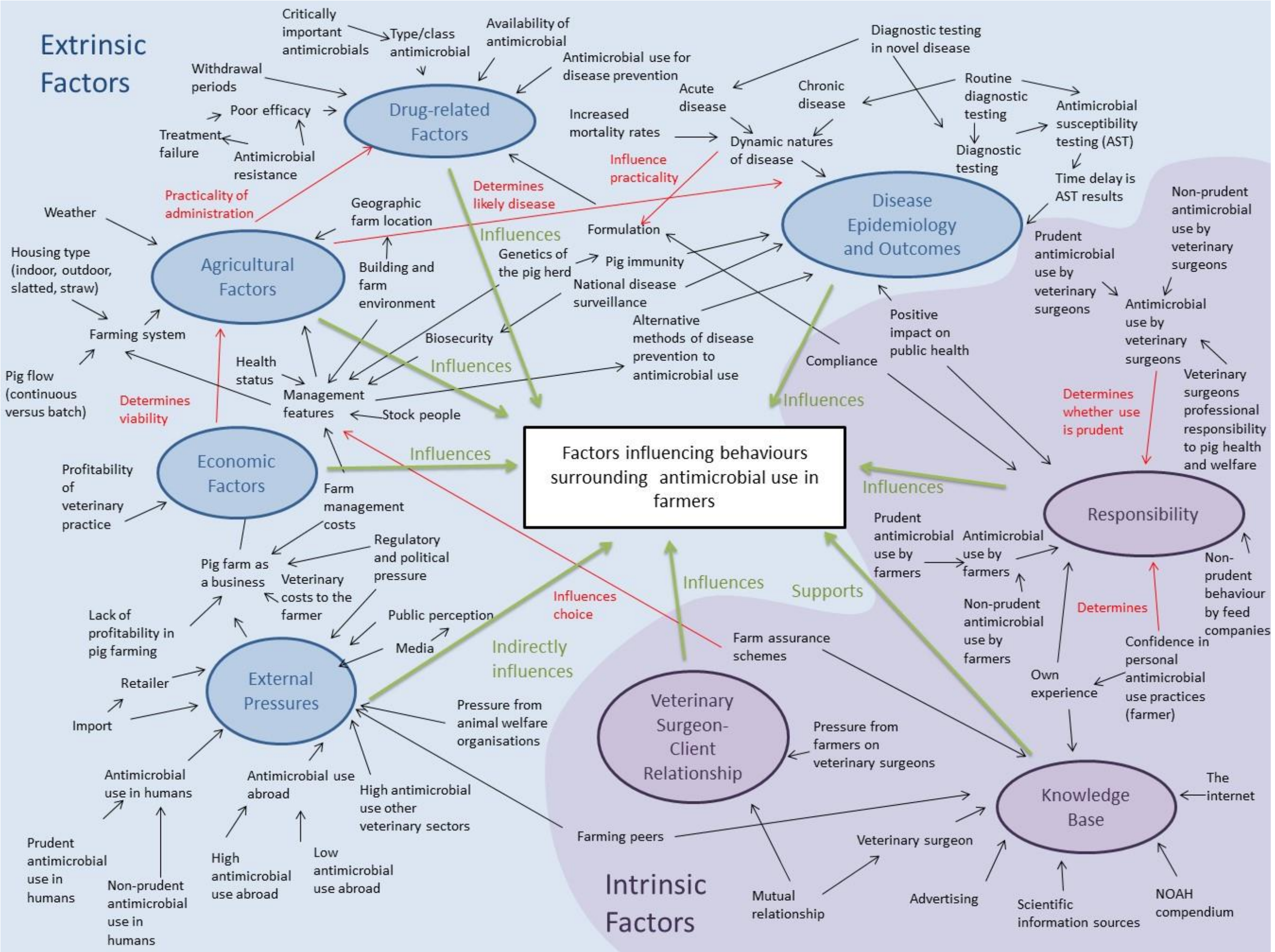
Poor public perception and misleading media publications on the subject of antimicrobial use in livestock have placed increasing pressure on the food producing animal sector; such pressure may result in a reluctance to share opinions by some (McCullough et al., 2015, Speksnijder et al., 2015b). A further limitation is that there is a potential for bias in the respondent population as farmers that agreed to be interviewed may be those that have a personal interest in antimicrobial use and, as such, their overall use may be lower compared to the UK pig industry as a whole. Thus, the views and opinions described in this study may exclude the majority opinion of UK pig farmers. However, the very open and honest discussion on antimicrobial use decisions which included describing behaviours which have been criticised through the media, such as the use of antimicrobials for disease prevention, suggests that the study presents accurate perceptions and behaviours (McNair et al., 2008).

Data saturation was reached whereby no new themes or ideas were coded for within the interview transcripts. Thus, it was not considered to be necessary to conduct any additional interviews as it would be unlikely to provide any further insight into perceptions on antimicrobial use in pig farmers (Guest, 2006). The purposive selection of participants from across different farming systems in the UK pig industry provided different and diverse opinions from across the UK pig sector (Mays and Pope, 1995, Bryman, 2012). However, it should be noted that whilst the contrasting opinions found in the study may be unique to the participant group, data may inform a more generalised theory to explain the behaviours and influences behind antimicrobial use decisions by pigs farmers in the UK (Bryman, 2012, Christley and Perkins, 2010).

Conclusion

This study offers detailed insights into the complex drivers behind antimicrobial use decisions by UK pig farmers. The relationship between the farmer and the veterinary surgeon was a key factor with farmers' relying on veterinary surgeons both as a supplier of antimicrobials, but also as the most trusted source of information on their use. There was an overall perception that farmers' identified that both themselves and their respective veterinary surgeons were responsible in their antimicrobial use. However, there were diverse opinions over the definition of responsible use and whether practices and behaviours were considered to conform to a defined meaning of the term. Farmers identified that low profitability and unstable contracts with retailers resulted in farms with limited scope to reinvest in buildings and management systems and considered these factors to be barriers to reducing antimicrobial use. A focus on educative initiatives for farmers to define what antimicrobial use practices exemplify responsible use and improved communication between farmers and veterinary surgeons may ensure that there is a common interest and shared goal to ensure that use on farms is optimal and only when necessary. Additionally, providing economically sustainable contracts may incentivise farmers to reinvest in the management and facility improvements required to minimise antimicrobial use.

Figure 1 – Thematic map of farmer perceptions on antimicrobial use in pigs



Appendix 3

Appendix to chapter 4

Factors related to antimicrobial use decisions by UK pig farmers: A qualitative study

<u>Appendix 3 – Appendix to chapter 4</u>
<u>Factors related to antimicrobial use decisions by UK pig farmers: A qualitative study</u>

Figure 3.1 – Interview topic guide

<u>Farmer In-depth Interview Topic Guide</u>

'Thank you for agreeing to take part in the interview today. I am Lucy Coyne and am a PhD student at the University of Liverpool. The interview is part of a Defra funded project exploring the use of antibiotics and the issues surrounding antibiotic resistance. The project is seeking to gain real insight into the views and beliefs of vets and farmers involved in the UK pig industry.'

When arranging the interview on the phone the following information will be sought about the farmer prior to the interview:
Size of pig herd – number of sows/pigs, farrow to finisher herd, breeding-only, finisher, independent farm or company farm, indoor or outdoor herd, type of housing if indoors eg. slatted, straw-based or part-slatted, animal flow eg. all-in-all out or continuous flow, feed type, closed herd or open herd, de-populated or re-stocked recently, number of years in the pig industry, where the farm supplies, if a member of British Farm Assurance or any other schemes eg RSPCA freedom foods.

1. Views on the current debate over antibiotic use and antibiotic resistance

What are your views on the current issue of antibiotic resistance?
Do you think that antibiotic use in pigs has an effect on human health?
Where do you think the duty for the responsible use of antibiotics lies?

2. Drivers and motivators behind administering antibiotics on farm or consulting with vet over the requirement to use antibiotics

Describe the events and thought processes behind a decision to use an antibiotic or to consult a vet about the requirement for an antibiotic, and the choice of the type and formulation of antibiotic which.

Consider:
- ✓ *Any protocol on antibiotic usages for the farm*
- ✓ *Injectable, in-feed or in- water formulations*
- ✓ *First line, second line choices, cephalosporins , fluoroquinolones*
- ✓ *Common conditions encountered*
- ✓ *Decision to start, continue and withdraw*

Who do you go to for advice and information on antibiotic choice?
Which information sources would you trust? (Consider the vet and other information sources)
In some other European countries vets are no longer able to dispense antibiotics. What are your views on this? What effect would such regulations have on your farm and the UK pig industry?
Do you think that your farm uses antibiotics responsibly?
Do you think that the pig industry in general uses antibiotics responsibly?

3. The licensing and regulation of antibiotics

What are your views on the licensed antibiotics for pigs?
What do you think about the regulations surrounding antibiotics?
What effect would the possible banning or restriction of fluoroquinolones (eg. Baytil Marbocyl) and third and fourth generation cephalosporins (Excenel, Naxcel) have?
What effect would adding macrolides (Tylan, Pulmotil) to this list have?

What are your views on the ban on advertising of antibiotics directly to farmers?

4. Husbandry practices and antibiotics
Do you think that there is variation in the antibiotic requirements of different husbandry practices?
How important do you consider good stockman and staff training to be on the management of your farm?

5. The limitations to reducing antibiotic use for both prevention and treatment
What is going to limit the ability to reduce antibiotic use in pigs?

6. How the UK pig industry and antibiotic usage within it compares with the EU and the rest of the world
How does the antibiotic usage in the UK pig industry sit within the EU and the rest of the world?

7. The future of pig farming
What does the future hold for pig farming?

Figure 3.2 – Reflections from farmer qualitative interviews

Interview F001

1. The interviewee presents the pig company as if they are advertising it and gives examples where their farm is superior to other pig farms.
2. The interviewee is very aware of the discussion over the use of 'critical antibiotics' in veterinary medicine and is conscious of potential bans or restrictions.
3. Being located in an area of high pig density is disadvantageous in terms of controlling disease and maintaining a high biosecurity on units.
4. The interviewee appears to have an extensive knowledge and experience of the intensive indoor pig industry in both the UK and abroad.

Interview F002

1. The interviewee appears to be very reactive to the economic demands on pig production and proactive in solving those and maintaining a profitable business.
2. The interviewee approaches the interview as if they are trying to sell the benefits of their pig company to the interviewer.
3. A vets' ability to dispense antibiotics directly to farmers and to profit from sales drives their frequent use.
4. The interviewee is very aware of public perception and is very open with about the company and admits areas of weakness.

Interview F003

1. The interviewee shows a high level of awareness of the issue of antimicrobial resistance and the possibility for the zoonotic transfer of resistance pathogens from animals to humans.
2. Antimicrobial use in humans is more responsible than in veterinary medicine as culture and sensitivity testing is carried out much more commonly.
3. The interviewee considers that future regulation on antimicrobial use in pigs must come from the Government as the industry has too much vested interest to regulate use.
4. The interviewee considers that antimicrobial use across the UK pig industry is fairly irresponsible but their experience of commercial intensive pig production is not current and was in the 1990s.

Interview F004

1. The interviewee considers that decisions on antibiotic use on farm are as a result of discussion with the vet and highly regards this to be a mutual relationship.
2. The interviewee is very knowledgeable about their farm but admits to not having sufficient knowledge on other systems to make comparisons.
3. The interviewee strongly believes that a lot of Government policy is poorly thought through as it comes from Politicians with little experience of the pig industry.
4. To be successful in the pig industry one has to be reactive and proactive to pressures such as legislation.

Interview F005

1. The interviewee strongly believed in ensuring that antibiotic use on the farm was as low as possible and only used antibiotics for treatment of disease and not for prevention.
2. The interviewee was very forward-thinking when establishing the unit in the 1970s to require minimal antibiotic use.
3. The interviewee strongly believes that other pig farms in the UK use more antibiotics than are necessary.
4. The interviewee has unusual opinion that high health herds are not that advantageous for the pig as exposure to pathogens results in better long-term immunity and lower impact from disease.

Interview F006

1. The interviewee admits to only having experience of their own pig unit and does not consider themselves to have sufficient knowledge to comment on other units.
2. The high cost of antibiotics is likely to deter farmers from overusing them.
3. The interviewee considers that it is the professional responsibility of the vet to ensure that farmers are using the minimum amount of antibiotics required on farms.
4. The interviewee has very balanced opinions and does not place blame or criticise others.

Interview F007

1. The interviewee does not seem very decisive in answers and requires prompts from the interviewer in order to elaborate and explain opinions.
2. The interviewee is very aware of the limitations of outdoor pig farming in terms of the difficulty in maintaining biosecurity.
3. The interviewee does not seem to be very well informed on the concept of ‘antimicrobials critical to human health’.
4. The difficulty in maintaining biosecurity on outdoor pig units is a major concern of the interviewee.

Interview F008

1. The interviewee has extensive experience of indoor and outdoor rearing systems yet has a strong opinion that outdoor systems are lower antibiotic users.
2. The interviewee appears to be very knowledgeable and aware of the importance of responsible use of antibiotics in pigs.
3. Having a healthy herd is the single most important factor in ensuring that antibiotic use is low on a farm.
4. The interviewee gives the impression of being a very good manager and having the ability to ensure there is conformity in pig management across farms within the company.

Interview F009

1. Due to the interviewee working for a company that has both a breeding herd and a commercial herd they have experience from both the breeding company and commercial pig production angle.
2. The interviewee is very proactive about alternative methods of disease prevention to antibiotic use.
3. The way in which the interviewee's company benchmarks antibiotic use between farms is unique and forward-thinking should such systems be introduced in the UK.
4. The interviewee is very open and honest in the way in which they are happy to discuss all aspects of antibiotic use within the company.

Interview F011

1. The interviewee feels strongly that a well-managed farm should not be reliant on high quantities of antibiotics.
2. The interviewee is very open to admit limitations in their knowledge such as the issue of the zoonotic transfer of bacteria between animals and humans.
3. Farmers and vets should be striving to look at alternative ways of preventing and managing disease than using prophylactic and therapeutic antibiotics.
4. The interviewee presents a strong economic argument as to why it is financially sensible from a farmer's point of view to use antibiotics responsibly on pig units.

Interview F012

1. The interviewee already has knowledge of the concerns over the use of the 'critical antibiotics'.
2. Good management is the key to reducing a farm's reliance on antibiotics.
3. The interviewee considers the difficulty in finding and retaining good stockman to be a major concern for the UK pig industry.
4. The interviewee appears to be very honest and their extensive knowledge of the importance of prudent antimicrobial use suggests that their usage is very responsible.

Interview F013

1. Although the interviewee is an organic producer they have perceptions of other pig rearing systems and can reflect on other systems in a manner that is only slightly biased.
2. Organic pig production uses fewer antibiotics when compared with non-organic pig production.
3. The interviewee considers the prophylactic use of antibiotics in pigs to be an example of irresponsible use.
4. The interviewee has a good understanding of the science behind the zoonotic transfer of bacteria and antibiotic resistance mechanisms.

Interview F014

1. The interviewee makes a distinction between responsible use and the amount of antibiotics used on farms; even if use is high they consider it responsible so long as

the correct antibiotic, at the correct dose rate and for the correct length of course is used.
2. The interviewee considers that any legislation restricting antibiotics would be justifiable if there was sufficient scientific evidence to support the legislation.
3. The interviewee acknowledges the difficultly in making a decision to withdraw prophylactic in-feed antibiotics.
4. The management of a farm is more significant in the amount of antibiotics used on farm that the particular farming system.

Interview F015

1. The interviewee is very aware of the importance of responsible use and they consider the fact that the unit does not use any prophylactic antibiotics as an example of this.
2. The interviewee strongly considers that improving the management of any unit, even with very old buildings, can reduce the requirement for antibiotics.
3. The habitual behaviours of farmers that have been passed on from senior to junior staff, such a routine in-feed antimicrobial use, can be difficult to alter.
4. The interviewee acknowledges that antimicrobial use across the UK pig industry may not always be responsible.

Interview F016

1. The interviewee appears to suggest that they consider the routine in-feed antimicrobial use to be irresponsible but then they contradict themselves by admitting that they used some prophylactic in-feed antimicrobials in the pig herd.
2. The interviewee's farm appears to have excellent productivity and to use proactive management and computer recording systems in order to achieve this.
3. Good management and facilities are vital in maintaining good health and welfare in the pig herd in order to reduce antimicrobial reliance.
4. The interviewee considers that the UK Government does not take a long-term view of legislation surrounding food animal production as the Government in power only considers the impact of political decisions as far as the next election.

Interview F017

1. The interviewee places great emphasis on the importance of correctly dosing in-water antimicrobials and on completing the course of treatment; they feel that some farmers and vets may not be responsible in this.
2. Good stockmanship is essential in early recognition of disease.
3. There are farmers that are using in-feed antimicrobials on prescription, not for disease prophylaxis, but for growth promotional reasons.
4. In-feed antimicrobial formulations may be under threat of being restricted across the EU but the interviewee feels strongly that this use is justifiable if done responsibly.

Interview F018

1. The interviewee feels that the profit from the sale of medicines is a conflict of interest and that vets may be irresponsible in prescribing practices due to this profit margin.
2. The health of the finisher pig is used to identify problems in the breeding herd.
3. The interviewee considers outdoor breeding systems to require less antimicrobials than indoor breeding systems; this may reflect that the majority of their breeding experience is on outdoor units.
4. Increasing investment in the development of new and improved vaccinations is the key to reducing antimicrobial usage in the UK pig industry.

Interview F019

1. The interviewee considers larger pig companies are better able to maintain a high health status in their pigs over independent farms due to more stable finances.
2. Streptococcus suis is a major threat to the UK pig industry and is responsible for a lot of in-feed prophylactic antimicrobial use.
3. The interviewee considers that the routine testing of gilts in pig herds within the company for disease surveillance is responsible for the small amount of antimicrobials used within the company.
4. The interviewee appears to be very knowledgeable of pigs within the company system but does not seem to have much experience outside of outdoor sow breeding units.

Interview F020

1. The interviewee appears to be very relaxed and open about answering questions and appears to give honest and truthful answers.
2. Prophylactic and therapeutic antimicrobial use is responsible in that it prevents the negative impact of disease.
3. The interviewee is very business driven and the cost and potential profit margin is weighed up before making decisions on management or antimicrobial changes for the farm.
4. The interviewee is very cynical of the general public and considers that, whilst they have good intentions to support UK producers, they are too far removed from farming to follow these intentions through.

Interview F021

1. The interviewee is concerned that there have been cuts in funding for research into antibiotic alternatives in livestock and that further research needs to be done for the long-term future of agriculture.
2. The availability of in-feed antimicrobial formulations is essential for the welfare of pigs.
3. The interviewee contradicts themselves in that they cite their vet as the only credible source of information on antibiotics but then state that they consider adverts to be essential in educating farmers on the range of antibiotics available.
4. The interviewee appears to have a fairly realistic viewpoint of the pig industry in terms of the narrow profit margins and low prices paid by retailers for pig meat.

Interview F022

1. The interviewee acknowledges that a link has been made between antimicrobial use in pigs and resistance in human medicine and shows awareness of this in their answers to questions over responsible use in pigs.
2. Management methods to reduce the use of antimicrobials on a farm must be on an individual farm basis as what works on one farm may not on a different farm.
3. The interviewee considers farmers reluctance to withdraw in-feed antimicrobials when used long term to be a major hurdle to reducing antimicrobial use in pigs across the UK.
4. The interviewee is very knowledgeable on the subject of responsible use and is confident that their use of antimicrobials is prudent

Table 3.1 - Major and minor themes identified in farmer interviews

Factors intrinsic to the farmer	**Factors extrinsic to the farmer**
Knowledge Base g) Veterinary surgeon h) Farming peers i) NOAH Compendium j) Own experience k) The internet l) Scientific information sources m) Advertising n) Farming assurance schemes **Responsibility** a) Prudent antimicrobial use by farmers b) Non-prudent antimicrobial use by farmers c) Prudent antimicrobial use by veterinary surgeons d) Non-prudent antimicrobial use by veterinary surgeons e) Professional responsibility of veterinary surgeon to pig health and welfare f) Confidence in personal antimicrobial use practices (farmers) g) Non-prudent behaviour by feed companies h) Compliance **Veterinary Surgeon-Client Relationship** c) Mutual relationship d) Client pressure	**Agricultural Factors** j) Farming system - Pig flow (all-in-all-out, continuous) - Housing type (indoor, outdoor, slatted, straw) k) Management features - Biosecurity - Health status - Buildings and farm environment - Stock people - Genetics of pig herd l) Geographic farm location m) Weather **Disease Epidemiology and Outcomes** f) Dynamic nature of disease - Acute disease - Chronic disease - Increased mortality rates g) Diagnostic testing - Routine diagnostic testing - Diagnostic testing in a novel disease situation - Antimicrobial susceptibility testing (AST) - Time delay in AST results h) National disease surveillance i) Alternative methods of disease prevention to antimicrobial use j) Pig immunity k) Safeguarding public health **Drug-related Factors** i) Availability of antimicrobial j) Good efficacy k) Poor efficacy - Antimicrobial resistance - Treatment failure l) Withdrawal periods m) Type/class of antimicrobial n) Critically important antimicrobials o) Formulation of antimicrobial p) Antimicrobial use for disease prevention **Economic Factors** f) Profitability of veterinary practices g) Veterinary costs for the farmer h) Farm management costs i) The lack of profitability in pig farming **External Pressures** j) Media pressure k) Public perception pressure l) Regulatory and political pressure m) Retailer pressure n) Importation pressure o) Pressure from animal welfare organisations p) High antimicrobial use abroad q) Low antimicrobial use abroad r) High antimicrobial use in other veterinary sectors s) Prudent antimicrobial use in human medicine t) Non-prudent antimicrobial use in human medicine

Chapter 5

Veterinary surgeons' perceptions and approaches to prescribing and the responsibility of antimicrobial use in pigs in the UK: A cross-sectional questionnaire study

Veterinary surgeons' perceptions and approaches to prescribing and the responsibility of antimicrobial use in pigs in the UK: A cross-sectional questionnaire study

Introduction

The emergence of resistant bacteria in human and veterinary medicine has highlighted the need to ensure that antimicrobial use is minimal, justified and prudent (Peeters et al., 2015, Burow et al., 2014). There is growing concern over the potential public health risk from the zoonotic transfer of resistant bacteria from livestock to humans; isolated events of such transfer are described in the literature, however, it is not currently possible to quantify the risk (Graveland et al., 2011, Ewers et al., 2012). Antimicrobial use characteristics in the pig sector, such as the comparatively high sales of products solely authorised for use in pigs, the administration of in-feed antimicrobials (Borriello et al., 2015, Anon, 2015j) and frequent prophylactic use (Callens et al., 2012), have identified pigs as a priority species for gaining a better understanding of antimicrobial use behaviours and ways in which overall use can be reduced (Anon, 2015d, Visschers et al., 2016, Visschers et al., 2015, Postma et al., 2016).

Guidelines on the use of antimicrobials in pigs have been produced and advocated by both the Pig Veterinary Society (PVS) and Responsible Use of Medicines in Agriculture Alliance (RUMA), to promote prudent prescribing practices which consider the appropriate class of antimicrobial, the role of antimicrobial susceptibility testing and alternative methods to treat and prevent disease (Anon, 2013g, Anon, 2014d). For example, the guidelines recommend that the use of antimicrobials classified as highest priority critically important antimicrobials by the World Health Organisation are only used if other antimicrobial classes are not available or are ineffective (Anon, 2012d). In relation to antimicrobial use in pigs this definition includes the fluoroquinolones, third and fourth generation cephalosporins and macrolides. The adoption and utilisation of such guidelines in pig practice is currently unknown, however, results from a previous study on UK cattle practice found that less than 3% of practices had written prescribing guidelines on antimicrobial use (Williams et al., 2012).

Clinical factors such as the pharmacological characteristics of antimicrobials, antimicrobial susceptibility testing results, clinical disease signs and predicted outcomes have been found to motivate antimicrobial use decisions in both human (Coenen et al., 2000, Rodrigues et al., 2013) and veterinary medicine (Gibbons et al., 2013, Busani et al., 2004, Sheehan, 2013).

Similarly, non-clinical factors relating to the prescriber and environment have been identified as influencing prescribing practices in human medicine (Rodrigues et al., 2013).

Research in livestock species have identified that non-clinical factors influence antimicrobial use such as a practitioners' sense of responsible antimicrobial prescribing practices, fear of clinical signs worsening should antimicrobials not be prescribed, professional stress and client compliance (Busani et al., 2004, Gibbons et al., 2013). Additionally, the context of antimicrobial use within the food producing animal sector also identifies some unique factors which drive antimicrobial use in livestock such as economic considerations for farms, including the cost of antimicrobials, and the influence of husbandry practices on antimicrobial use (Speksnijder et al., 2015b, Sheehan, 2013).

Existing quantitative studies have attempted to investigate and quantify antimicrobial use, and the associations with particular practices in food producing animal species (Sheehan, 2013, Dunlop et al., 1998, Gibbons et al., 2013, Stevens et al., 2007), however there has been little research investigating prescribing practices in the United Kingdom (UK) pig industry. The aim of this study was to determine the behavioural influences and attitudes surrounding antimicrobial prescribing practices and responsibility in veterinary surgeons working with pigs in the UK using a questionnaire. Findings from the qualitative study (Chapters 2 and 3) informed the design of the questionnaire and this quantitative study aimed to assess the generalisability of the concepts with a larger population of veterinary practitioners working with pigs in the UK.

Methods

Questionnaire design

The design and content of the questionnaire was informed by results from focus groups (Coyne et al., 2014) and interviews with twenty one veterinary surgeons (chapter 3) working in UK pig practice. Key themes and shared opinions were explored in the questionnaire but subject areas or questions that sparked passionate or diverse responses were also covered in order to gauge opinion.

The questionnaire consisted of four sections (Appendix 4, figure 4.4) which included demographic information on the participant and the veterinary practice; current prescribing behaviours and potential barriers to reducing antimicrobial use in pigs; the responsibility of antimicrobial use behaviours; and three clinical scenarios designed to gauge the role of diagnostic testing in prescribing decisions, antimicrobial formulations and classes of antimicrobials used for both therapeutic and prophylactic reasons. In addition, it sought to explore the frequency that respondents reported using the highest priority critically important antimicrobials (Anon, 2012d); the fluoroquinolones, third and fourth generation cephalosporins and macrolides. In addition, the use of colistin was also considered alongside these classes of antimicrobials due to its importance in human medicine in treating highly resistant bacterial infection and its frequent use in pigs (Anon, 2013k, De Briyne et al., 2014).

The questionnaire consisted of both open and closed questions including multiple Likert scale questions to gauge opinion on agreement, frequency, importance and likelihood of a variety of motivations behind antimicrobial prescribing behaviours, and attitudes surrounding antimicrobial use, in pigs. Open questions were also used to gauge opinion where the possible number of responses was too great to construct a closed question format. In addition, open questions minimised possible bias in the responses by stimulating free thought in participants instead of selecting a response from a finite number of alternative answers. Open questions were most commonly used in an expansion form where they follow a closed question in order to seek further information on ‘how’ and ‘why’ respondents held certain opinions and perceptions. This method allowed the researchers to gain additional views and perceptions which may not have been elicited from previous qualitative research (O'Cathain and Thomas, 2004).

The language and phrasing of terminology specific to the pigs were based upon previous knowledge of the pig industry, advice from the pig veterinary surgeon co-supervising the project, language used in the interviews and feedback from the piloting of the questionnaire. The questionnaire was created using the Adobe FormsCentral (Adobe Systems Incorporated, USA) software. The electronic version of the survey was available as a HTML form which was hosted at a dedicated link through the Adobe platform. This electronic form was converted to an identical pdf document and printed for postal dissemination.

Piloting

An electronic version of the questionnaire was piloted amongst three vets working within the farm animal practice at the University of Liverpool and the paper format was piloted via the postal route in two veterinary surgeons working within private farm animal practice. It was not possible to pilot the questionnaire on specialist pig practitioners due to the small total population of pig veterinary surgeons. The length of time it took to complete the questionnaire was recorded alongside any comments or concerns with the questionnaire content. Any queries over the clarity of the questions were discussed either in person or in telephone conversation with the participants and any changes to improve the questionnaire were made subsequently.

Ethical approval was granted for the study from the University of Liverpool Veterinary Science Research Ethics Committee prior to the piloting of the questionnaire. Approval was also granted by the survey control unit at Defra prior to the dissemination of the final questionnaire.

Sample selection

The sample for the questionnaire included all veterinary surgeons working in England, Scotland and Wales whose caseload included pigs kept as production animals; practices located in Northern Ireland were excluded from the sample population. The sampling frame was determined using the Royal College of Veterinary Surgeons (RCVS) online 'Find a Vet' database. Nine hundred and thirty seven results were found when searching for practices, within the UK, that state they treated 'Pigs' in the 'Advanced Search' option. Practices were telephoned and asked to confirm that they still undertook some production pig work and what the approximate percentage of the caseload consisted of pig work.

The names of veterinary surgeons that treated pigs were requested. Practitioners were then listed in the database alongside their gender, position within the practice, whether they were a partner or associate, and the year and place of graduation. These details were obtained through the 'Staff' information in the Veterinary Practice RCVS listings and the RCVS Veterinary Surgeon Registers. Three practices simply stated that all of the veterinary surgeons did pig work and two practices stated that one veterinary surgeon had a particular interest in pig work but would not disclose the name of the individual. For these practices information was sought from the practice websites and all veterinary surgeons listed as doing farm animal work were included in the database. A final list of two hundred and sixty one vets across one hundred and four veterinary practices was compiled.

Questionnaire dissemination

An electronic version of the questionnaire was emailed through the PVS mailing list. The e-mail included an overview of the project and a direct hyperlink to an Adobe Forms Central webpage with the questionnaire. The electronic version of the questionnaire was initially e-mailed on the 4 September 2014 with a second reminder on the 6 October 2014. In addition, a link to the questionnaire was also posted on the PVS website on the 18 November 2014. A final reminder was e-mailed on the 15 December 2014 informing members that the survey would close on the 31 December. The electronic questionnaires included a space for the participant's name and veterinary practice so that participants would not receive a paper copy of the questionnaire if they had already completed it online.

A paper copy was sent to all veterinary practitioners in the list, who had not already completed the questionnaire online, alongside a covering letter and a Freepost return envelope to facilitate responses. The first paper copy of the questionnaire and covering letter were sent on the 24 October 2014. A postcard reminder was sent to non-responders on the 17 November 2014. A second copy of the questionnaire and covering letter was then sent to non-responders on the 1 December 2014. All questionnaires had a unique identity number written on them that matched to veterinary surgeons in the database so that respondents did not receive reminders.

Statistical Analysis

Data analysis was completed using Microsoft Excel 2010 (Microsoft Corporation, Redmond, Washington, USA) and SPSS Statistics 22.0 (IBM SPSS Statistics for Windows Version 22.0. Armonk, NY: IBM Corp). Descriptive statistics relating to the demographic information of respondents and their respective practices were produced. Closed questions were analysed descriptively by determining percentages for the response categories for each section of the questionnaire. In some cases 5 point Likert scale question categories were combined in order to produce a 3 point Likert scale response where numbers in outlying categories were small. For example, never, rarely, sometimes, often, always condensed to give the follow categories; never or rarely, sometimes, often or always.

Chi-squared or Fishers Exact tests (fewer than 5 responses in one or more categories) were used to test the statistical significance of whether respondents were members of PVS or not and whether the respondent was a mixed species or specialist pig practitioner (a specialist pig veterinary surgeon was defined as an individual that spent 100% of their time treating pigs) against the closed questions in the questionnaire. P values <0.05 were deemed significant Since April 2013 veterinary surgeons conducting real welfare assessments as part of the Red Tractor Assurance scheme (Anon, 2013q), which covers around 85% of English pig producers (Anon, 2015o), have been required to be members of PVS. Thus, this was considered to be a key variable in identifying which veterinary surgeons had a clinical caseload consisting of commercial pig herds rather than smallholder pig keepers.

Open questions were analysed using a thematic approach. Initially the free text answers were read in order to gain a general understanding of the views and opinions of respondents. All of the open question responses were transferred into Atlas.ti V.7.7.1. (ATLAS.ti Scientific Software Development) for further analysis. The free text was re-read and ideas generated were categorised and linked to form distinct codes. These codes described the thematic content of the data. These data were then quantified by the frequency with which each theme was identified within the responses and descriptive data were transferred into SPSS Statistics 22.0 (IBM SPSS Statistics for Windows Version 22.0. Armonk, NY: IBM Corp) for analysis.

Results

Response Rate

In total 148 (56.7%) of 261 questionnaires were returned. Of these 61 were completed (7 were returned electronically and 54 were postal); two were returned incomplete except for the demographic section and therefore were not included in the usable responses; 70 were returned stating that the veterinary surgeon did not do sufficient pig work to complete the questionnaire; 12 veterinary surgeons were not working at the practice addresses; 3 individuals chose to opt out of completing the questionnaire as they were involved in the qualitative part of the project; and 1 individual did not wish to partake in the study. Consequently, the number of eligible responses was 179 (removing responses where the veterinary surgeon was no longer at the address or did not do sufficient pig work to be included in the sample population) giving a useable response rate of 34.1%.

Demographic information on veterinary practices and respondents

Information on veterinary practices

The veterinary surgeons who responded to the questionnaire represented a range of types of clinical practice. Over half of the respondents worked within mixed practice (59.7%, n=37), followed by specialist pig practices (22.6%, n=14), or farm animal only practices (8.1%, n=5). A further 3.2% (n=2) of the respondents were in the ‘other’ category which included farm animal and equine practices and a University referral practice. Of the respondents, 62.9% (n=39/61) worked within practices of ten or fewer veterinary surgeons with a range from 1 to 40 veterinary surgeons at each practice.

The greatest percentage of respondents were located in the Yorkshire and Humber region (23.6%, n=17/61), the North East (11.1%, n=8/61) and Eastern regions (11.1%, n=8/61) reflecting the underlying population of pig veterinary surgeons. The geographic distribution of the responding and underlying sample of veterinary practices is shown in Appendix 4, Figure 4.1.

Information on veterinary surgeons

The majority of respondents were male (70.5%, n=43), 27.9% (n=17) were female and 1.60% (n=1) chose not to disclose their gender. This closely resembled the sample population which comprised of 67.7% men and 32.3% women. The number of years of experience of veterinary surgeons varied with 10.0% (n=6) of respondents having qualified less than 5 years ago, 15.0% (n=9) having qualified 6-15 years ago, 25.0% (n=15) having qualified 16-25 years ago and 50.0% (n=30) having qualified over 26 years ago.

Over half of the participants were senior veterinary surgeons (55.0%, n=33), whilst 36.7% (n=22) were assistant veterinary surgeons and 8.3% (n=5) classified themselves as consultants. In comparison the sample population consisted of 50.4% senior veterinary surgeons, 46.8% veterinary assistants and 2.8% veterinary consultants. A minority of respondents (14.7%, n=9) had completed postgraduate study relating to pig medicine, whilst 85.3% (n=52) did not hold any relevant postgraduate qualifications.

A large proportion of respondents, 74.2% (n=46/61), were members of PVS but only 20.3% (n=12/61) of the participants were members of the British Veterinary Association (BVA). PVS and BVA memberships were highly negatively correlated; no individuals were members of both organisations and only one respondent was a member of neither (Appendix 4, Table 4.1). Further analysis of the relationship between PVS and BVA members revealed that all respondents that were not PVS members (100.0%, n=13/59) spent less than 25 % of their time treating pigs (Appendix 4, Table 4.2) and all worked in mixed practices. Thus, in univariable analysis PVS membership was used as a proxy to compare these two types of veterinary surgeon.

The clinical pig caseload varied between respondents with 32.7% (n=20) of respondents spending 100% of their time undertaking pig work whilst 57.5% (n=29) of respondents spent less than 25% of their time working with pigs and the remainder between 26-99% (9.8%, n=12). The majority of veterinary surgeons (67.2%, n=41/61) mainly saw pigs housed indoors. Three quarters of respondents (75.4%, n=46) had equal numbers of breeding and feeding pigs under their care with 18.0% (n=11) seeing more feeding pigs and only 6.6% (n=4) having more breeding sows under their care (Appendix 4, Table 4.3).

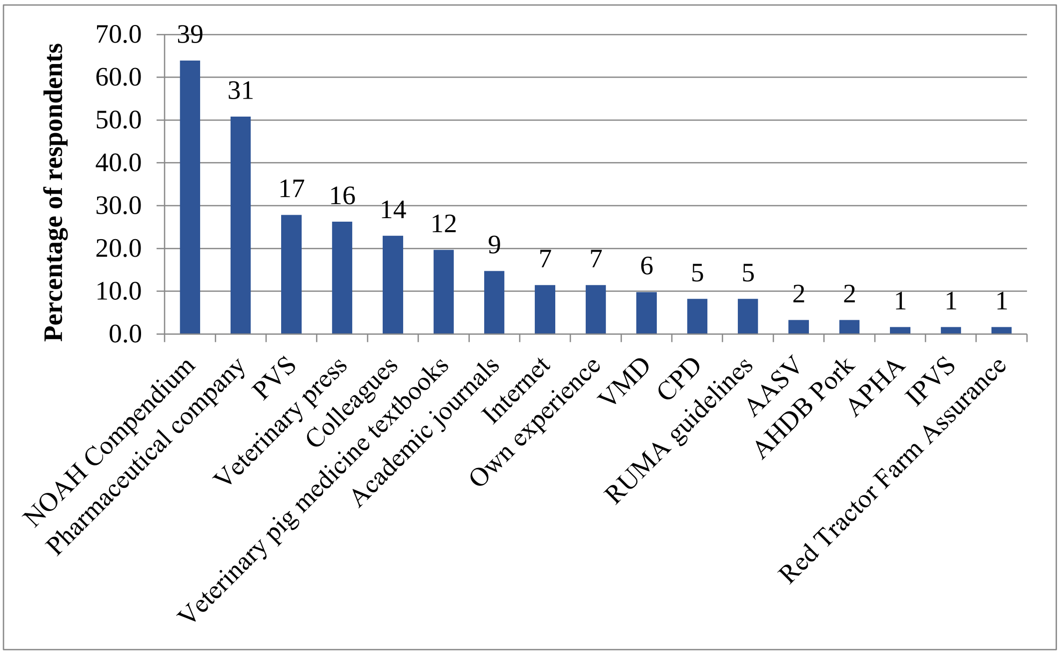
Current antimicrobial prescribing practices

Information sources of antimicrobial use in pigs

In a free text box respondents listed the main sources of information they consulted on antimicrobial use in pigs (Figure 1). Pharmaceutical companies and the National Office of Animal Health (NOAH) compendium were the most frequently cited sources; others included PVS and advice from colleagues. Those cited less frequently included the RUMA guidelines and information from University studies

Figure 1

The information sources on antimicrobial use in pigs cited by UK veterinary surgeons respondents (n=59)



NOAH Compendium –National Office of Animal Health Compendium, PVS – Pig Veterinary Society VMD – Veterinary Medicines Directorate, CPD – Continuing Professional Development, RUMA – Responsible use of Medicines in Agriculture Alliance guidelines, CPD – continuing professional development, AASV – American Association of Swine Veterinarians, AHDB Pork- UK levy board representing pig production, APHA – Animal and Plant Health Agency, IPVS – International Pig Veterinary Society.

Some 35.1% (n=20/57) of respondents stated that their practice currently had written prescribing guidelines for antimicrobial use in pigs when asked the question in a closed question format. However, 63.9% (n=39) of respondents listed information sources for prescribing guidelines that their practice followed when asked this question in an open question format. Of these, the most common sources referenced included PVS Society (n=14), RUMA (n=11), the VMD (n=6) and the British Veterinary Association (BVA) n=3) (Appendix 4, Figure 4.2).

Factors influencing a veterinary surgeons' decision to prescribe an antimicrobial

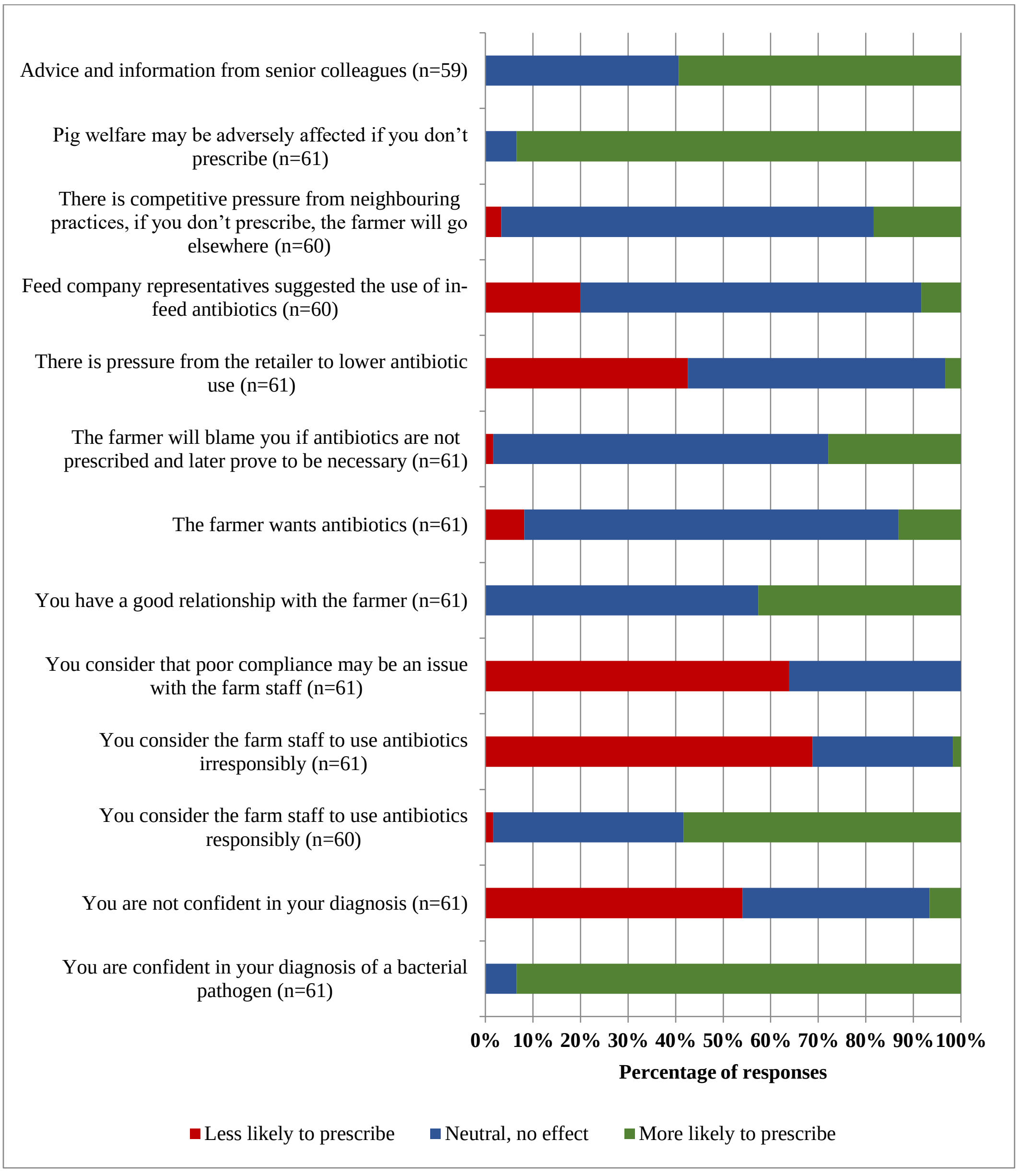
Factors influencing whether a veterinary surgeon is more or less likely to prescribe an antimicrobial are shown in Figure 2 and statistical analysis are shown in Appendix 4, Table 4.4. . Confidence in a diagnosis of a bacterial pathogen was considered to be a major influence on prescribing. The welfare of pigs was also deemed very important with the majority of respondents being more likely to prescribe if they thought pig welfare may be adversely affected should an antimicrobial not be prescribed. Advice from senior colleagues was also identified as a positive motivation towards prescribing antimicrobials.

Factors relating to the relationship between the veterinary surgeon and the client were found to influence prescribing decisions by respondents including the perception of the responsibility of farm staff and the potential compliance rates. There were significant contrasting opinions between mixed species and specialist pig veterinary surgeons; specialist pig practitioners were more likely to prescribe antimicrobials if they considered farm staff to use them responsibly compared to mixed species veterinary surgeons (p=0.01). Mixed species veterinary surgeons were also significantly more likely to prescribe antimicrobials (58.5%, n=24/41) if they perceived a positive relationship with the farmer when compared to specialist pig practitioners (10.0%, n=2/20) (p=<0.0005). The majority of respondents felt that the perception that the farmer wants antimicrobials would not motivate them to prescribe. However, those that felt identified this would make them more likely to prescribe antimicrobials were all mixed species rather than specialist pig practitioners (p=0.035). 29.5% of respondents felt that fear of blame from the farmer should antimicrobials prove to be necessary would make them more likely to prescribe.

Factors relating to external pressures on the veterinary surgeons were not thought to significantly influence prescribing by respondents. The majority of participants felt that pressure from feed company representatives would have no effect on prescribing. In contrast, 42.6% (n=26/61) of respondents felt that pressure from retailers would make them less likely to prescribe whilst a small minority felt that competitive pressure from neighbouring veterinary practices would drive them to prescribe. There were no statistically significant associations between respondent characteristics and whether external factors influenced prescribing decisions.

Figure 2

Veterinary surgeon opinion on factors likely to influence the decision of whether or not to prescribe an antimicrobial.



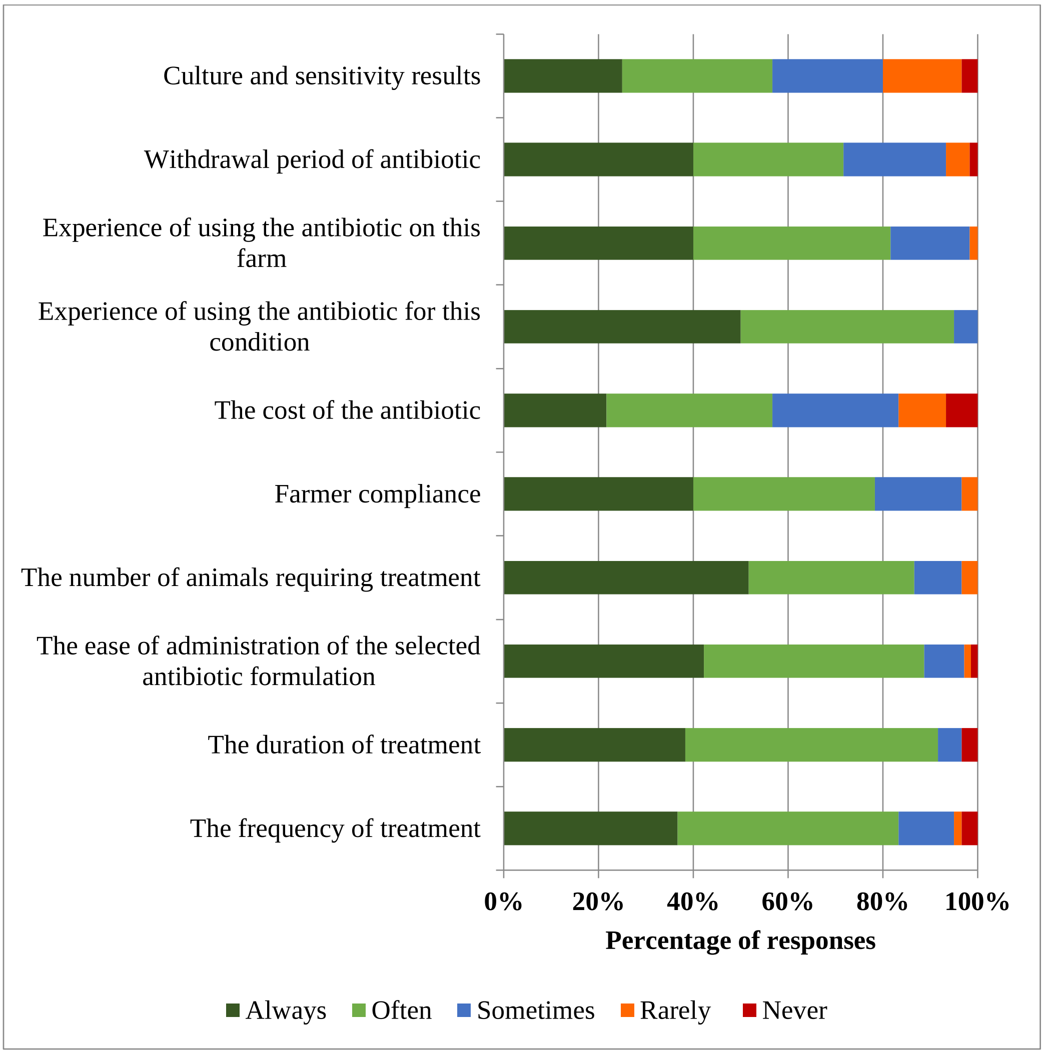
Factors influencing veterinary surgeons' decisions as to which antimicrobial to prescribe

The majority of participants considered factors relating to the frequency and the duration of treatment as either often or always influencing their decision of which antimicrobial to prescribe (Figure 3). Other clinical factors such as the ease of administration and the number of animals requiring treatment were also identified as being important. A spectrum of opinion was observed when antimicrobial susceptibility testing was considered as a possible driver to prescribing a particular type of antimicrobial; 48.3% (n=29) considered it often or always; 31.7% (n=19) sometimes and 20.0% (n=12) rarely or never influencing prescribing. However the majority of respondents often or always considered both experience of using the antimicrobial for the suspected or diagnosed condition and experience of using the antimicrobial on the particular farm to influence the decision as to which antimicrobial to prescribe. The withdrawal period of an antimicrobial was often or always identified as a key factor by many (71.1%, n=29/60). Farmer compliance was commonly identified as driving the decision as to which antimicrobial to prescribe, whereas the influence of the cost of an antimicrobial on prescribing decisions divided opinion amongst veterinary surgeons.

Analysis revealed that PVS members more commonly included withdrawal periods in prescribing decisions (p=0.04) than non-members (Appendix 4, Table 4.5). In addition, mixed species practitioners also stated they considered compliance more commonly than specialist pig veterinary surgeons (p=0.02).

Figure 3

Veterinary surgeon responses for factors considered when deciding which type of antimicrobial to prescribe (n=60).



Opinions on antimicrobial resistance and the role of antimicrobial susceptibility testing

Antimicrobial susceptibility testing when a bacterial infection was initially suspected was described as being carried out often or always by under a fifth of participants however, this figure doubled if antimicrobial susceptibility testing was being carried out following treatment failure (Table 1). PVS members reported carrying out testing more commonly than non-members both on initial visits (p=0.009) and following treatment failure (p=0.037). (Appendix 4, Table 4.6).

Around half of respondents indicated that they sometimes or often encountered treatment failure whilst the other half rarely or never felt that a lack of efficacy was an issue. PVS members encountered treatment failure less commonly than non-members (p= 0.03). Over half of the respondents rarely or never considered that this lack of response was due to antimicrobial resistance. The majority stated that they rarely or never felt they had to change an antimicrobial because of resistance demonstrated on culture and sensitivity testing.

Table 1

Veterinary surgeon opinion on reported frequency of antimicrobial susceptibility testing, antimicrobial efficacy and the role of antimicrobial resistance.

	Never	**Rarely**	**Sometimes**	**Often**	**Always**
How often on an initial visit do you carry out bacterial culture and antibiotic sensitivity testing when a bacterial infection is suspected?	5 (8.2%)	19 (31.1%)	25 (41.0%)	11 (18.0%)	1 (1.6%)
How often do you carry out bacterial culture and antibiotic sensitivity testing when a bacterial infection has not responded to the first antibiotic used?	1 (1.6%)	13 (21.3%)	21 (34.4%)	14 (23.0%)	12 (19.7%)
How often do you encounter a lack of response to the antibiotics used?	3 (4.9%)	27 (44.3%)	30 (49.2%)	1 (1.6%)	0 (0.0%)
How commonly do you feel that this lack of response may be due to antibiotic resistance?	6 (9.8%)	31 (50.8%)	19 (31.1%)	5 (8.2%)	0 (0.0%)
How often do you have to change an antibiotic because of resistance demonstrated on culture and sensitivity testing?	11 (18.0%)	30 (49.2%)	17 (27.9%)	2 (3.3%)	1 (1.6%)

Factors that would influence a veterinary surgeons' decision to prescribe an in-feed over an in-water antimicrobial formulation

Veterinary surgeons' perceptions on factors that would drive them to prescribe an in-feed over an in-water antimicrobial formulation are shown in Table 2. Disease characteristics, such as whether the disease was chronic or acute in nature, and the quality of the water delivery system on farms were the most frequently cited considerations as to whether in-feed or in-water antimicrobials would be selected. The number of animals affected, availability and cost were also a consideration for many. Compliance was also cited with the choice of formulation being the administrative method that the respondent felt was most likely to be delivered correctly by the stock person.

Table 2

Reported factors considered by respondents to influence the decision to prescribe an in-feed antimicrobial over an in-feed formulation and the number of times they were cited.

Factors identified by veterinary surgeons as influencing a decision to prescribe an in-feed over an in-water antimicrobial	**N**	**Example Quotation**
Disease characteristics	19	*'In feed - disease prevention or low level disease'*
Quality of water facilities	19	*'Water medications depend on water intake and quality of water supply and drinkers and whether water bowls are present. Many farms do not have the infrastructure to support water medication…'*
Number of animals requiring treatment	13	*'How many animals to treat?'*
Availability of antimicrobials	10	*'Delivery of antibiotic/type of antibiotic needed/formulation of antibiotic available.'*
Cost	9	*'…more cost effective with more effective response than water medication.'*
Farmer compliance	9	*'Skill of the stockperson - can they be relied upon to medicate water daily.'*
Speed at which antimicrobial can be administered	8	*'so I can 'wait' for in-feed'*
Appetite of pigs	5	*'(sick pigs or acute disease will not eat)'*
Length of antimicrobial course	5	*'Requiring long term treatment.'*

Footnote - others factors mention <5 times included housing of pigs requiring treatment, accuracy of dosing, withdrawal period, water intake of pigs, type of feeding system – wet or dry, disease prevention, ease of administration, efficacy, temperament of pigs and type of pig.

The relationship between disease characteristics and the choice of antimicrobial formulation

The choice of which antimicrobial formulation to use in a number of different clinical scenarios is shown in Table 3. In scour in a litter of piglets in an indoor conventional farrowing crate over half of the respondents would opt to use an oral drench whilst an injectable antimicrobial was the formulation of choice for the majority of veterinary surgeons for an individual sow with mastitis housed outdoors. In-water formulations were the preference for treating acute gastrointestinal disease but choice varied depending on number of pigs affected with more individuals opting for injectable and less for in-water when only 20 pigs were affected. In contrast, in-feed antimicrobials were the most popular method of administration chosen in the respiratory disease scenarios.

In the infertility scenario in a herd of sows housed either indoors or outdoors the majority of respondents stated that in-feed formulations were preferred in sows housed both indoors and outdoors. However in scenarios of *Streptococcus suis* in a group of 400 finishing pigs the preferred method of administration for pigs housed indoors was in-water antimicrobials whilst in finishing pigs accommodated outdoors the greatest number of respondents selected an in-feed formulation.

Table 3

Antimicrobial formulation chosen by veterinary surgeons for different clinical scenarios

	Injectable	In-feed	In-water	Oral drench	No preference
Scour in a litter of piglets farrowed indoors in a conventional crate system (n=56)	17 (30.4%)	0 (0.0%)	1 (1.8%)	35 (62.5%)	3 (5.4%)
Acute gastrointestinal disease affecting 20 of 400 finishing pigs housed indoors (n=56)	22 (39.3%)	2 (3.6%)	26 (46.4%)	1 (1.8%)	5 (8.9%)
Acute gastrointestinal disease affecting ~125 of 2500 finishing pigs housed indoors (n=54)	1 (1.9%)	6 (11.1%)	44 (81.5%)	1 (1.9%)	2 (3.7%)
Chronic respiratory disease affecting >400 of 400 finishing pigs housed indoors (n=55)	0 (0.0%)	35 (63.6%)	17 (30.9%)	0 (0.0%)	5 (5.5%)
Chronic respiratory disease affecting <250 of 2500 finishing pigs housed indoors (n=50)	2 (4.0%)	32 (64.0%)	11 (22.0%)	2 (4.0%)	3 (6.0%)
Mastitis in an individual sow housed outdoors (n=56)	54 (96.4%)	2 (3.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Infertility of bacterial origin in a herd of sows housed outdoors (n=49)	5 (10.2%)	40 (81.6%)	1 (2.0%)	2 (4.1%)	1 (2.0%)
Infertility of bacterial origin in a herd of sows housed indoors (n=50)	8 (16.0%)	32 (64.0%)	8 (16.0%)	1 (2.0%)	1 (2.0%)
Strep. suis with a 2% mortality and a 5% morbidity in a group of 400 finishing pigs housed indoors (n=56)	10 (17.9%)	17 (30.4%)	23 (41.1%)	0 (0.0%)	6 (10.7%)
Strep. suis with a 2% mortality and a 5% morbidity in a group of 400 finishing pigs housed outdoors (n=53)	4 (7.5%)	26 (49.1%)	17 (32.1%)	0 (0.0%)	6 (11.3%)

Veterinary surgeon opinion on how commonly pigs are medicated continually from weaning through to slaughter

Veterinary surgeon opinion was sought on how commonly pigs are medicated continually from weaning until slaughter. Respondents identified that the continual use of antimicrobials was less common in pigs under their care in comparison to the UK pig industry in general (Table 4).

Table 4

Likert scale to show the frequency that respondents' felt that antimicrobials were used continually in pigs from weaning until slaughter

	Never	Rarely	Sometimes	Often	Always
Do you currently have or have you historically had any pigs under your care that are medicated throughout life from weaning through to slaughter? (n=60)	35 (58.3%)	16 (26.7%)	8 (13.3%)	1 (1.7%)	0 (0.0%)
How often do you think that pigs are medicated from weaning through to slaughter in the UK pig industry? (n=59)	1 (1.7%)	16 (37.1%)	19 (49.2%)	13 (22.0%)	0 (0.0%)

Veterinary surgeon opinion on the relationship between management features/systems and the amount of antimicrobials used

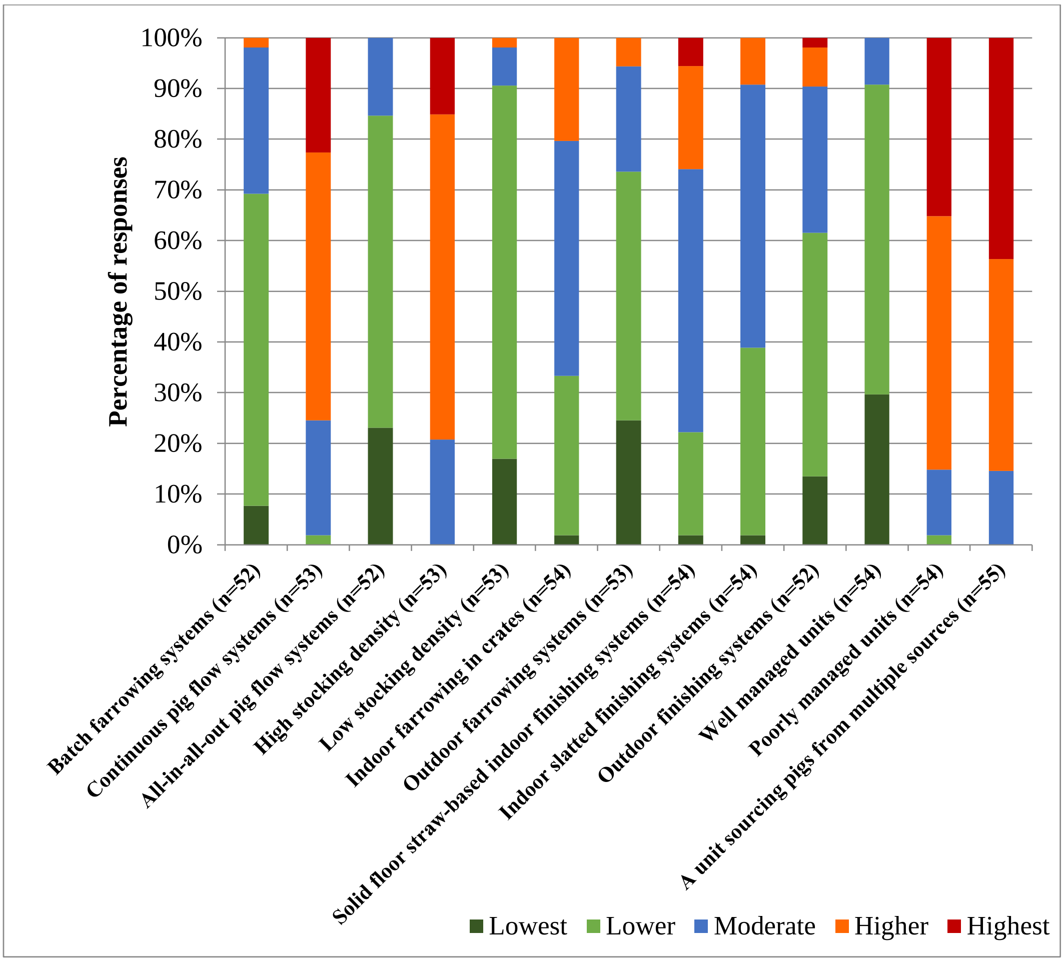
Veterinary surgeon opinion on how different management features and systems influenced the amount of antimicrobial used on farm is shown in Figure 4. The majority of participants felt that batch farrowing systems and all-in-all-out pig movement were lower or the lowest antimicrobial users, whereas, continuous pig flow systems, high stocking densities and units obtaining pigs from multiple sources were deemed as higher or the highest users.

Overall, veterinary surgeons linked outdoor farrowing systems with lower use when compared with indoor farrowing in crates. Veterinary surgeon opinion on the amount of antimicrobial used in indoor slatted finishing systems and solid floor straw-based indoor systems resulted in a spectrum of opinions with around half of respondents rating both as moderate antimicrobial users. However, around a quarter of veterinary surgeons linked straw-based systems more commonly with being a higher antimicrobial use system whilst slatted systems were related more commonly with being lower or the lowest antimicrobial users. Outdoor finishing systems were seen by the majority of respondents as lower antimicrobial users but over a third considered them to be moderate or higher users.

PVS members associated batch farrowing with lower use than non-members (p=0.001) and PVS members also associated outdoor farrowing (p=0.02) and slatted finishing (p=0.02) systems with lower antimicrobial use more commonly than non-members (Appendix 4, Table 4.7). Specialist pig practitioners identified all-in-all-out pig flow systems as a lower antimicrobial use system more commonly compared with mixed species veterinary surgeons (p=0.02).

Figure 4

Veterinary surgeon opinion on the use of antimicrobials on pigs units using different management systems and husbandry practices



Beneficial measures and barriers to the reduction of antimicrobial use in pigs

Veterinary surgeons were asked whether they considered a list of factors relating to management, economics, farmer and veterinary surgeon behaviour and potential policy measures were barriers, beneficial or to have a neutral effect on potentially reducing the total amount of antimicrobials used in pigs (Table 5).

Factors relating to behaviour

Farmer reluctance to change current practices was frequently identified as a barrier to reducing use, however, the majority of respondents felt that veterinary surgeons educating farmers on herd health improvements would be beneficial in reducing antimicrobial use in pigs. Mixed species practitioners identified farmer reluctance as a barrier significantly more commonly than specialist pig veterinary surgeons (p=0.001) (Appendix 4, Table 4.8).

Factors relating to potential policy

The effect of banning antimicrobial classes classified as the highest priority critically important antimicrobials divided participant opinion. For example, whilst the majority felt that there would be no effect on total antimicrobial use if the macrolides were banned equal numbers of individuals felt that this would be a barrier and beneficial. A similar spectrum of responses was observed when veterinary surgeons contemplated the effects of a ban on the fluoroquinolones and the third and fourth generation cephalosporins. Mixed species veterinary surgeons held the opinion that banning the use of fluoroquinolones and third and fourth generation cephalosporins would be beneficial to reducing antimicrobial use in pigs significantly more commonly than specialist pig veterinary surgeons (p=0.001). Similarly, PVS members less frequently identified a ban as beneficial when compared with non – members (p=0.002).

The majority considered that the concept of a ‘penalty system’ whereby farms with high antimicrobial use are given a warning, and benchmarking of antimicrobial use between pig units would be beneficial in reducing antimicrobial use on pig units. Mixed species veterinary surgeons were more confident that a penalty system for high antimicrobial use would be beneficial when compared with specialist pig practitioners (p=0.013). Conversely, the concept of ‘decoupling’ antimicrobial dispensing and prescribing was felt to have no effect on reducing antimicrobial use in pigs by many. Banning in-feed antimicrobials was deemed potentially beneficial by half of respondents with approximately a quarter considering it to be a barrier and the remaining quarter to have no effect. Controlling the authorisation of cheaper generic antimicrobial products was not considered by most to have any effect on the total amount of antimicrobials used in pigs.

Reducing imports of pig meat from other countries with higher antimicrobial use when compared with the UK divided opinion amongst respondents with some identifying that it would be beneficial in reducing antimicrobial use in pigs however; others did not feel it would have any effect on use. Mixed species veterinary surgeons more frequently identified this as a benefit when compared with specialist pig practitioners (p=0.022).

Factors relating to management

Overall, most felt that modernising indoor pig accommodation and locating pig units in areas that are isolated from other pig farms were beneficial in minimising antimicrobial requirements. However, the consequences of increasing the use of outdoor breeding and straw-based finishing systems resulted in a spectrum of opinions amongst participants. The majority of participants considered alternative methods of preventing disease such as a more effective and a wider range of vaccinations and de-populating and re-populating low health status pig herds with higher health status stock to be beneficial in reducing overall antimicrobial use in pigs.

Factors relating to economics

Over half of veterinary surgeons did not consider economic factors such as either increasing or decreasing the cost of antimicrobials for farmers would have any effect on the total amount of antimicrobials used in pigs. The impact of increasing the profitability of pig meat prices on total antimicrobial use in pigs divided opinion amongst respondents with some identifying it as a benefit whilst others identified it as having no effect or a barrier.

Table 5

Veterinary surgeon opinion on whether different measures would be considered to be a barrier, beneficial or have no effect on the total amount of antimicrobial used in pigs in the UK.

	Barrier	Neutral, no effect	Beneficial
Behavioural factors			
Farmer reluctance to change current practices (n=60)	50 (83.3%)	8 (13.3%)	2 (3.3%)
Vet reluctance to change current practices (n=60)	45 (75.0%)	14 (23.3%)	1 (1.7%)
Vets educating farmers on ways to improve herd health (n=58)	0 (0.0%)	4 (6.9%)	54 (93.1%)
Factors relating to potential policy			
Banning in-feed antibiotic formulations (n=57)	13 (22.8%)	15 (26.3%)	29 (50.9%)
A ‘penalty system’ of penalties for high antibiotic usage in pigs, such as the “yellow card” system in Denmark (n=57)	7 (12.3%)	6 (10.5%)	44 (77.2%)
Banning the use of the fluoroquinolones and the third and fourth generation cephalosporins (n=57)	11 (19.3%)	28 (49.1%)	18 (31.6%)
Banning the use of the macrolides (n=57)	17 (29.8%)	23 (40.4%)	17 (29.8%)
A benchmarking system, whereby antibiotic usage is benchmarked between farms (n=59)	3 (5.1%)	22 (37.7%)	34 (57.6%)
‘Decoupling’ the dispensing and prescribing of antibiotics so that vets are no longer able to dispense antibiotics directly and can only prescribe antibiotics to clients (n=58)	14 (24.1%)	40 (69.0%)	4 (6.9%)
Further controls on the licensing of cheaper generic antibiotic products (n=59)	3 (5.2%)	37 (63.8%)	18 (31.0%)
Reducing imports from other countries with high antibiotic use (n=59)	2 (3.4%)	23 (39.0%)	34 (57.6%)
Factors relating to management			
Eradicating swine dysentery from the UK (n=58)	1 (1.7%)	9 (15.3%)	49 (83.1%)
Modernising indoor pig accommodation (n=58)	0 (0.0%)	5 (8.5%)	54 (91.5%)
Increased use of straw-based finishing systems (n=58)	10 (17.2%)	30 (51.7%)	18 (31.0%)
Increased use of outdoor breeding systems (n=57)	5 (8.6%)	37 (63.8%)	16 (27.6%)
More effective vaccines (n=61)	0 (0.0%)	2 (3.4%)	56 (96.6%)
A wider range of vaccines (n=59)	0 (0.0%)	2 (3.5%)	55 (96.5%)
De-populating and re-populating low health status pig herds with higher health status stock (n=59)	0 (0.0%)	6 (9.8%)	55 (90.2%)
Locating pig units in areas that are isolated from other units (n=58)	0 (0.0%)	10 (16.9%)	49 (83.1%)
Factors relating to economics			
Increased profitability of pig meat price (n=58)	5 (8.5%)	21 (35.6%)	33 (55.9%)
Increasing the cost of antibiotics for farmers (n=58)	7 (12.1%)	34 (58.6%)	17 (29.3%)
Decreasing the cost of antibiotics for farmers (n=59)	21 (36.2%)	36 (60.3%)	2 (3.4%)

Practical solutions to reducing antimicrobial use in pigs

Volunteered information in an open question allowed additional comments on the listed beneficial measures and barriers to the reduction of antimicrobial use in pigs were mainly divided between concern over the effects of reducing overall antimicrobial use in pigs and the effect of banning the critically important antimicrobials (Table 6). Some veterinary surgeons also added additional practical suggestions on reducing the total amount of antimicrobials used in pigs including further education of farmers and veterinary surgeons on prudent prescribing practices, restrictions on the importation of pig meat from countries with lower production and economic proposals. These economic proposals included the concept of financial incentives for producers to improve the quality of housing and facilities in order to minimise antimicrobial requirements and fixed pricing of antimicrobials so that veterinary practices are not able to discount antimicrobials for producers.

Table 6

Volunteered responses on methods to reduce the total amount of antimicrobial used in pigs in the UK and the effects of banning the highest priority critically important antimicrobials

	Barriers	Benefits
Reducing antimicrobial use in pigs	Cost of productivity would increase for farmers (n=4) Negative welfare implications (n=6) Higher production costs in the UK compared to other countries (n=1) Poor efficacy of vaccinations currently available (n=1) Poor education of veterinary surgeons on responsible use (n=1)	Improvements in pig housing and facilities (n=3) Improvements in the health status of pig herds (n=3) Improvements in pig husbandry practices (n=3) Move towards sourcing pigs from a single site (n=2)
Banning the critically important antimicrobials (CIAs) in pigs	Increased use of non-CIA antimicrobials classes (n=3) Increased resistance to non-CIA antimicrobial classes (n=1) Negative animal welfare implications (n=1) No reduction in the total amount of antimicrobials used in pigs (n=1) No alternative long acting antimicrobial products to maximise compliance (n=1)	

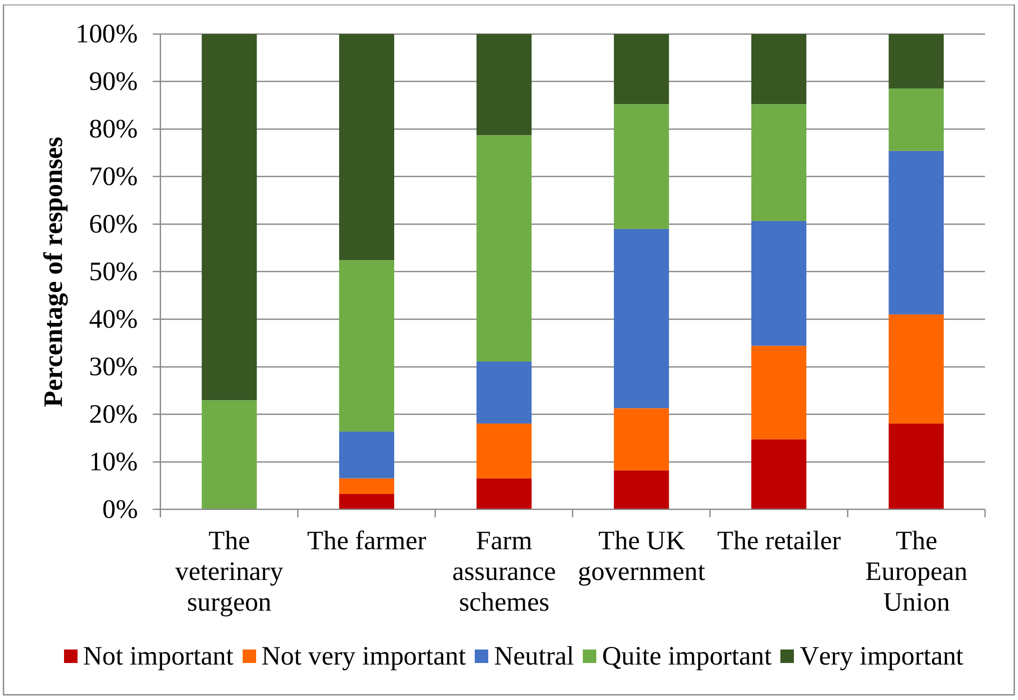
Responsible use in the pig and other veterinary sectors

Responsibility for monitoring the prudent use of antimicrobials

Veterinary surgeons rated the importance of different actors for monitoring and safeguarding the prudent use of antimicrobials in pigs (Figure 5). All of the respondents considered that veterinary surgeons had an important role in ensuring responsible use and farmers were also deemed important. The majority of participants also felt that farm assurance schemes were important. However, opinion was more divided on the role of the retailer and the UK and EU governments in monitoring the responsible use of antimicrobials. PVS members more frequently considered the retailer to be either quite or very important (p=0.003) and the EU to be less important when compared with the views of non-PVS members (p=0.013) (Appendix 4, Table 4.9).

Figure 5

Veterinary surgeons' ratings of which actors are important in monitoring responsible antimicrobial use in pigs (n=61) .



Antimicrobial prescribing practices and the veterinary surgeons' sense of responsibility

Respondent opinion was sought on whether certain antimicrobial prescribing and use practices would be considered responsible and justifiable (Table 7). Macrolides were considered to be usually or always justified by the majority of respondents. However, fluoroquinolones and third and fourth generation cephalosporins divided opinion with around half considering their use to be usually or always justified and a similar proportion of practitioners responding that their use was rarely justified. Veterinary surgeons showed some uncertainty over their opinions on the use of colistin with 15% (n=8/53) of respondents stating that they were unsure, but the majority felt that the use was usually or always justified. Overall, the majority of veterinary surgeons felt that the use of antimicrobials for therapeutic reasons was either usually or always justified. The justification for the use of antimicrobials for disease prevention created a spectrum of responses; however, the majority felt that in-feed antimicrobial use was either usually or always justified.

Although the use of antimicrobials for growth promotion purposes was banned throughout the European Union in 2006, the questionnaire sought veterinary surgeon opinion on whether such use was ever justified. The majority of participants felt that this was either never or rarely justified with a small minority of respondents indicating it was either usually or always justified. PVS members significantly more frequently considered the use of fluoroquinolones (p=0.001), colistin (p=0.001), third and fourth generation cephalosporins (p=0.038), antimicrobials for disease prevention (p=0.05) and in-feed antimicrobials (p=0.002) to be justified often or always when compared with non-members (Appendix 4, Table 4.10).

Table 7

Veterinary surgeons' views on what was considered to be justified as the responsible use of antimicrobials in pigs.

	Never	**Rarely justified**	**Usually justified**	**Always justified**	**Unsure**
The use of the fluoroquinolones in pigs (n=55)	1 (1.8%)	24 (43.6%)	22 (40.0%)	4 (7.3%)	4 (7.3%)
The use of the colistin in pigs (n=53)	3 (5.7%)	9 (17.0%)	26 (49.1%)	7 (13.2%)	8 (15.1%)
The use of third and fourth generation cephalosporins in pigs (n=56)	1 (1.8%)	25 (44.6%)	22 (39.3%)	4 (7.1%)	4 (7.1%)
Use of macrolides (n=56)	0 (0.0%)	8 (14.3%)	34 (60.7%)	11 (19.6%)	3 (5.4%)
Antibiotic use for therapeutic reasons (n=58)	0 (0.0%)	0 (0.0%)	15 (25.9%)	42 (72.6%)	1 (1.7%)
Antibiotic use for prophylactic reasons (n=58)	2 (3.4%)	13 (22.4%)	36 (62.1%)	3 (5.2%)	4 (6.9%)
Antibiotic use to increase growth rates or production (n=58)	33 (56.9%)	20 (34.5%)	1 (1.7%)	1 (1.7%)	3 (5.3%)
The use of in-feed antibiotics in pigs (n=58)	0 (0.0%)	7 (12.1%)	44 (75.9%)	4 (6.9%)	3 (5.2%)

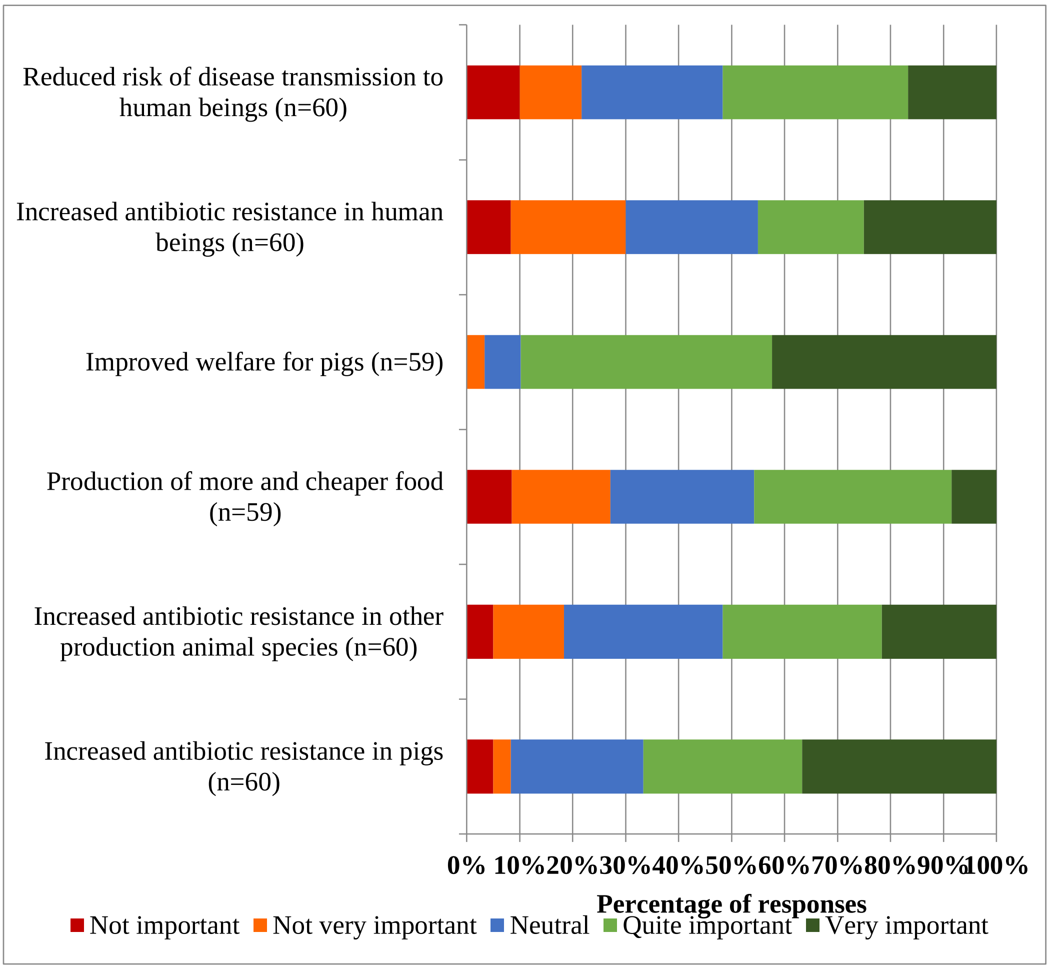
Consequences from the use of antimicrobials in pigs

Respondents rated the importance of different potential consequences related to the way antimicrobials are currently used in UK pigs (Figure 6). The majority of veterinary surgeons felt that antimicrobial resistance in pigs was an important consequence from the use of antimicrobials in pigs. However, opinion was divided on the impact of antimicrobial use in pigs on other production animal species; PVS members rated resistance in other production animal species as being less important when compared with non-members ($p=0.004$).

The importance of consequences from antimicrobial use in pigs on resistance levels in humans also split opinion with non-PVS members more frequently rating antimicrobial use in pigs as being important in human antimicrobial resistance when compared with PVS members ($p=0.031$). Half of respondents felt that antimicrobial use in pigs was important in reducing the risk of disease transmission to humans and the majority of respondents felt that antimicrobial use in pigs was important for improving welfare in pigs. Significant associations are shown in Appendix 4, Table 4.11.

Figure 6

Veterinary surgeon opinion on the consequences from the use of antimicrobials in pigs



Veterinary surgeon opinion on the impact on the pig industry should veterinary surgeons lose the right to dispense antimicrobials directly to clients

Views on the consequences should veterinary surgeons no longer be able to dispense antimicrobials directly to clients was sought. There was concern by many respondents that such regulation would result in it becoming more difficult to monitor antimicrobial use on farms and furthermore participants held the opinion that there was an increased likelihood of antimicrobials being sourced through illegal channels, or that it would result in a time delay in treating pigs. Only 22% (n=13/59) agreed that 'decoupling' would reduce the amount of antimicrobial used in pigs.

There was also concern over the potential negative financial consequences for veterinary practices should veterinary surgeons lose the ability to dispense antimicrobials directly to clients. Over half of all respondents agreed or strongly agreed that some veterinary practices may go out of business under such regulation. However, there was less concern amongst respondents over farms going out of business if antimicrobials were not supplied by vets.

Table 7

Veterinary surgeon opinion on the impact should antimicrobial use be ‘decoupled’ so that veterinary surgeons are no longer able to dispense antimicrobials directly to clients. (n=59)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
It would be beneficial for the vet-farmer relationship	33 (55.9%)	0 (0.0%)	18 (30.5%)	7 (11.9%)	1 (1.7%)
It would put some vet practices out of business	6 (10.2%)	0 (0.0%)	11 (18.6%)	31 (52.5%)	11 (18.6%)
It would mean that vets are less able to monitor antibiotic use on farms	8 (13.6%)	0 (0.0%)	10 (16.9%)	19 (32.2%)	22 (37.3%)
Farmers would be more likely to obtain antibiotics from ’black market’ sources	6 (10.2%)	0 (0.0%)	9 (15.3%)	26 (44.1%)	18 (30.5%)
It would put some farms out of business	24 (40.7%)	0 (0.0%)	21 (35.6%)	11 (18.6%)	3 (5.1%)
It would result in a time delay in treating sick animals	7 (11.9%)	0 (0.0%)	2 (3.4%)	25 (42.4%)	25 (42.4%)
It would reduce the amount of antibiotics prescribed in the pig sector	31 (52.5%)	0 (0.0%)	15 (25.4%)	12 (20.3%)	1 (1.7%)

Opinions on the impact of a potential ban on the veterinary use of fluoroquinolones

Veterinary surgeons showed greatest concern for the impact of a ban on the fluoroquinolones, on the health and welfare of piglets (Figure 7(a)). In contrast, the majority felt that there would be no effect on the health and welfare of finishing pigs or sows. Specialist pig veterinary surgeons recognised the negative welfare impact of a ban on the fluoroquinolones on piglets more often when compared with mixed species practitioners ($p=0.007$) (Appendix 4, Table 4.12(a)).

When respondents considered the impact of a ban on the fluoroquinolones on the health and welfare of other species or sectors, veterinary surgeons were most concerned over a negative impact of a ban in cattle, poultry and companion animals there was less concern over there being a negative impact on equines and sheep. Contrasting opinions were found when the consequences on the levels of resistance in humans and pigs of a potential ban on the fluoroquinolones. Specialist pig practitioners felt that there would be no effect on antimicrobial resistance levels in pigs more commonly when compared to mixed species practitioners (p=0.003) (Appendix 4, Table 4.11(a)).

Opinions on the impact of a potential ban on the veterinary use of third and fourth generation cephalosporins

The majority of veterinary surgeons felt that there would be no effect on the health and welfare of finishing pigs or sows should the third and fourth generation cephalosporins be banned (Figure 7(b)). However, there was slightly more concern over the effect of a ban on the health and welfare of piglets. There were no significant differences in the opinions of pig and mixed species veterinary surgeons on the effect of a ban on the third and fourth generation cephalosporins on the health and welfare of piglets, finishing pigs or sows. When other species sectors were considered most concern was shown by veterinary surgeons over the negative welfare implications from a ban on cattle and companion animals.

Overall, the majority of participants felt that there would be no improvements in pig management on farms if third and fourth generation cephalosporin use was to be banned whilst over a third felt that there would be a positive impact. Mixed species veterinary surgeons more commonly held the opinion that there would be a positive impact on improvements in pig management on farms should the use of the third and fourth generation cephalosporins be restricted when compared with specialist pig veterinary surgeons (p=0.007) (Appendix 4, Table 4.12(b)).

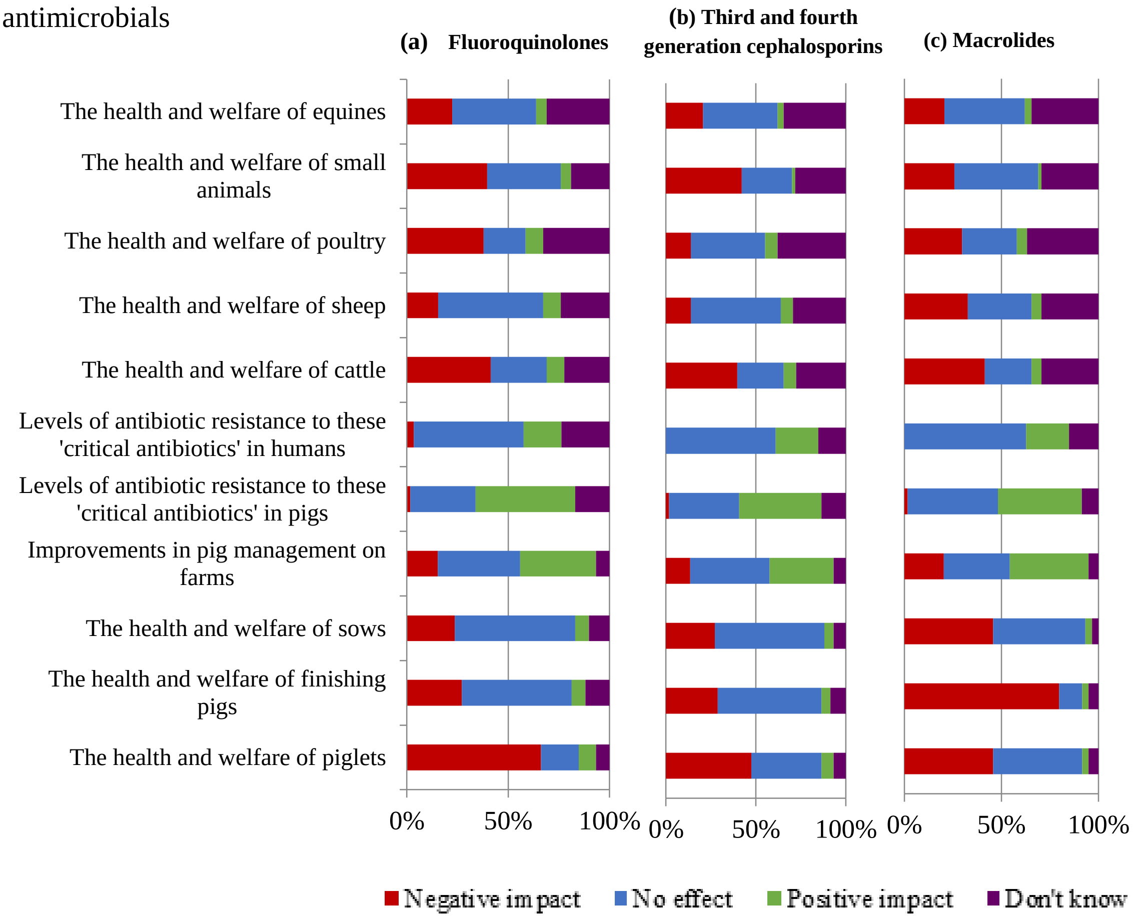
The majority of respondents felt that a ban on the third and fourth generation cephalosporins was likely to have a positive impact on antimicrobial resistance levels in pigs. However, fewer identified this positive link to humans with the majority stating that there would be no effect on antimicrobial resistance levels in humans.

Opinions on the impact of a potential ban on the veterinary use of macrolides

If the macrolides were to be banned there was greatest concern that this would have negative consequences for the health and welfare of finishing pigs whereas, the majority felt that there would be no effect on the health and welfare of piglets and sows (Figure 9(c)). The impact of a ban on the management of pig farms divided opinion with 40.7% (n=24/59) thinking there would be a positive impact whilst 33.9% (n=20/59) identified that there would be no effect. Veterinary surgeons generally expressed opinions that a ban on the macrolides would result in negative welfare consequences for cattle, sheep and poultry. Conversely the majority identified that there would be no impact on companion animals and equines. The majority of respondents felt that there would be no effect from a ban on the impact of antimicrobial resistance levels to macrolides in humans. However, opinion was divided on the impact of reducing levels of infections resistant to macrolides in pigs following a ban.

Figure 7

Veterinary surgeon opinion on the impact of a potential ban on the critically important antimicrobials



The responsibility of antimicrobial use in different sectors

Veterinary surgeon perceptions on how responsible antimicrobial use was perceived to be in the pig sector when compared with other veterinary sectors were assessed (Table 8). Overall participants generally had a neutral opinion when comparing the pig veterinary sectors with other sectors with the exception of the small animal sector and cattle sectors. Over a third felt use was less responsible in small animals whilst the beef cattle sector divided opinion with equal numbers of respondents considering antimicrobial use to be both neutral or more responsible in comparison to use in pigs.

Table 8

Veterinary surgeon opinion on how responsible antimicrobials are used in other veterinary sectors when compared with the pig sector

	Less responsibly	**Neutral**	**More responsibly**	**Don't know**
Beef cattle	7 (11.7%)	23 (38.3%)	23 (38.3%)	7 (11.7%)
Dairy cattle	12 (20.0%)	22 (36.7%)	20 (33.3%)	6 (10.0%)
Equine	14 (23.7%)	20 (33.9%)	16 (27.1%)	9 (15.3%)
Poultry	14 (23.3%)	24 (40.0%)	10 (16.7%)	12 (20.0%)
Sheep	11 (18.3%)	22 (26.7%)	18 (30.0%)	9 (15.0%)
Small animals	23 (38.3%)	18 (30.0%)	12 (20.0%)	7 (11.7%)

Mixed species veterinary surgeons more commonly held the opinion that antimicrobial use in beef cattle, dairy cattle and sheep were more responsible than in pigs (Table 9). There were no significant differences in the perceptions of specialist pig and mixed species veterinary surgeons on how prudent antimicrobial use was in poultry, small animals and equines in comparison to pigs.

Table 9

Cross-tabulation of mixed species and specialist pig veterinary surgeons opinion on the responsibility of antimicrobial use in other species sectors

		Is the veterinary surgeon a specialist pig practitioner or a mixed species practitioner?								
		Specialist pig veterinary surgeon				**Mixed species veterinary surgeon**				**P Value**
		LR	**N**	**MR**	**DK**	**LR**	**N**	**MR**	**DK**	
Beef cattle (n=60)	**n**	2	12	1	5	5	11	22	3	0.001
	%	10.0	60.0	5.0	25.0	12.2	26.8	53.7	7.3	
Dairy cattle (n=60)	**n**	5	9	1	5	7	13	19	2	0.01
	%	25.0	45.0	5.0	25.0	17.1	31.7	46.3	4.9	
Equine (n=59)	**n**	6	6	2	5	8	14	14	5	0.2
	%	31.6	31.6	10.5	26.3	19.5	34.1	34.1	12.2	
Poultry (n=60)	**n**	2	6	6	6	12	18	4	7	0.06
	%	10.0	30.0	30.0	30.0	29.3	43.9	9.8	17.1	
Sheep (n=60)	**n**	5	8	1	6	6	14	17	4	0.020
	%	25.0	40.0	5.0	30.0	14.6	34.1	41.5	9.8	
Small animals (n=60)	**n**	9	4	1	6	14	14	11	2	0.2
	%	45.0	20.0	5.0	30.0	34.1	34.1	26.8	4.9	

LS – Less responsible, N – neutral, MR – More responsible, DK – Don’t know.

<u>Discussion</u>

This study investigated the behavioural influences and perceptions of responsibility surrounding antimicrobial prescribing practices in a census study of veterinary surgeons working with commercial pigs in the UK.

Veterinary surgeons reported consulting a wide variety of different information sources on antimicrobial use in pigs. The NOAH Compendium, which contains the Specific Product Characteristic (SPC) datasheets for the majority of antimicrobials authorised in the UK (Anon, 2013a), and pharmaceutical companies were the most frequently cited information sources with PVS being the third most commonly consulted source by respondents. The

NOAH compendium and pharmaceutical company information offer guidance on how to use antimicrobials prudently through the choice of an appropriate antimicrobial for the presenting condition, the correct dose and optimal course length (Paskovaty et al., 2005). Additionally, the NOAH Compendium recommends that antimicrobial susceptibility testing is carried out before the use of certain classes of antimicrobial deemed important to human medicine; for example the fluoroquinolones and the third and fourth generation cephalosporins (Anon, 2013a). However, they do not offer guidance on the potential over-use of broad-spectrum antimicrobials and classes whose use should not be a first line treatment option (Paskovaty et al., 2005). The latter information is available through the PVS guidelines which offer guidance on which classes of antimicrobial should be used as first, second and third line treatment options and when antimicrobial susceptibility testing should be conducted prior to the use of certain classes (Anon, 2014d). Similarly, a study into cattle practitioners found that respondents consulted the NOAH Compendium and pharmaceutical companies more frequently than the veterinary associations for information on antimicrobial prescribing (Williams et al., 2012).

The decision that an antimicrobial is required was driven by both clinical and non-clinical factors. Clinical factors such as confidence in their diagnosis, and a desire to avoid the negative welfare implications of disease, are also commonly described in human and veterinary medicine (De Briyne et al., 2013, Coenen et al., 2002), and are motivated by the prescribers' personal and professional responsibility (Busani et al., 2004, Mattick et al., 2014). Once the decision to prescribe an antimicrobial has been made factors relating to the ease of administration were found to influence the decision as to which antimicrobial to prescribe; such as treatment frequency and duration, the number of affected animals and antimicrobial formulation. In addition, antimicrobial susceptibility testing was identified as motivating prescribing decisions however; this was cited as being carried out more frequently following initial treatment failure. Similarly, it has been described as being an underutilised tool in veterinary (De Briyne et al., 2013) and human medicine (Lance and Axel, 2004).

PVS members reported conducting antimicrobial susceptibility testing more frequently when compared with non-members; this may reflect that their clinical caseload is more likely to include larger commercial farm assured pig units; which are often higher antimicrobial users when compared with smallholder units (Stevens et al., 2007, van der Fels-Klerx et al., 2011). It is important to consider the context of farm assurance veterinary visits as there is a current requirement that veterinary surgeons are PVS members in order to conduct these visits (Anon, 2014f). In addition, at the time the research was conducted PVS members benefited from access to specific guidelines on antimicrobial use in pigs which promote the use of antimicrobial susceptibility testing (Anon, 2014d). Since this research was completed these guidelines are now available to non-members as well.

In parallel with other studies in human and veterinary medicine treatment failures were seldom identified as a major concern in clinical practice (Speksnijder et al., 2015b, Simpson et al., 2007, Buller et al., 2015). Additionally, when treatment failures were encountered respondents rarely considered these were as a result of antimicrobial resistance. Buller and others described a similar concept whereby veterinary surgeons generally did not consider antimicrobial resistance to be the primary cause of treatment failures (Buller et al., 2015) whilst Simpson and others recognised that the majority of physicians did not consider antimicrobial resistance to have a major effect on their clinical work and it was infrequently considered in prescribing decisions (Simpson et al., 2007).

Veterinary surgeons perceived that a reduced risk of disease transmission to human beings was a more important consequence from the use of antimicrobials in pigs, than the potential for increased antimicrobial resistance in humans. Similarly, the literature shows that majority of veterinary surgeons acknowledged the potential for resistance in humans as a consequence of antimicrobial use in pigs (Visschers et al., 2016, Speksnijder et al., 2015b, Cattaneo et al., 2009). However, Speksnijder and others identified that the majority of farm animal practitioners in the Netherlands perceived indiscriminate prescribing in human medicine to be the most significant driver of antimicrobial resistance in humans (Speksnijder et al., 2015b). The perception held by respondents that antimicrobial use in pigs may reduce the risk of disease transmission to humans is supported by some extent by the theory that antimicrobial use in livestock may reduce microbial load and shedding, and therefore, may lead to a lower chance of meat products being contaminated with zoonotic pathogens (Landers et al., 2012). However, such theories are poorly supported in published studies whilst the negative public health consequences from the zoonotic transfer of resistant bacteria from livestock to humans are well documented (Liu et al., 2015, Agersø et al., 2012, Taylor et al., 2008, Burow et al., 2014).

Factors relating to the veterinary surgeons' relationship with the farmer were the most common non-clinical factors that were considered to drive antimicrobial prescribing decisions; respondents frequently considered that a good relationship may drive use. The literature reflects respondent opinion on the importance of a positive relationship between veterinary surgeons and livestock producers and identifies the high reliance that farmers place on this relationship for information on antimicrobials (Hall and Wapenaar, 2012, Sheehan, 2013, Friedman et al., 2007, Dunlop et al., 1998). In parallel, maintaining the doctor-patient relationship is considered to influence prescribing behaviours in physicians (Butler et al., 1998).

The confidence of the veterinary surgeon in the farmers' ability to use antimicrobials in a responsible manner was identified as motivating prescribing decisions. Respondents considered compliance in their decision to prescribe an antimicrobial and in which antimicrobial formulation to prescribe. For example, administering in-feed formulations was identified as requiring fewer farmer skills and precision than in-water antimicrobials and was therefore linked with higher compliance. Ensuring that the route of administration chosen maximises compliance has been recognised as a prescribing behaviour in veterinary medicine (De Briyne et al., 2013, Gibbons et al., 2013) and may be one reason for the commonality of the use of in-feed antimicrobials in pigs (Chauvin et al., 2002, Stevens et al., 2007).

Veterinary surgeons identified factors such as disease prevention as the prescription indication, poor quality water facilities, large number of animals requiring treatment, poor availability of antimicrobials and lower costs as justifications for using in-feed over in-water antimicrobial formulations. The literature supports respondent perceptions by showing that in-feed and in-water antimicrobials are more commonly administered to larger numbers of animals whilst injectable formulations are usually reserved for individual animals (Stevens et al., 2007, Rajic et al., 2006, Chauvin et al., 2002) and the specific use of in-feed antimicrobials for prophylaxis is a commonly described behaviour (Stevens et al., 2007, Ungemach et al., 2006). The importance of water quality has been a major focus of efforts to reduce antimicrobial use (Anon, 2015d, Postma et al., 2015b) and re-investing and improving existing water delivery facilities have been integral in the successful reduction in antimicrobial use observed in the Netherlands (Anon, 2015a). Additionally, the consideration (Gibbons et al., 2013, Sheehan, 2013, Speksnijder et al., 2015b) and the poor availability of some antimicrobial products (Sheehan, 2013) have been identified as driving prescribing decisions by livestock practitioners.

Respondents demonstrated confidence in their antimicrobial use decisions and considered that the majority of prescribing practices in pigs were responsible; similar self-confidence has been shown in human and veterinary medicine (Rodrigues et al., 2013, Gibbons et al., 2013). Prescribing practices under debate such as the use of in-feed antimicrobials, prophylactic antimicrobial use and the use of critically important antimicrobials in pigs were considered by the majority to be justifiable. In-feed antimicrobials are frequently utilised for the purposes of disease prevention in pigs (Callens et al., 2012) and whilst prophylaxis is generally considered to be prudent and necessary in some clinical situations (Callens et al., 2012, Speksnijder et al., 2015b) there has been a move to seek alternative methods of preventing disease in pigs (Anon, 2015d, Postma et al., 2015b).

Overall, respondents identified that the use of the highest priority critically important antimicrobials in pigs was responsible and they were seldom chosen as first line options in the clinical scenarios. Reserving these antimicrobials for clinical cases where non-critically important antimicrobials are not indicated or efficacious has been described in veterinary medicine (De Briyne et al., 2013) and such behaviours have been used to assess the comparative responsibility of prescribing behaviours of veterinary surgeons and physicians (Busani et al., 2004, Wood et al., 2007). Overall, veterinary surgeons considered that a ban on the use of these classes would have no effect on the total amount of antimicrobial used in pigs in the UK. However, with the critically important antimicrobials currently representing around 20% of the total antimicrobial use in pigs in Europe (De Briyne et al., 2014) it is likely that banning certain classes of antimicrobial would significantly alter prescribing patterns, if not total use levels.

Since the questionnaire study was completed there has been increased concern over the use of colistin in pigs due to the recent findings that plasmid transfer is a potential route of resistance transmission (Liu et al., 2015, Webb et al., 2015). This has highlighted concern over the potential for the zoonotic transmission to humans via the food chain. Consequently, the Responsible Use of Medicines in Agricultural Alliance (RUMA) announced that the use of colistin would be voluntarily restricted by the UK veterinary sectors from 4 December 2015 whereby colistin should be an antimicrobial of last resort which should only be used if susceptibility testing shows that it is the only effective antimicrobial available to treat pigs (Anon, 2016a). Additionally PVS have updated their prescribing guidelines to reflect that colistin should only be used as a last line treatment option (Anon, 2014d).

Whilst the majority of veterinary surgeons considered the use of colistin to be justifiable it proved to be an area of uncertainty by many respondents. Antimicrobial sales of colistin are low in the UK in comparison to other European countries. For example, in 2013 it represented 0.3 per cent of the mg per population correction unit whereas, colistin sales were comparatively high elsewhere and formed 4.6 per cent of the mg of population correction unit in Germany, whilst the figure stands at 3.0 per cent and 2.1 per cent in Italy and Spain, respectively (Anon, 2015j). Thus, whilst any effect on the health and welfare of pigs in the

UK cannot be predicted it is likely that any European-level restrictions would have a more significant effect on other member states when compared with the UK.

Veterinary surgeons expressed concern that antimicrobial use may be less responsible by other veterinary surgeons within the pig industry and in other food producing species sectors. The questionnaire sought opinion on the commonality of the continual and long-term use of antimicrobials in pigs. Such habitual behaviours have been identified in pigs (Sheehan, 2013, Visschers et al., 2014) and are not consistent with the current UK guidelines on the responsible use of antimicrobials in pigs (Anon, 2013g, 2015b). Respondents identified that such practices were uncommon on their clients' farms but the majority felt that such practices may be more common elsewhere in the UK pig industry. This concept in which such prescribing behaviours are not a concern in the prescribers' own environment, but in which they are identified as more frequent in external settings has been identified in human medicine (Rodrigues et al., 2013). Similarly, participants highlighted that they perceived irresponsible use as being an issue in other veterinary species sectors when compared to the pig sector.

There were differences recorded in the perceptions of specialist pig veterinary surgeons and those that worked within mixed species practices. For example, respondents working within specialist pig practice more frequently considered antimicrobial use in sheep, beef and dairy cattle to be less responsible than use in pigs compared with mixed species practitioners. This concept whereby the issue of irresponsible use is considered by respondents to be a behaviour associated with individuals in a distinctly different societal group is referred to as 'othering' (Johnson et al., 2004). In this example specialist pig veterinary surgeons define themselves as responsible antimicrobial users which sit in a separate group of prescribers to veterinary surgeons who treat cattle and sheep. This concept is shown in human medicine where doctors consider other medical professionals to display less responsible antimicrobial prescribing behaviours when compared to their own prescribing decisions (Barden et al., 1998, Butler et al., 1998, Rodrigues et al., 2013, Simpson et al., 2007).

There was a spectrum of opinion as to what influence changes in farming systems and management practices would have on the amount of antimicrobial used in pigs; parallel diversity of opinion is seen in the literature (Stevens et al., 2007, Fertner et al., 2015, Scott et al., 2006). However, in-line with other studies respondents identified that it was essential that units were well managed in order to minimise antimicrobial requirements (Anon, 2015d, Postma et al., 2016, Coyne et al., 2016) and that good internal biosecurity, such as all-in-all-out movement of pigs, were practiced (Garforth et al., 2013, Postma et al., 2015b). The literature highlights vaccination as a highly regarded alternative method of preventing disease to antimicrobial use in pigs (Postma et al., 2015b, Anon, 2015d, Buller et al., 2015) and veterinary surgeons in this study identified that improvements in the efficacy and availability of vaccinations would be beneficial in reducing antimicrobial use. .

As previous policy to withdraw the use of growth promoters in livestock had not reduced the total amount of antimicrobials used in pigs in the Netherlands new legislation was introduced in order to achieve this goal (Speksnijder et al., 2015a). Participant opinion agreed with this notion as respondents felt that policy banning in-feed antimicrobials, benchmarking farms on antimicrobial use and the use of a penalty system for high antimicrobial users were likely to have a beneficial effect on reducing the total antimicrobial amount used in pigs. A penalty system whereby producers are penalised for prolonged high antimicrobial use has been successful in Denmark in reducing antimicrobial use in pigs (Aarestrup, 2012). This has been widely publicised and may have influenced the respondent opinions reported. In contrast, the majority of respondents reflected that legislation to ‘decouple’ the right to dispense from the right to prescribe antimicrobials would have no effect on the total amount used in pigs in the UK. This is supported somewhat by the wide spectrum of antimicrobial sales totals from across Europe in countries that have introduced such legislation; ranging from Norway and Sweden, with some of the lowest sales to Italy, with one of the highest (Anon, 2015j).

The useable response rate of 34.1% was satisfactory when compared with similar questionnaire studies on antimicrobial use. For example, a questionnaire on antimicrobial use in UK pig farms had a response rate of 25.5% (Stevens et al., 2007), whilst a study on antimicrobial use by cattle veterinary surgeons had a response rate of only 17.1% (Williams et al., 2012). In addition a further 27% of the questionnaires were returned by veterinary surgeons who stated that they did not see commercial pigs; thus it is highly likely that there was a similar or greater proportion of the non-responding sample population who also did not see sufficient pigs to complete the questionnaire and so opted not to return the questionnaire or inform the authors. However, the respondent population characteristics in terms of gender, position within the veterinary practice, geographic location and species caseload were found to be representative of the census population and as such the responses were considered to be of sufficient value to draw meaningful conclusions on antimicrobial prescribing behaviours in UK pig veterinary surgeons.

Other reasons for non-response to the questionnaire may be related to the increasing number of requests on veterinary surgeons to complete such questionnaires and the time pressures face by practitioners. In addition public, political and media pressure relating to antimicrobial resistance have placed increasing pressure on the food producing animal sector and veterinary profession; such pressure may result in a reluctance to share opinions by some (McCullough et al., 2015, Speksnijder et al., 2015b, Morris et al., 2016). Thus there is the potential for bias in the respondent population as veterinary surgeons that completed the questionnaire may be those that have a personal interest in antimicrobial use and, as such, their views may not be representative of that of the whole population. There may be limitations in self-reported behaviours in which participants may respond to questions in a way in which they believe the authors expect them to, rather than truly reporting actual practices (Bowling, 2005). The inclusion of open questions in the questionnaire attempted to reduce the effects of such bias by requiring respondents to propose novel ideas or perceptions not motivated by closed question options (O'Cathain and Thomas, 2004).

Conclusions and implications

This study has highlighted that the drivers behind antimicrobial prescribing decisions by pig veterinary surgeons are multifactorial and complex. It has identified the importance of non-clinical factors in influencing prescribing behaviours such as the veterinary surgeon-client relationship and farmer compliance. Any interventions to reduce antimicrobial use at a farm level would rely on the veterinary surgeons’ ability to communicate and educate the farmer so that antimicrobial use is responsible, minimal and only necessary if alternative methods to treat and prevent disease are not feasible. Whilst veterinary surgeon opinion frequently identified that legislative policy measures to reduce antimicrobial use may be effective.

Appendix 4

Appendix to chapter 5

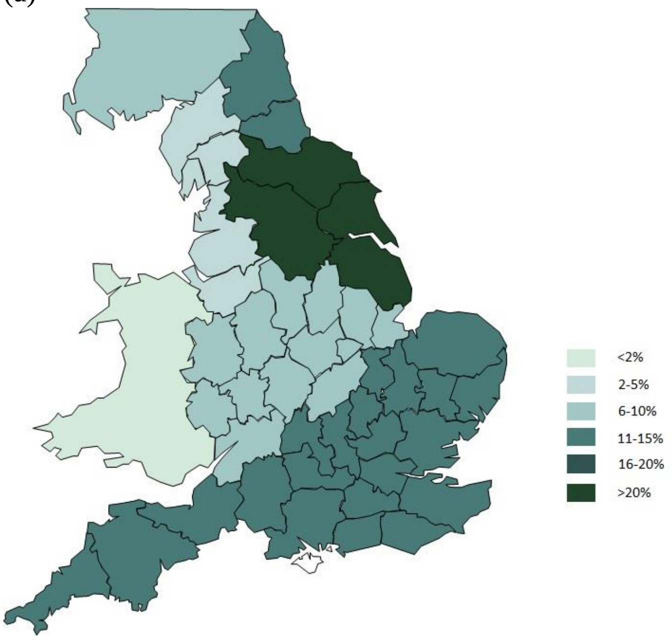
Veterinary surgeons' perceptions and approaches to prescribing and the responsibility of antimicrobial use in pigs in the UK: A cross-sectional questionnaire study

Appendix 4 – Appendix to chapter 5 Veterinary surgeons' perceptions and approaches to prescribing and the responsibility of antimicrobial use in pigs in the UK: A cross-sectional questionnaire study

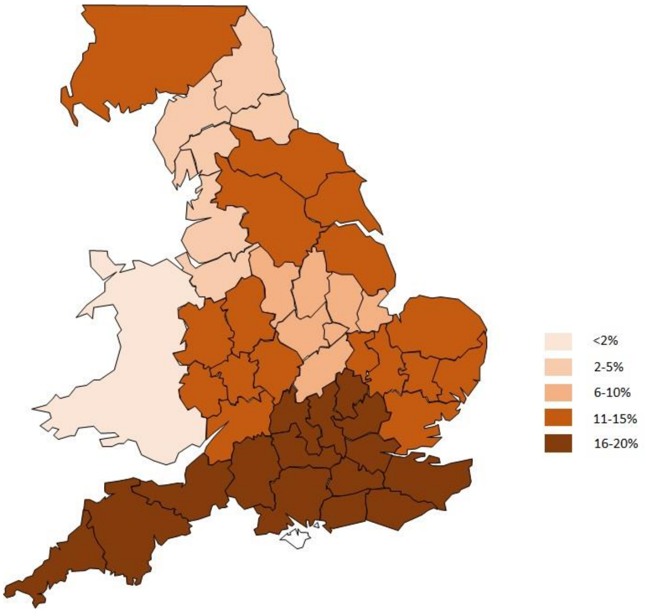
Figure 4.1

Map to show the geographic distribution of (a) proportion of respondents' veterinary practices by region compared with (b) the geographic location of the veterinary practices in the sample population by region (n=61).

(a)



(b)



Footnote - Due to the small number of veterinary practices that undertake commercial pig work in the UK practices are not identified individually due to maintain confidentiality so are only identified by their geographic location

Table 4.1

Crosstabulation to show respondent membership of Pig Veterinary Society (PVS) and British Veterinary Association (BVA)

		Are you currently a member of the British Veterinary Association?		Total
		No	Yes	
Are you currently a member of the Pig Veterinary Society?	**No**	1 (7.7%)	12 (92.3%)	13
	Yes	46 (100%)	0 (0%)	46
Total		47	12	59

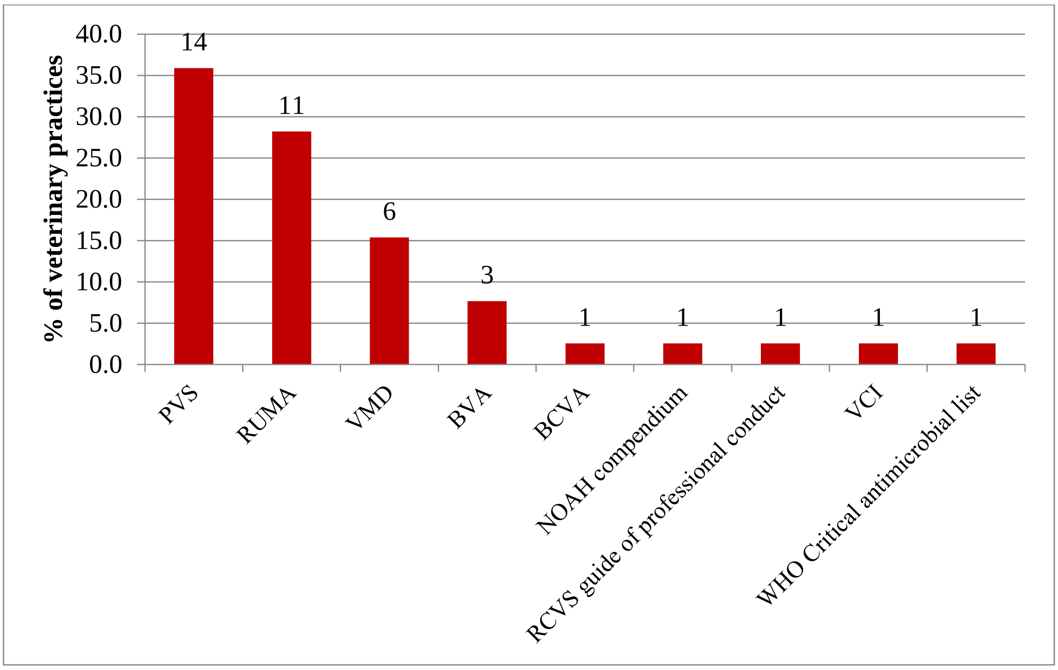
Table 4.2
Crosstabulation of PVS membership and the percentage of time respondents spend doing pig work

		What percentage of your time do you spend doing pig work?				
		Less than 25%	**25-50%**	**51-75%**	**More than 75%**	**100%**
PVS membership	**No**	13 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	Yes	14 (30.4%)	2 (4.3%)	7 (15.2%)	3 (6.5%)	20 (43.5%)

Table 4.3
The characteristics of the clinical pig caseload seen by 61 veterinary surgeons responding to the questionnaire

	N	%
Housing characteristics of pig caseload		
Majority housed indoors	41	67.2
Majority housed outdoors	6	9.8
Housed equally as commonly indoors as outdoors	5	8.2
Organic herds	3	4.9
Majority smallholding housing non specified	6	9.8
Breeding sow and feeding pig split of pig caseload		
Majority are breeding sows	4	6.6
Majority are feeding pigs	11	18.0
Equal number of breeding sows and feeding pigs	46	75.4

Figure 4.2
The antimicrobial prescribing guidelines adopted by veterinary practices



PVS – Pig Veterinary Society, RUMA - Responsible use of Medicines in Agriculture Alliance, VMD – Veterinary Medicines Directorate, BVA – British Veterinary Association, BCVA – British Cattle Veterinary Association, NOAH –National Office of Animal Health Compendium, RCVS – Royal College of Veterinary Surgeons, VCI – Veterinary Council of Ireland, WHO – World Health Organisation

Table 4.4
Univariable associations between respondent characteristics and factors influencing a veterinary surgeons' decision to prescribe an antimicrobial. Only significant (p<0.05) associations are shown.

You consider the farm staff to use antimicrobials responsibly					
		Less likely to prescribe	**Neutral, no effect**	**More likely to prescribe**	**P Value**
Respondent caseload	**Specialist pig**	0 (0%)	13 (65%)	7 (35%)	0.011
	Mixed species	1 (2.5%)	11 (27.5%)	28 (70%)	
You have a good relationship with the farmer					
Respondent caseload	**Specialist pig**	0 (0%)	18 (90%)	2 (10%)	<0.0005
	Mixed species	0 (0%)	17 (41.5%)	24 (58.5%)	
The farmer wants antibiotics					
Respondent caseload	**Specialist pig**	3 (15%)	17 (85%)	0 (0%)	0.035
	Mixed species	2 (4.9%)	31 (75.6%)	8 (19.5%)	

Table 4.5

Univariable associations between respondent characteristics and factors motivating the decision over which antimicrobial to prescribe. Only significant (p<0.05) associations are shown.

		Rarely or never	Sometimes	Often or always	p-value
Farmer compliance					
Type of vet	**Mixed species**	0 (0%)	5 (12.5%)	35 (87.5%)	0.02
	Specialist pig	2 (10%)	6 (30%)	12 (60%)	
Withdrawal periods					
PVS member	**Yes**	1 (2.2%)	10 (21.3%)	35 (74.5%)	0.04
	No	1 (10%)	2 (20%)	7 (70%)	

Table 4.6

Univariable associations between respondent characteristics and the frequency with which they conduct antimicrobial susceptibility testing. Only significant (p<0.05) associations are shown.

		Rarely or never	Sometimes	Often or always	P value
Susceptibility testing on initial visit					
PVS member	**Yes**	13 (28.3%)	22 (47.8%)	11 (23.9%)	0.009
	No	10 (76.9%)	2 (15.4%)	1 (7.7%)	
Susceptibility testing following treatment failure					
PVS member	**Yes**	8 (17.4%)	15 (32.6%)	23 (50%)	0.035
	No	6 (46.2%)	5 (38.5%)	2 (15.4%)	
Frequency of encountering treatment failure					
PVS member	**Yes**	20 (69.0%)	26 (89.7%)	0 (0.0%)	0.03
	No	9 (31.0%)	3 (10.3%)	1 (100.0%)	

Table 4.7

Univariable associations between respondent characteristics and their opinions on antimicrobial requirements of different management systems/features. Only significant (p<0.05) associations are shown.

		Lower or lowest	Moderate	Higher or highest	P value
Batch farrowing systems					
PVS member	**Yes**	34 (82.9%)	7 (17.1%)	0 (0%)	0.001
	No	2 (22.2%)	6 (66.7%)	1 (11.1%)	
All-in-all-out pig flow systems					
Type of vet	**Mixed species**	25 (75.8%)	8 (24.2%)	0 (0.0%)	0.02
	Specialist pig	19 (100%)	0 (0%)	0 (0%)	
Outdoor farrowing systems					
PVS member	**Yes**	33 (80.5%)	6 (14.6%)	2 (4.9%)	0.02
	No	4 (40%)	5 (50%)	1 (10%)	
Indoor slatted finishing systems					
PVS member	**Yes**	19 (45.2%)	21 (50%)	2 (4.8%)	0.02
	No	1 (10%)	6 (60%)	3 (30%)	

Table 4.8

Univariable associations between respondent characteristics and their opinions on whether measures were considered to be a barrier, beneficial or have no effect on the total amount of antimicrobial used in pigs. Only significant (p<0.05) associations are shown.

		Barrier	Neutral, no effect	Beneficial	P value
Farmer reluctance to change current practices					
Type of vet	**Mixed species**	37 (92.5%)	1 (2.5%)	2 (5.0%)	0.001
	Specialist pig	13 (65.0%)	7 (35.0%)	0 (0.0%)	
A ‘penalty system’ of penalties for high antibiotic usage in pigs, such as the “yellow card” system in Denmark					
Type of vet	**Mixed species**	2 (5.1%)	4 (10.3%)	33 (84.6%)	0.013
	Specialist pig	5 (27.8%)	2 (11.1%)	11 (61.1%)	
Banning the use of the fluoroquinolones and the third and fourth generation cephalosporins					
Type of vet	**Mixed species**	4 (10.8%)	16 (43.2%)	17 (45.9%)	0.001
	Specialist pig	7 (35%)	12 (60%)	1 (5%)	
PVS member	**Yes**	11 (25%)	24 (54.5%)	9 (20.5%)	0.002
	No	0 (0%)	3 (27.3%)	8 (72.7%)	
Further controls on the licensing of cheaper generic antibiotic products					
Type of vet	**Specialist pig**	2 (10%)	16 (80%)	2 (10%)	**0.022**
	Mixed species	1 (2.6%)	21 (55.3%)	16 (42.1%)	

Table 4.9

Univariable associations between respondent characteristics and who should be responsible for the monitoring responsible antimicrobial use in pigs. Only significant (p<0.05) associations are shown.

The retailer					
		Not very or not important	**Neutral**	**Quite or very important**	**P value**
PVS member	**Yes**	18 (40%)	15 (33.3%)	12 (26.7%)	0.003
	No	3 (23.1%)	0 (0%)	10 (76.9%)	
The EU government					
PVS member	**Yes**	22 (48.9%)	17 (37.8%)	6 (13.3%)	0.013
	No	3 (23.1%)	3 (23.1%)	7 (53.8%)	

Table 4.10
Univariable assoications between respondent characteristics and veterinary surgeon opinion on what was considered to define responsible antimicrobial use. Only significant (p<0.05) associations are shown.

		Unsure	Never or rarely justified	Always or often justified	P value
The use of fluoroquinolones in pigs					
PVS member	**Yes**	0 (0%)	16 (40%)	24 (60%)	0.01
	No	0 (0%)	8 (88.9%)	1(11.1%)	
The use of colistin in pigs					
PVS member	**Yes**	3 (7.5%)	6 (15%)	31 (77.5%)	0.001
	No	4 (36.4%)	5 (45.5%)	2 (18.2%)	
The use of third and fourth generation cephalosporins in pigs					
PVS member	**Yes**	0 (0%)	17 (41.5%)	24 (58.5%)	0.038
	No	0 (0%)	8 (80%)	2 (20%)	
Antibiotic use for prophylactic use					
PVS member	**Yes**	0 (0%)	8 (19.5%)	33 (80.5%)	0.050
	No	0 (0%)	6 (54.5%)	5 (45.5%)	
The use of in-feed antibiotics in pigs					
PVS member	**Yes**	0 (0%)	3 (7%)	40 (93%)	0.002
	No	2 (15.4%)	4 (30.8%)	7 (53.8%)	

Table 4.11
Univariable associations between respondent characteristics and veterinary surgeon opinion on the importance of possible consequences from the use of antimicrobials in pigs. Only significant (p<0.05) associations are shown.

		Not very or not important	Neutral	Very or quite important	P value
Increased antibiotic resistance in other production animal species					
PVS member	**Yes**	9 (20.5%)	18 (40.9%)	17 (38.6%)	0.004
	No	2 (15.4%)	0 (0%)	11 (84.6%)	
Increased antibiotic resistance in human beings					
PVS member	**Yes**	16 (36.4%)	13 (29.5%)	15 (34.1%)	0.031
	No	2 (15.4%)	1 (7.7%)	10 (76.9%)	

Table 4.12

Univariable assoicaitions between whether the respondent is a mixed species or specialist pig veterinary surgeon and opinion on the impact of a ban on the use of the fluoroquinolones, third and fourth generation cephalosporins and the macrolides. Only significant (p<0.05) associations are shown.

(a) Fluoroquinolones					
		Negative impact	**No effect**	**Positive impact**	**p-value**
The health and welfare of piglets					
Type of vet	**Mixed species**	21 (58.3%)	11 (30.6%)	4 (11.1%)	0.007
	Specialist pig	18 (94.7%)	0 (0%)	1 (5.3%)	
Levels of antibiotic resistance to these 'critical antibiotics' in pigs					
Type of vet	**Mixed species**	0 (0%)	8 (25%)	24 (75%)	0.003
	Specialist pig	1 (5.9%)	11 (64.7%)	5 (29.4%)	
(b) Third and fourth generation cephalosporins					
Improvements in pig management on farms					
Type of vet	**Mixed species**	8 (22.2%)	12 (33.3%)	16 (44.5%)	0.007
	Specialist pig	0 (0%)	14 (73.7%)	5 (26.3%)	

Figure 4.3 - Accompanying letter sent to veterinary surgeons with questionnaire

UNIVERSITY OF LIVERPOOL

Antibiotic Prescribing Practice in Pigs

Dear

We recently sent you a questionnaire as part of a survey to gain a better understanding of the use of antibiotic prescribing practices in pigs in the UK. This is a national survey of all veterinary surgeons, who see pigs that are kept as production animals, as part of their caseload. If you still wish to share your views an additional copy of the questionnaire and pre-paid return envelope have been included with this letter. All replies are strictly confidential and greatly appreciated.

Antibiotics are at the forefront of tackling infectious disease both in humans and animals, offering very effective ways of rapidly combating a wide range of pathogens. However, the rise in resistance, and lack of development of new compounds, is of concern to both human and animal health. Your participation in this study will offer a deeper understanding on the subject of antibiotic prescribing practices in pigs in the UK. A willingness to share your views in this area will help demonstrate engagement of the UK pig sector with the wider issues surrounding antibiotic use. The acquisition of such information will improve the knowledge base on which any future interventions may be made, thus gaining real opinion of practising vets is essential in order to represent the concerns and views of the UK pig industry.

The questionnaire consists of 4 sections. **Section A** asks for information about yourself and your veterinary practice; **section B** considers your current antibiotic prescribing practices; **section C** covers your views on antibiotic prescribing and responsibility. **Section D** contains four scenarios. These questions explore the type of antibiotic you might prescribe to the animals described in the scenarios and the reasons behind the decision. There are no right or wrong answers to the scenario questions, their purpose is to gather information about when and what type of antibiotics clinicians use to treat pigs.

You can fill in this paper questionnaire or an electronic version can be found online at https://adobeformscentral.com/?f=yf5faxE0GifrTnjC*sPSXw This link has also been circulated via the Pig Veterinary Society. All responses will remain completely confidential. The information that you provide will be maintained and analysed at the University of Liverpool and will not be made available to other parties. Participation in this study is entirely voluntary and you may withdraw at any time. Completing the questionnaire should take no longer than 20 to 30 minutes. Once the study is completed we will make our findings available via PVS and they will also be reported through the veterinary literature in due course.

The study is being led by researchers at Liverpool University and Mr Richard Pearson, a partner at the George veterinary practice in Wiltshire who specialises in pig work. This project is funded by the VMD and agreement for use has been obtained from the devolved administrations. If you would like a copy of the questionnaire in the Welsh language or have any questions concerning this study please don't hesitate to contact us by email at l.a.coyne@liv.ac.uk or phone at 01517956011.

Once completed please return the questionnaire to us using the enclosed pre-paid envelope.

Thank you for your time and interest in this project.
Yours sincerely,

L. Coyne

Lucy Coyne, Gina Pinchbeck, Sophia Latham, Nicola J Williams, Rob Smith, Susan Dawson

Department of Epidemiology and Population Health, University of Liverpool, Leahurst, Chester High Road, Neston, Cheshire, CH64 7TE

Figure 4.4 – Veterinary surgeon questionnaire

UNIVERSITY OF LIVERPOOL

Antibiotic Prescribing Practice in Pigs

We are conducting a survey of veterinary surgeons who work in pig practice in order to gain a better understanding of the use of antibiotics in pigs. For this we are contacting all veterinary surgeons in the UK whose caseload includes pigs that are kept as production animals to ask them to complete a questionnaire about antibiotic prescribing in pigs. Completing the questionnaire should take no longer than 30 minutes.

Your participation in this study will help us to better understand antibiotic prescribing practices in pigs in the UK. We are hoping for a high response rate and your willingness to share your views in this area will help demonstrate engagement of the UK pig sector with the wider issues surrounding antibiotic use

All responses will remain anonymous and are completely confidential. The information that you provide will be maintained and analysed at the University of Liverpool and will not be made available to other parties. Participation in this study is entirely voluntary and you may withdraw at any time.

Answering the questions

This questionnaire consists of four sections:
Section A: Practice and participant information.
Section B: Current antibiotic prescribing.
Section C: Responsibility.
Section D: A series of clinical scenarios.

Please answer all questions in each of the sections.

Please select the box or circle (□ or ○) for the answer that you consider is most appropriate from the multiple choice answer options given. Please select <u>one</u> option unless otherwise stated.

For open-ended questions please answer in writing in the text box provided as much or as little as you wish.

SECTION A – PRACTICE AND PARTICIPANT INFORMATION

Participant Name [ ]　　Name of Practice [ ]

The following questions ask you about you and your practice.

A1. What geographic region is the practice located in?

○ East Midlands
○ Eastern
○ North East
○ North West
○ South East
○ South West
○ West Midlands
○ Yorkshire and the Humber
○ Scotland
○ Wales
○ England - Other [ ]

A2. Is the practice that you work in?

- ○ Specialist pig practice
- ○ Farm animal only practice
- ○ Pig practice within a pig production company
- ○ Mixed practice
- ○ Other [ ]

A3. If your practice only includes pigs, please go to the next question (A4). If a mixed or farm animal only practice, please specify percentage (%) split of practice caseload by animal below:

Beef Cattle	Dairy Cattle	Exotics	Horses	Pigs
[ ]	[ ]	[ ]	[ ]	[ ]
Poultry	Sheep	Small Animal	Other, please specify	
[ ]	[ ]	[ ]	[ ]	

A4. How many vets in total do you have working in your practice?

[ ]

A5. How many vets are there are in your practice that routinely do some pig work?

[ ]

A6. Does your veterinary practice have any specific written prescribing guidelines for antibiotic use in pigs?

- ○ Yes
- ○ No
- ○ Don't know

A7. What is your gender?

- ○ Female
- ○ Male
- ○ Prefer not to say

A8. Which year did you graduate with your veterinary degree?

[ ]

A9. Which University did you graduate from?

- ○ University of Bristol
- ○ University of Cambridge
- ○ University College Dublin
- ○ University of Edinburgh
- ○ University of Glasgow
- ○ University of Liverpool
- ○ University of Nottingham
- ○ Royal Veterinary College
- ○ Other [ ]

A10. Do you hold any postgraduate qualifications?

- ○ Yes
- ○ No
- ○ Prefer not to say

If yes, please list

A11. Do you work full-time?

- ○ Yes
- ○ No
- ○ Prefer not to say

If part-time please state percentage of full-time work.

A12. What is your position within the practice?

- ○ Partner Veterinary Surgeon
- ○ Assistant Veterinary Surgeon
- ○ Locum Veterinary Surgeon
- ○ Other

A13. To what Veterinary Associations are you currently a member? Please select as many options as are applicable to you.

- ☐ Pig Veterinary Society
- ☐ British Veterinary Association
- ☐ British Small Animal Veterinary Association
- ☐ British Cattle Veterinary Association
- ☐ Sheep Veterinary Association
- ☐ British Equine Veterinary Association
- ☐ British Veterinary Poultry Association
- ☐ Other

A14. What percentage of your time do you spend doing pig work?

- ○ 100%
- ○ More than 75%
- ○ 51-75%
- ○ 25-50 %
- ○ Less than 25%

A15. Approximately what percentage of your caseload of pigs would be categorised as the following types of herds?

Indoor breeding only herds	Outdoor breeding only herds	Indoor feeding only herds	Outdoor feeding only herds
Indoor breeding and finishing herds	**Outdoor breeding and finishing herds**	**Breeding company stock**	**Organic herds**

Others, please specify

SECTION B - CURRENT ANTIBIOTIC PRESCRIBING

B1. What are your main source(s) of information on antibiotics and their use in pigs ? Please list all the main sources below.

B2. Have you or your practice adopted or used any specific prescribing guidelines for information on antibiotic prescribing for example professional or statutory bodies or other sources? If yes please list?

B3. What are your opinions on the current range of antibiotics available for use in pigs in the UK?

- ◯ The range is sufficient for my needs
- ◯ The range is insufficient for my needs

Are there any areas where you feel your therapeutic choices are particularly restricted?

B4. Do you think the range of antibiotics authorised in pigs has changed over time?

- ◯ Yes, there is a bigger range of antibiotics available for use in pigs now than in the past
- ◯ Yes, there is a smaller range of antibiotics available for use in pigs now than in the past
- ◯ No, there has not been a change in the range of antibiotics available for use in pigs over time

B5. How often on an initial visit do you carry out bacterial culture and antibiotic sensitivity testing when a bacterial infection is suspected?

	Never	Rarely	Sometimes	Often	Always
B5.	◯	◯	◯	◯	◯

If this varies with situation, please outline your common practice

B6. How often do you carry out bacterial culture and antibiotic sensitivity testing when a bacterial infection has not responded to the first antibiotic used?

	Never	Rarely	Sometimes	Often	Always
B6.	○	○	○	○	○

If this varies with situation, please outline your common practice

B7. Do you perform bacterial culture in-house?

- ○ Yes, always
- ○ Yes, sometimes
- ○ Never
- ○ Don't know

B8. How often do you encounter a lack of response to the antibiotics used?

	Never	Rarely	Sometimes	Often	Always
B8.	○	○	○	○	○

Please give any examples that you feel may be relevant

B9. How commonly do you feel that this lack of response may be due to antibiotic resistance?

	Never	Rarely	Sometimes	Often	Always
B9.	○	○	○	○	○

Please give any examples that you feel may be relevant

B10. How often do you have to change an antibiotic because of resistance demonstrated on culture and sensitivity testing?

	Never	Rarely	Sometimes	Often	Always
B10.	○	○	○	○	○

Please give any examples that you feel may be relevant

B11. Which of the following factors are likely to influence your decision as a pig practitioner to prescribe antibiotics?

	Less likely to prescribe	Neutral , no effect	More Likely to prescribe
You are confident in your diagnosis of a bacterial pathogen	○	○	○
You are not confident in your diagnosis	○	○	○
You consider the farm staff to use antibiotics responsibly	○	○	○
You consider the farm staff to use antibiotics irresponsibly	○	○	○
You consider that poor compliance may be an issue with the farm staff	○	○	○
You have a good relationship with the farmer	○	○	○
The farmer wants antibiotics	○	○	○
The farmer will blame you if antibiotics are not prescribed and later prove to be necessary	○	○	○
There is pressure from the retailer to lower antibiotic use	○	○	○
Feed company representatives suggested the use of in-feed antibiotics	○	○	○
There is competitive pressure from neighbouring practices, if you don’t prescribe, the farmer will go elsewhere	○	○	○
Pig welfare may be adversely affected if you don’t prescribe	○	○	○
Advice and information from senior colleagues	○	○	○

B12. Once you have decided to prescribe an antibiotic, how commonly would you consider the following factors when deciding which type of antibiotic to prescribe?

	Never	Rarely	Sometimes	Often	Always
The frequency of treatment	○	○	○	○	○
The duration of treatment	○	○	○	○	○
The ease of administration of the selected antibiotic formulation	○	○	○	○	○
The number of animals requiring treatment	○	○	○	○	○
Farmer compliance	○	○	○	○	○
The cost of the antibiotic	○	○	○	○	○
Experience of using the antibiotic for this condition	○	○	○	○	○
Experience of using the antibiotic on this farm	○	○	○	○	○
Withdrawal period of antibiotic	○	○	○	○	○
Culture and sensitivity results	○	○	○	○	○

B13. Which would be your preferred formulation of antibiotic for the following situations?

	Injectable	In-feed	In-water	Oral drench
Scour in a litter of piglets farrowed indoors in a conventional crate system	O	O	O	O
Acute gastrointestinal disease affecting 20 of 400 finishing pigs housed indoors	O	O	O	O
Acute gastrointestinal disease affecting ~125 of 2500 finishing pigs housed indoors	O	O	O	O
Chronic respiratory disease affecting >400 of 400 finishing pigs housed indoors	O	O	O	O
Chronic respiratory disease affecting <250 of 2500 finishing pigs housed indoors	O	O	O	O
Mastitis in an individual sow housed outdoors	O	O	O	O
Infertility of bacterial origin in a herd of sows housed outdoors	O	O	O	O
Infertility of bacterial origin in a herd of sows housed indoors	O	O	O	O
Strep. suis with a 2% mortality and a 5% morbidity in a group of 400 finishing pigs housed indoors	O	O	O	O
Strep. suis with a 2% mortality and a 5% morbidity in a group of 400 finishing pigs housed outdoors	O	O	O	O

B14. What are the factors that would cause you to choose to prescribe an in-feed antimicrobial formulation over an in-water formulation?

B15. Do you currently have or have you historically had any pigs under your care that are medicated throughout life from weaning through to slaughter?

	Never	Rarely	Sometimes	Often	Always
B15.	O	O	O	O	O

B16. How often do you think that pigs are medicated from weaning through to slaughter in the UK pig industry?

	Never	Rarely	Sometimes	Often	Always
B16.	○	○	○	○	○

B17. In your opinion which management features/systems in your opinion have the highest and lowest use of antibiotics in general?

	Lowest	Lower	Moderate	Higher	Highest
Batch farrowing systems	○	○	○	○	○
Continuous pig flow systems	○	○	○	○	○
All-in-all-out pig flow systems	○	○	○	○	○
High stocking density	○	○	○	○	○
Low stocking density	○	○	○	○	○
Indoor farrowing in crates	○	○	○	○	○
Outdoor farrowing systems	○	○	○	○	○
Solid floor straw-based indoor finishing systems	○	○	○	○	○
Indoor slatted finishing systems	○	○	○	○	○
Outdoor finishing systems	○	○	○	○	○
Well managed units	○	○	○	○	○
Poorly managed units	○	○	○	○	○
A unit sourcing pigs from multiple sources	○	○	○	○	○

B18. Please consider each of the measures below and consider whether they would be beneficial, have no or a neutral effect or be a barrier to reducing the total amount of antibiotics used across the UK pig industry?

	Barrier	Neutral , no effect	Beneficial
Farmer reluctance to change current practices	○	○	○
Vet reluctance to change current practices	○	○	○
Vets educating farmers on ways to improve herd health	○	○	○
Banning in-feed antibiotic formulations	○	○	○
A 'penalty system' of penalties for high antibiotic usage in pigs, such as the "yellow card" system in Denmark	○	○	○
Banning the use of the fluoroquinolones and the third and fourth generation cephalosporins	○	○	○
Banning the use of the macrolides	○	○	○
A benchmarking system, whereby antibiotic usage is benchmarked between farms	○	○	○
'Decoupling' the dispensing and prescribing of antibiotics so that vets are no longer able to dispense antibiotics directly and can only prescribe antibiotics to clients	○	○	○
Eradicating swine dysentery from the UK	○	○	○
Modernising indoor pig accommodation	○	○	○
Increased use of straw-based finishing systems	○	○	○
Increased use of outdoor breeding systems	○	○	○
More effective vaccines	○	○	○
A wider range of vaccines	○	○	○
De-populating and re-populating low health status pig herds with higher health status stock	○	○	○
Locating pig units in areas that are isolated from other units	○	○	○
Increased profitability of pig meat price	○	○	○
Increasing the cost of antibiotics for farmers	○	○	○
Decreasing the cost of antibiotics for farmers	○	○	○
Further controls on the licensing of cheaper generic antibiotic products	○	○	○
Reducing imports from other countries with high antibiotic use	○	○	○

Discuss any concerns you may have over these measures

SECTION C - RESPONSIBILITY

C1. There is diverse opinion on what is considered to represent prudent or responsible antibiotic use in pigs. Please indicate whether or not you consider the following to be a justified indication for the use of antibiotics in pigs.

	Never justified	Rarely Justified	Usually Justified	Always justified	Unsure
The use of the fluoroquinolones in pigs	○	○	○	○	○
The use of colistin in pigs	○	○	○	○	○
The use of third and fourth generation cephalosporins in pigs	○	○	○	○	○
The use of the macrolides in pigs	○	○	○	○	○
Antibiotic use for therapeutic reasons	○	○	○	○	○
Antibiotic use for prophylactic reasons	○	○	○	○	○
Antibiotic use to increase growth rates or production	○	○	○	○	○
The use of in-feed antibiotics in pigs	○	○	○	○	○

C2. Please rate the importance of the following when considering what you believe the likely or possible consequences are of the use of antibiotics in pigs as they are currently used in the UK.

	Not Important	Not Very important	Neutral	Quite Important	Very Important
Increased antibiotic resistance in pigs	○	○	○	○	○
Increased antibiotic resistance in other production animal species	○	○	○	○	○
Production of more and cheaper food	○	○	○	○	○
Improved welfare for pigs	○	○	○	○	○
Increased antibiotic resistance in human beings	○	○	○	○	○
Reduced risk of disease transmission to human beings	○	○	○	○	○

C3. Please rate the importance of the following when considering who should be responsible for monitoring prudent antibiotic usage in pigs?

	Not Important	Not Very important	Neutral	Quite Important	Very Important
The vet	○	○	○	○	○
The farmer	○	○	○	○	○
Farm Assurance Schemes	○	○	○	○	○
The UK Government	○	○	○	○	○
The Retailer	○	○	○	○	○
The European Union	○	○	○	○	○

C4. New EU legislation has been proposed that would separate the right to dispense from the right to prescribe for vets, so this may affect a vet's ability to dispense antibiotics directly to farmers. Considering the pig sector specifically what would be your opinion of the effects of this legislation if it was introduced?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It would be beneficial for the vet-farmer relationship	○	○	○	○	○
It would put some vet practices out of business	○	○	○	○	○
It would mean that vets are less able to monitor antibiotic use on farms	○	○	○	○	○
Farmers would be more likely to obtain antibiotics from 'black market' sources	○	○	○	○	○
It would put some farms out of business	○	○	○	○	○
It would result in a time delay in treating sick animals	○	○	○	○	○
It would reduce the amount of antibiotics prescribed in the pig sector	○	○	○	○	○

Others, please specify

Certain classes of antibiotics have been classified as being 'Critical to human health'. These include the fluoroquinolones, the third and fourth generation cephalopsorins and the macrolides.

C5. Considering the following what impact do you think banning the fluoroquinolones would have on the UK veterinary sector? No effect, a negative impact or a positive impact?

	Negative impact	No effect	Positive Impact	Don't know
The health and welfare of piglets	○	○	○	○
The health and welfare of finishing pigs	○	○	○	○
The health and welfare of sows	○	○	○	○
Improvements in pig management on farms	○	○	○	○
Levels of antibiotic resistance to these 'critical antibiotics' in pigs	○	○	○	○
Levels of antibiotic resistance to these 'critical antibiotics' in humans	○	○	○	○
The health and welfare of cattle	○	○	○	○
The health and welfare of sheep	○	○	○	○
The health and welfare of poultry	○	○	○	○
The health and welfare of companion animals	○	○	○	○
The health and welfare of equines	○	○	○	○

C6. Considering the following what impact do you think banning the third and fourth generation cephalosporins would have on the UK veterinary sector? No effect, a negative impact or a positive impact?

	Negative impact	No effect	Positive Impact	Don't know
The health and welfare of piglets	○	○	○	○
The health and welfare of finishing pigs	○	○	○	○
The health and welfare of sows	○	○	○	○
Improvements in pig management on farms	○	○	○	○
Levels of antibiotic resistance to these 'critical antibiotics' in pigs	○	○	○	○
Levels of antibiotic resistance to these 'critical antibiotics' in humans	○	○	○	○
The health and welfare of cattle	○	○	○	○
The health and welfare of sheep	○	○	○	○
The health and welfare of poultry	○	○	○	○
The health and welfare of companion animals	○	○	○	○
The health and welfare of equines	○	○	○	○

C7. Considering the following what impact do you think banning the <u>macrolides</u> would have on the UK veterinary sector? No effect, a negative impact or a positive impact?

	Negative impact	No effect	Positive Impact	Don't know
The health and welfare of piglets	○	○	○	○
The health and welfare of finishing pigs	○	○	○	○
The health and welfare of sows	○	○	○	○
Improvements in pig management on farms	○	○	○	○
Levels of antibiotic resistance to these ‘critical antibiotics’ in pigs	○	○	○	○
Levels of antibiotic resistance to these ‘critical antibiotics’ in humans	○	○	○	○
The health and welfare of cattle	○	○	○	○
The health and welfare of sheep	○	○	○	○
The health and welfare of poultry	○	○	○	○
The health and welfare of companion animals	○	○	○	○
The health and welfare of equines	○	○	○	○

C8. We are interested in your perception of how responsibly antibiotics are used in other veterinary sectors. In general would you consider the following sectors of the veterinary profession to use antibiotics more or less responsibly than the pig veterinary sector?

	Less responsibly	Neutral	More responsibly	Don't know
Beef cattle	○	○	○	○
Dairy cattle	○	○	○	○
Equine	○	○	○	○
Poultry	○	○	○	○
Sheep	○	○	○	○
Small Animals	○	○	○	○

Please outline any specific areas of concern you may have regarding responsible use

SECTION E - SCENARIOS

SCENARIO 1

On a 150 farrow-to-finish farm, a farmer has recently bought in some gilts from a breeding company in order to improve the genetics of his breeding herd. These gilts were quarantined and have been housed in a separate straw yard from the existing sow herd. A continuous farrowing system is employed on the farm and the farrowing crates have solid floors. Crates are usually hosed out between litters but a recent cold spell has meant that the washing out routines have been reduced. The piglets are showing signs of creamy yellow scour and dehydration in the first 3 days of life. Morbidity is around 20% and there is a mortality rate of 10% in piglets less than 48 hours old. You presume a preliminary diagnosis of E.Coli.

1.1 In the first instance would you carry out any specific diagnostics to assist in your diagnosis and treatment ?

- ○ Yes
- ○ No
- ○ Don't know

If yes, please state what diagnostics you would use.

1.2 How likely would you be to use antibiotics as part of the treatment for these piglets ?

	Very unlikely	Unlikely	Neutral	Likely	Very likely
1.2	○	○	○	○	○

1.3 If likely or very likely, please list the antibiotic regimens, and drug formulations that you would be likely to use as a first line and as a second line treatment. Include the duration of treatment.

First choice.

Second choice.

1.4 Would you treat unaffected litter-mates in affected litters?

- ○ Yes
- ○ No
- ○ Don't know

If yes, please list the antibiotic regimens, and drug formulations that you would be likely to use, in order of preference and include the duration of treatment.

SCENARIO 2

A farm is part of a three site production system receiving pigs from three separate low health status breeding herds. The farm finishes pigs to slaughter weight in an intensive slatted system. A group of finishers of mixed ages between 16 and 24 weeks of age are coughing. The group are of an uneven size and around 80% of the group appear to be affected. The pigs are not currently receiving any medication.

2.1 In the first instance would you carry out any specific diagnostics to assist in your diagnosis and treatment ?

- ○ Yes
- ○ No
- ○ Don't know

If yes, please state what diagnostics you would use.

2.2 How likely would you be to use antibiotics as part of the treatment for this group of finishers?

	Very unlikely	Unlikely	Neutral	Likely	Very likely
2.2	○	○	○	○	○

2.3 If likely or very likely, please list the antibiotic regimens, and drug formulations that you would be likely to use as a first line and as a second line treatment. Include the duration of treatment.

First choice.

Second choice.

2.4 Would you treat any of the other finishers on the farm with antibiotics?

- Yes
- No
- Don't know

If yes, which pigs would you treat?

If yes, please list the antibiotic regimens, and drug formulations that you would be likely to use and include the duration of treatment.

SCENARIO 3

A 120 farrow-to-finish indoor farm is maintained as a closed herd. Sows farrow in traditional slatted farrowing crates. Weaners are moved at 4 weeks into straw-based nursery accommodation, where a continuous pig flow system is employed. A new farm manager calls you as he is experiencing sporadic deaths in the weaners, and weaners exhibiting neurological signs including nystagmus, paralysis, tremor, and paddling. The farmer has also experienced isolated cases of arthritis. All of the nursery pens appear to be affected equally and there is a morbidity of around 1% and a mortality of 0.5%.

3.1 In the first instance would you carry out any specific diagnostics to assist in your diagnosis and treatment ?

- Yes
- No
- Don't know

If yes, please state what diagnostics you would use.

3.2 How likely would you be to use antibiotics as part of the treatment for this group of finishers?

	Very unlikely	Unlikely	Neutral	Likely	Very likely
3.2	○	○	○	○	○

3.3 If likely or very likely, please list the antibiotic regimens, and drug formulations that you would be likely to use as a first line and as a second line treatment. Include the duration of treatment.

First choice.

Second choice.

3.4 Would you treat any other groups of pigs or sows on the farm with antibiotics?

- ○ Yes
- ○ No
- ○ Don't know

If yes, which groups would you treat?

If yes, please list the antibiotic regimens, and drug formulations that you would be likely to use. Include the duration of treatment.

3.5 Would you use antibiotics for the prevention of further disease outbreaks on this farm?

- ○ Yes
- ○ No
- ○ Don't know

If yes, please list the antibiotic regimens, and drug formulations that you would be likely to use:

If yes, how often would you review this medication?

Thank you for your time. Your participation in the study is greatly appreciated.

Chapter 6

Pig farmers perceptions and attitudes on antimicrobial use in pigs in the UK: A questionnaire study

Pig farmers perceptions and attitudes on antimicrobial use in pigs in the UK: A questionnaire study

Introduction

There is increasing concern over the threat of antimicrobial resistance to human and animal health, with growing efforts by the medical and veterinary professions to reduce prescribing and ensure that use is minimal and justifiable (Anon, 2013g, 2015l, O’Neill, 2015). Antimicrobial use in food producing animals has come under the spotlight due to concerns over the potential public health implications from the transfer of resistant bacteria from animals to humans (Valentin et al., 2014, Graveland et al., 2011). Currently, the greatest percentage of antimicrobials sold in the UK are authorised for use in food producing animals with antimicrobials authorised solely for pigs having the highest sales of products for use in a single species (Borriello et al., 2015). These concerns have placed antimicrobial use in pigs under increasing scrutiny with various research initiatives and working groups investigating methods of reducing use and seeking viable alternatives to antimicrobial use (Anon, 2011b, Anon, 2015 d, m).

Veterinary surgeons are the only individuals permitted to prescribe antimicrobials in the UK. However, the role of administering and overseeing treatment usually falls to the farmer. Consequently, various UK and European organisations have targeted training and published guidelines aimed at advising farmers on the responsible use of antimicrobials in livestock (Anon, 2013g, p, 2015n). There is also a recent voluntary initiative in the UK to collect farm-level data on antimicrobial use in pigs which will comply with anticipated European legislation (Anon, 2013h, 2026d). These data should provide a baseline figure on total antimicrobial use in pigs in anticipation of the expected future reduction targets on antimicrobial use in agriculture (O'Neill, 2016).

Studies into antimicrobial prescribing by physicians and veterinary surgeons have identified that both clinical factors, relating to the characteristics of the disease and patient, and non-clinical factors, such as client expectation and economic limitations, influence antimicrobial prescribing decisions (Rodrigues et al., 2013, Speksnijder et al., 2015b, Gibbons et al., 2013). Food producing animals occupy a unique position whereby factors relating to animal husbandry and the economic viability of a farm influence the prescribing decisions of veterinary surgeons (Speksnijder et al., 2015b, Visschers et al., 2015, Visschers et al., 2014). It is essential that these and other factors are explored further with farmers due to the direct effect that they have on the antimicrobial requirements of their farm.

At present research into antimicrobial use in pigs has focused on quantifying the differences in the way in which antimicrobials are used, for example for treatment or prevention of disease, (Callens et al., 2012, Chauvin et al., 2002, Sjölund et al., 2016, De Briyne et al., 2014), economic considerations (Rojo-Gimeno et al., 2016) and differences in the management systems employed (van der Fels-Klerx et al., 2011, Postma et al., 2015a). To date there have been a few studies that have sought to explore farmer opinion on antimicrobial resistance and measures to reduce use (Visschers et al., 2015, Visschers et al., 2016), and one study scoping perceptions on use in fattening pigs in the EU (Visschers et al., 2014).

This study aimed to explore the perceptions of UK farmers on the ways in which antimicrobials are used on farms and to assess knowledge, concerns and opinions on antimicrobial resistance. In addition, to investigate farmer understanding of and practices which define responsible use and efforts to reduce antimicrobial use in pigs.

Methods

Questionnaire design and dissemination

The in-depth qualitative interviews conducted prior to this study informed the design and content of the questionnaire (chapters 3 and 4) which encompassed the eight major themes that emerged through the qualitative analysis of transcripts from interviews with pig farmers across England and Scotland. Key themes and shared opinions were explored in an attempt to determine opinions across a representative sample of pig farmers. In addition, more detailed questions on the drivers behind antimicrobial use on individual farms were explored through common disease scenarios which were described by interviewees. The questionnaire consisted of four sections as follows (Appendix 5. Figure 5.1):

- **Section A -** Farm and participant information
  This sought demographic information on the participant, the characteristics of the farm and the role of their respective veterinary surgeon.
- **Section B** – Current opinion on antimicrobial use in pigs
  This covered information sources on antimicrobial use in pigs by farmers, the role of diagnostic testing on farms, factors influencing the decision to administer an antimicrobial, the role of antimicrobials in preventing disease, alternatives to antimicrobials and the role of husbandry in antimicrobial use.
- **Section C** – Pig disease and antimicrobial use

This section looked at the relationship between diseases and antimicrobial use. Questions enquired about diseases commonly encountered on the participants' farm and antimicrobials used in these situations, the series of events which may occur on suspecting a particular disease is present on the farm and the different classes of antimicrobials.

- **Section D** – Responsible antimicrobial use
  This sought opinion on what farmers considered to be responsible antimicrobial use in pigs, the potential consequences of such use, potential benefits and barriers of various strategies to reduce antimicrobial use, the issue and awareness of critically important antimicrobials and participant perceptions on how prudent they considered antimicrobial use in pigs to be in the UK, outside of the UK and how responsible antimicrobial use was in human medicine.

The questionnaire consisted of both open and closed questions. Likert scales were commonly used to gauge opinion on agreement, importance and likelihood of a variety of motivations behind antimicrobial use behaviours and what constitutes responsible use in pigs. Previous knowledge of the pig industry and advice from a pig veterinary surgeon were used in order to ensure that the correct terminology was used and that the wording of the questions was clear. The questionnaire was piloted on five farmers through existing contacts, two with the researcher present so that feedback from the participant was able to be discussed in person. The length of time it took to complete the questionnaire was recorded alongside any comments or concerns with the questionnaire content.

The questionnaire was created in Microsoft Word and was distributed alongside a covering letter and a Freepost return envelope to facilitate responses. An initial copy was posted out on the week beginning the 5 January 2015, followed by a reminder postcard to non-responders three weeks later and a second copy of the questionnaire was sent three weeks later to non-respondents. All questionnaires had a unique identity number that matched to farmers in the database so that respondents did not receive reminders. The study was publicised by the National Pig Association through an article on their website to advertise the study and encourage participation. An email address and phone number of the primary researcher was also included in the covering letter should farmers have any additional questions or queries. The accompanying letter and questionnaire are shown in Appendix 5, Figures 5.9 and 5.10.

Sample selection

The geographical scope of the study was to seek information from a sample of 1500 pig farms across England, Scotland and Wales. A review of the regional breakdown of the breeding herd revealed that 93% of this population was located in England, with 6% in Scotland and <1% of the breeding sows located in Wales (2013). Based upon this regional breakdown a sample of 1380 farms was sought from England, 106 from Scotland and 25 from Wales (Appendix 5, Table 5.1). The same stratified random sampling methodology, based on type and farm size, was employed to select farmers as was used for the qualitative interviews (Chapter 4). The percentages of farms selected from each category are shown in Appendix 5, Table 5.2. As England represents 92% of the pig industry across all three countries it was considered acceptable to use the same sampling methodology to select pig holdings in Wales and Scotland. Any farms with less than 5 breeding sows or less than 50 fattening pigs were excluded as these were considered to be unlikely to represent holdings in which pigs were kept as production animals. The names and addresses of farmers were selected from the 2014 Defra June Survey of Agriculture and Horticulture for England and Wales and from the Scottish Government's Agricultural Census Analysis Team for Scotland. The selected address database provided by the government agencies included 58 direct duplicates of the name of the recipient and address. Therefore, in total 1442 questionnaires were disseminated to pig farmers in England, Wales and Scotland.

Ethical approval for the study was granted from the University of Liverpool prior to the piloting of the questionnaire and approval was also granted by the survey control unit at Defra prior to the dissemination of the final questionnaire.

Statistical Analysis

Data analysis was completed using Microsoft Excel 2010 (Microsoft Corporation, Redmond, Washington, USA) and SPSS Statistics 22.0 (IBM SPSS Statistics for Windows Version 22.0. Armonk, NY: IBM Corp). Descriptive statistics relating to the demographic information of respondents and their respective farms were produced. Closed questions were analysed by determining percentages for the numerous response categories for each section of the questionnaire. In some cases 5 point Likert scale question categories were combined in order to produce a 3 point Likert scale response. For example, never, rarely, sometimes, often, always condensed to give the follow categories; never or rarely, sometimes, often or always.

Chi-squared or Fisher’s Exact tests (fewer than 5 responses in one or more categories) were used to test the statistical significance of comparative respondent categories against bivariate closed questions in the questionnaire. Continuous variables were analysed using either the non-parametric Mann-Whitney test (for bivariate responses) or the Kruskal-Wallis test (for responses with three or more categories). P values <0.05 were deemed significant.

Two explanatory variables were included in univariable analysis and these included whether the breeding or feeding herd were housed indoors or outdoors and the number of breeding sows or feeding pigs in the herd. In some questions additional variables were included in order to add greater depth to the analysis; these are outlined in the results.

Open questions were analysed using a thematic approach. Initially free text answers were read in order to gain a general understanding of the views and opinions of respondents. The open question responses were transferred into Atlas.ti V.7.7.1. (ATLAS.ti Scientific Software Development) for further analysis. The free texts were re-read and ideas generated were categorised and linked to form distinct codes. These codes described the thematic content of the data. These data were then quantified by the frequency with which each theme was identified within the responses and descriptive data were transferred into SPSS Statistics 22.0.

Results

Response Rate

In total 511/1442 (35%) participants responded however, only 261 of these included completed questionnaires; 250 were returned not completed or the questionnaire was returned to the researcher as the address was incorrect. Reasons given for not completing a questionnaire were: 62% (n=155) were returned as pigs were no longer kept by the farmer; 21.2% (n=53) were duplicate listings of the same farm in the database due to one pig holding being listed under two or more addresses for example, the residential farm house and commercial business address; 7.3% (n=18) of the questionnaires were returned by Royal Mail as incorrect addresses; 5.3% (n=13) of respondents declared that they did not own the pigs located on the farm and were caring for pigs owned by another individual or pig production company, thus they were not responsible for antimicrobial decisions on the pig unit and could not complete the questionnaire; 3.3% (n=8) of respondents felt that they did not have sufficient knowledge to complete the questionnaire; 0.4% (n=2) of respondents were unable to complete a questionnaire due to illness; and 0.2% (n=1) of the individuals who received a questionnaire were deceased. Hence the overall useable response rate was

18.1% (261/1442). However, a usable response rate of 21.4% was observed when addressees who were not eligible for inclusion were excluded.

The usable response rate for each farm category (farms with breeding sows and fattening pigs, fattening pigs only and breeding sows only) is shown in Table 1 and was calculated based on the number of questionnaires which were sent out once duplicates were removed (total 1442) for each farm category and the number of completed questionnaires received within each farm category.

Table 1

Usable responses from different farm type categories; farms with breeding sows and fattening pigs, farms with breeding sows only and farms with fattening pigs only.

	Number of questionnaires sent out after direct duplicates removed (n)	**Number of questionnaires returned completed (n)**	**Percentage usable response rate in each farm category**
Breeding and fattening	714	131	18.3%
Breeding only	587	114	19.3%
Fattening only	141	16	11.3%
Total	1442	261	18.1%

<u>Background information on farmers and their respective pig units</u>

Respondent characteristics

The questionnaire respondents had a variety of roles on their respective farms. Over half were managers of a single pig unit (55.9%, n=147) whilst 15.2% (n=40) were independent farm owners and 13.7% (n=36) managed multiple pig units. Other roles reported less frequently were stock people (7.2%, n=19), contract finishers (1.9%, n=5), smallholders (1.5%, n=4) and semi-retired farmers (0.8%, n=2).

Farm characteristics and husbandry practices

The geographic distribution of the pig units of respondents' showed that the greatest percentage of respondents were located in the Yorkshire and Humber region (22.4%, n=59/257), with a high proportion of responses also in Eastern regions (18.3%) (n=48/257) and the South West (16.0%, n=42/257). Generally the responses reflected the underlying population of pig farmers (Appendix 5, Figure 5.2).

The majority of the respondents worked on indoor units (Figure 1). A small proportion of farms were classified as specialist with 4.6% (n=12/259) of respondents being from organic farms and 1.9% (n=5/259) being from specialist breeding units. Approximately two thirds of the respondent farms were either members of the Red Tractor Assured Food Standards scheme or the Quality Meat Scotland Assurance scheme, whilst 6.0% were members of an organic assurance scheme and 28.5% were members of the RSPCA Assured scheme (Formerly RSPCA Freedom Foods). All of the respondents that were RSPCA Assured Scheme members were also members of either Red Tractor or Quality Meat Scotland Assurance schemes (Table 2).

Figure 1 - Housing characteristics of respondent farms by farm classification. Respondents were asked to ‘tick all that apply’ so that both breeding sows and feeding pigs could be included for breeding to finish pig units.

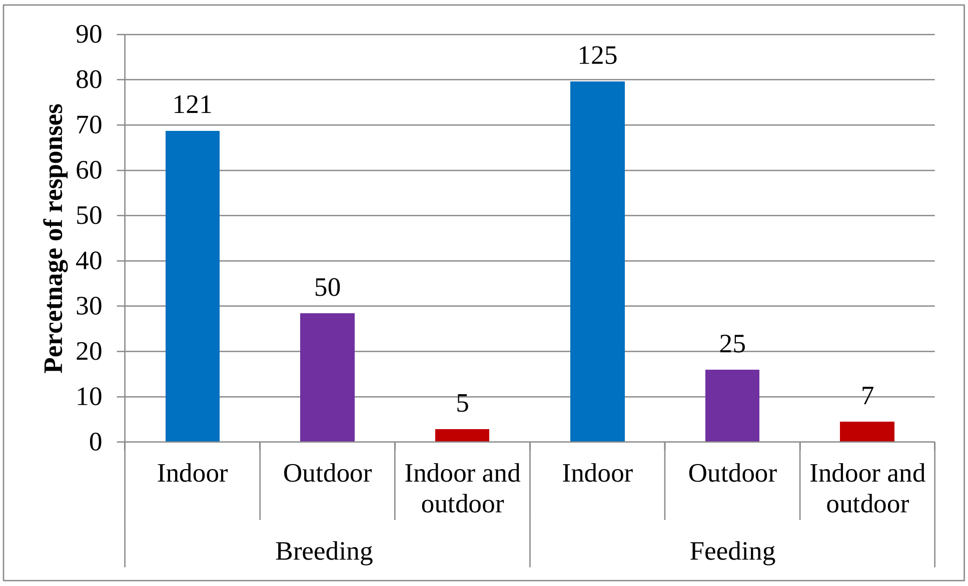


Table 2 - Membership of assurance schemes by respondent farms

	Red Tractor Assured Food Standards	Quality Meat Scotland Assurance	RSPCA Assured	Soil Association	Organic Farms and Growers Association	Organic Food Federation	Scottish Organic Producers Association
%	58.2	7.2	28.5	3.8	1.1	0.76	0.38
n	153	19	75	10	3	2	1

There was a substantial variation in the number of breeding sows and feeding pigs respondents were responsible for. The median number of breeding sows was 155 with a range from 2 to 40,000 sows whilst the median number of feeding pigs was 1150 with a range from 1 to 300,000 (Figure 2). The average number of pigs housed together as a group for each category of pigs are shown in Table 3.

Figure 2 - Number of breeding sows and feeding pigs on respondent farms

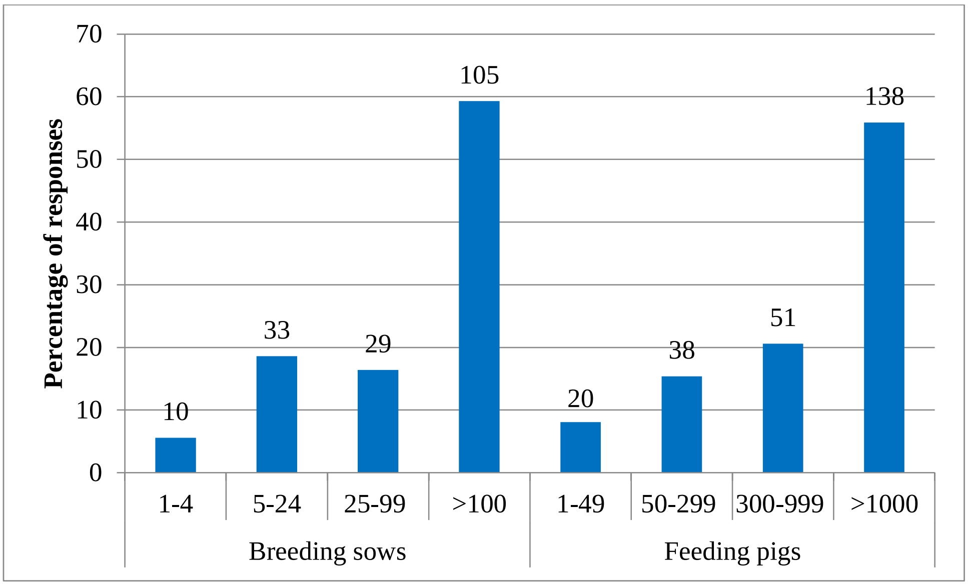


Table 3

Median sizes of groups housed together for different groups of pigs

	Weaner pigs	Fattening pigs	Dry sows
Median group size	30	20	5
Range	1-1000	1-1000	1-180

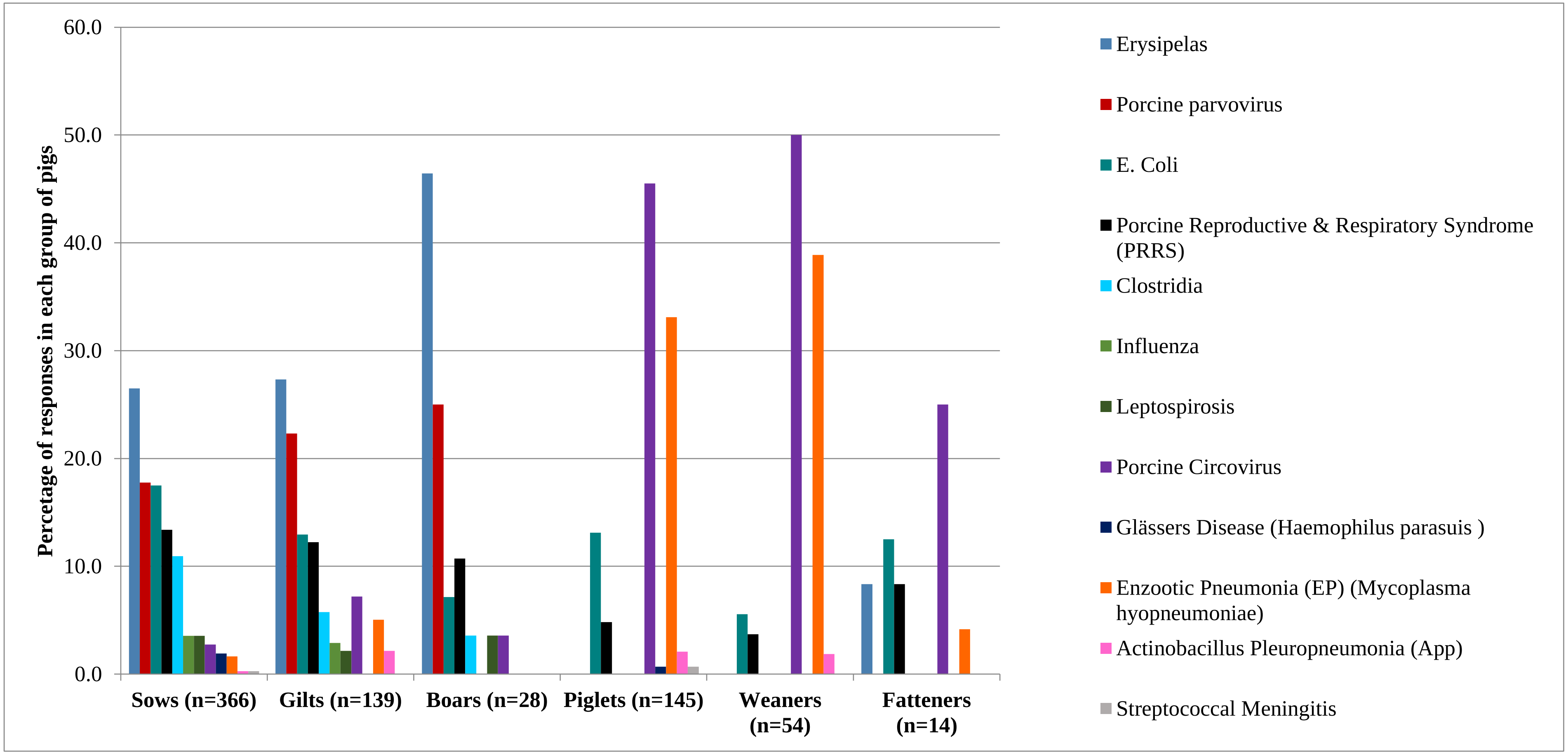
Indoor straw-based systems were the most commonly used for farrowing sows, dry sows and feeding pigs. However almost a third of the dry sows (28.7%, n=51/178) and farrowing sows (28.1% n=47/167) were housed outdoors (Appendix 5, Figure 5.3). The majority of the respondents' indoor pig accommodation was naturally rather than artificially ventilated.

The way in which pig movement was managed on the respondent farms varied. All-in-all-out pig flow systems were most frequently employed across the farms for dry sows (85.2%, n=138/ 162) whilst continuous pig flow was marginally more common in both breeding sows (52.3%, n=89/167) and feeding pigs (52.2%, n=120/ 230) (Appendix 5, Figure 5.4). Pellet feeding systems followed by meal/cob were most commonly employed across respondent farms. (Appendix 5, Figure 5.5).

Farm vaccination procedures

Sows were the most frequently vaccinated group of pigs on the respondents' farms with 49.1% (n=366) of all of the reported vaccination events being in this group whilst fatteners were the least frequently vaccinated group (1.0%, n=14). The other groups of pigs that were cited as receiving vaccinations were as follows piglets (19.4%, n=145), gilts (18.6%, n=139), weaners (7.2%, n=54), and boars (3.8%, n=28) (Figure 3). Across all of the groups erysipelas (20.1%, n=150/746) was the most frequent disease vaccinated against followed by Porcine Circovirus (16.1%, n=120). The *Streptococcus suis* vaccination was the least frequently used vaccination with its use only being reported on two respondents' farms.

Figure 3 - Frequency of reported vaccination events by disease type in each group of pigs on respondents' farms (n = 746 (total number of vaccination events))

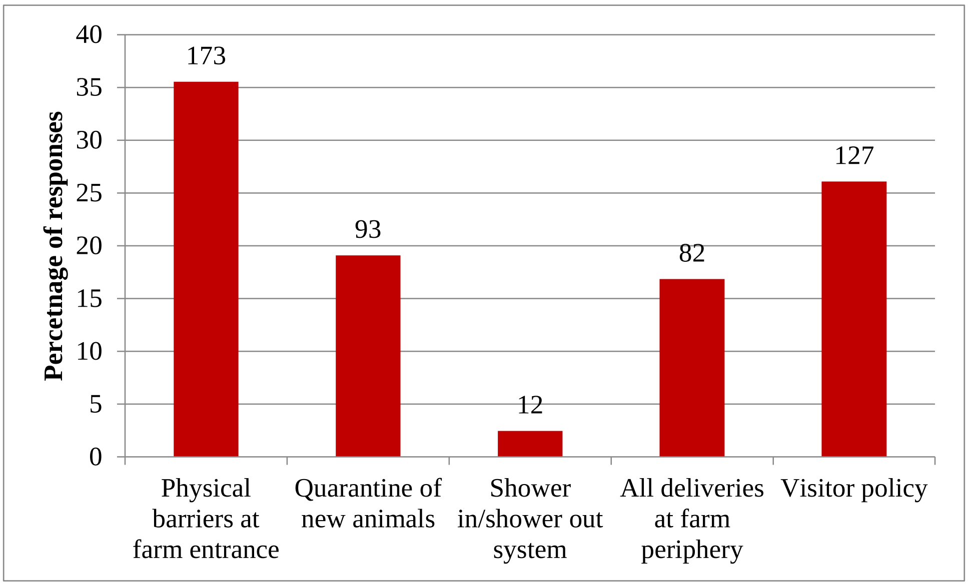


Farm biosecurity procedures

The majority of the respondents' herds were open (73.0%, n=189) with only 27.0% (n=70) being closed (no incoming stock or semen). The majority of the open units only brought semen and not live pigs on to the unit for breeding purposes (Appendix 5, Figure 5.6). The majority 82.3% (n=181, total responses=220) of respondents stated that either they or their veterinary surgeon were aware of the health status of any incoming stock. Pigs brought on to respondents' farms for feeding purposes were most commonly from a single source (74.6%, n=97/130). Figure 4 shows the frequency of the employment of different biosecurity measures.

Figure 4

The frequency of different biosecurity measures employed by farms.



The role of the veterinary surgeon on the farm

The majority of farmers used a specialist pig veterinary surgeon from a private practice (48%, n=123) or from a pig production company (14.4%, n=37). The remainder used a farm or mixed practice veterinary surgeon from private practice (37.6%, n=96). Over two thirds (69.1%, n=179) reported that their veterinary surgeon attended for quarterly visits with 8.0% (n=21) of farmers stating that their veterinary surgeon attended more often than every three months. The veterinary surgeon attended for emergencies only on 14.7% (n=38) of farms and 8% (n=21) had not been attended by a veterinary surgeon in the last 12 months.

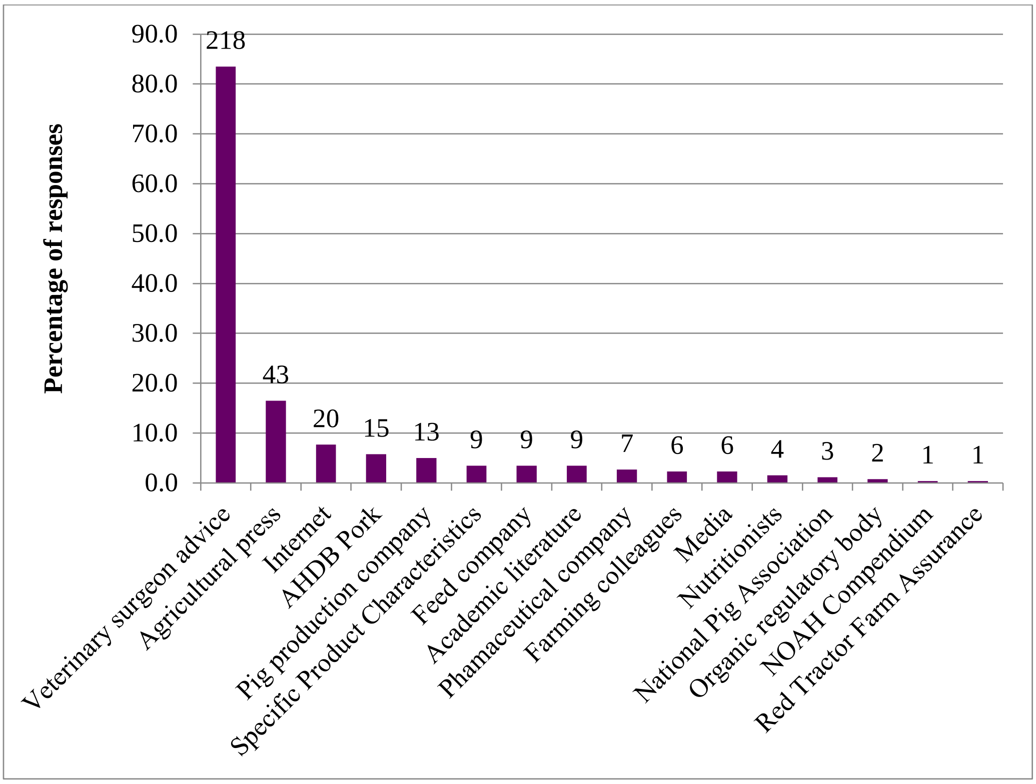
Perceptions on the behavioural influences behind antimicrobial use in pigs

Information sources on antimicrobial use

Farmers volunteered 16 sources of information that they consulted on antimicrobials in pigs (Figure 5); 83.5% of the respondents cited veterinary surgeons as one of their main sources of information. Other sources cited frequently included the agricultural press, the internet and AHDB Pork.

Figure 5

The information sources on antimicrobial use in pigs cited by respondents in n=242 farmers (more than one source could be indicated).



AHDB Pork- UK levy board representing pig production, SPCs – Specific Product Characteristics (antimicrobial product data sheets), NPA – National Pig Association, NOAH Compendium –National Office of Animal Health Compendium, Red Tractor – Red Tractor Farm Assurance scheme.

Factors influencing farmer decisions to use an antimicrobial

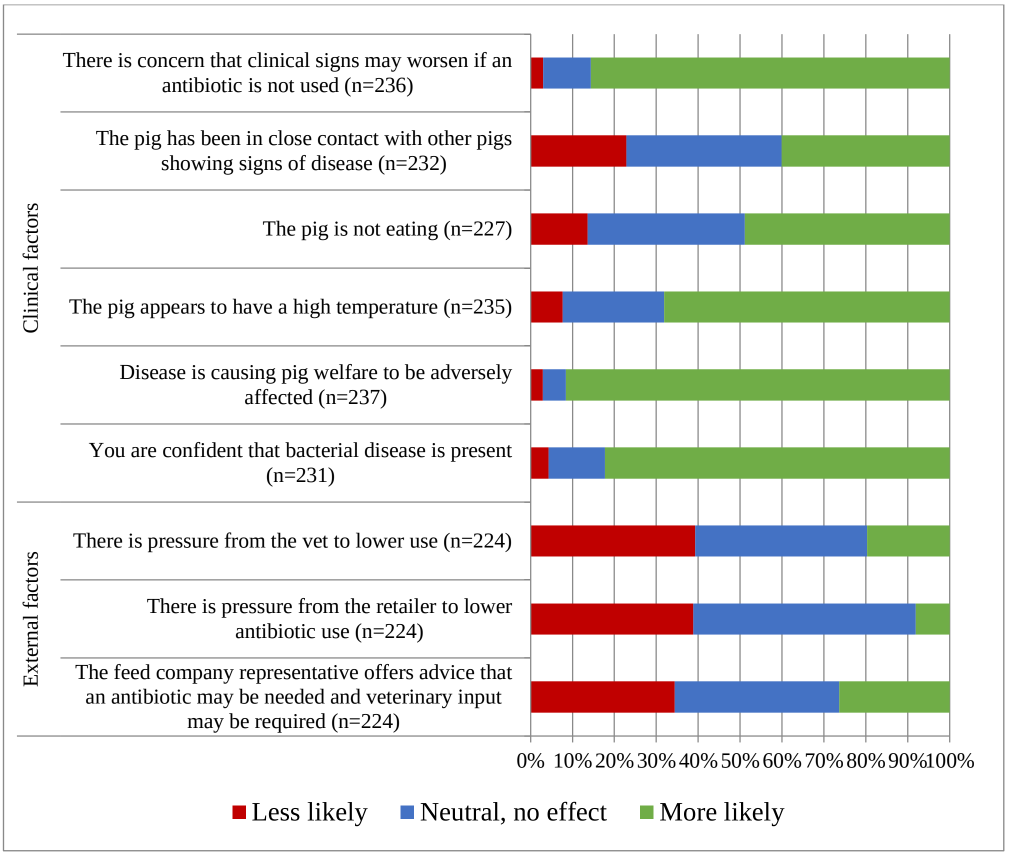
Overall, respondents considered clinical factors would influence antimicrobial use more frequently when compared with external factors (Figure 6). Confidence in the presence of a bacterial disease, concern that pig welfare may adversely affected and that clinical signs may worsen if an antimicrobial is not used were considered to drive antimicrobial use by over three quarters of respondents. In addition, the majority of respondents felt that a pig having a high temperature would result in them being more likely to use antimicrobials.

Analysis revealed some significant associations between clinical factors which influenced respondents' antimicrobial use decisions and respondent and farm characteristics (Appendix 5, Table 5.3). Individuals from farms with a greater median number of breeding sows more frequently used antimicrobials if they were confident that a bacterial disease was present than those with fewer breeding sows. Individuals from both indoor breeding (p=0.008) and feeding (p=0.041) farms were more likely to use antimicrobials if the pig appeared to have a high temperature than those from outdoor units. Similarly, farmers from indoor breeding systems were more likely to use an antimicrobial if the pig was not eating than those from outdoor systems (p=0.001).

When the respondents considered the influence of external factors on antimicrobial use approximately one third felt that pressure from retailers or veterinary surgeons would make them less likely to use an antimicrobial. There were no significant associations between external pressures that drove antimicrobial use decisions and respondent and farm characteristics (Appendix 5, Table 5.4).

Figure 6

Factors influencing the respondents' decision to administer an antimicrobial.



Opinions on antimicrobial resistance and the role of diagnostic testing

Diagnostic testing on routine farm veterinary visits was described as being carried out always or often by 15.3% (n=39/254) of respondents with 50% (n=127/254) never or rarely utilising this. However, this reported frequency increased if a new disease outbreak was suspected with 60.0% (n=144/240) stating diagnostic testing would be carried out always or often (Appendix 5, Figure 5.7).

Additional variables included in analysis of this question included the pig density of the location of the pig unit and whether the unit was an open or closed herd, both of which relate to the likely contact with other pig herds. Analysis revealed that routine diagnostic testing was reported more frequently on farms with a greater median number of both breeding sows (p=<0.001) and finishing pigs (p=<0.001), indoor feeding herds (p=0.018) and closed herds (p=0.002).

In a new disease outbreak situation respondents from farms with a greater median number of both breeding sows (p=<0.001) and finishing pigs (p=<0.001) reported conducting diagnostic testing more frequently than those with a smaller number of breeding sows and finishing pigs (Appendix 5, Table 5.5).

Over half of respondents indicated that they never or rarely encountered treatment failure after using antimicrobials (64.2%, n=151) whilst 17.4 % (n=41) sometimes and 18.3% (n=43) often or always did. Respondents also infrequently associated treatment failure with antimicrobial resistance; 74.6% (n=179/240) rarely or never considered antimicrobial resistance to be the cause of treatment failure. However, it should be noted that there was also uncertainty on the association between treatment failure and antimicrobial resistance with 18.3% of respondents (n=44/24) replying ‘don’t know’ (Appendix 5, Figure 5.8).

Analysis showed that respondents from indoor breeding systems more frequently identified treatment failure when compared to those from outdoor systems (p=0.001). There were no significant associations relating to the frequency with which antimicrobial resistance was considered to be the cause of treatment failure (Appendix 5, Table 5.6).

Advantages and limitations of different formulations of antimicrobials

Farmers volunteered the advantages and limitations of injectable, in-feed, in-water and oral drench formulations of antimicrobials for use in pigs (Table 4). Injectable formulations of antimicrobials were considered to be most suitable when individual animals required treatment, however their use was considered to be limited in some circumstances due to the difficulty in restraining larger pigs for administration, the stress this may cause to the pig and that their administration required skilled staff.

Whilst in-feed and in-water medication were considered to be advantageous for use in groups of animals, each was identified as having their own advantages and limitations. In-feed formulations were considered to be of limited value in inappetent pigs and conversely in-water was considered to be of value in such circumstances. However, in-water use was considered to be limited in some cases by the requirement for specialist equipment. Participants identified that both routes of administrations were beneficial due to the low levels of stress on the pigs when administering antimicrobials.

No oral drenches are currently authorised for use in adult pigs in the UK and as such their use is limited to piglets (Anon, 2013a). However, farmers considered oral drench formulations were a practical route of administration to ensure that an accurate dose is given for individual piglets. Difficulties in restraining piglets for administration and the time and labour requirement of the process were cited as limitations to their use. The levels of stress associated with administration divided opinion with some holding the opinion that administration was highly stressful, and therefore was a disadvantage and others reflecting that an oral drench was a low stress route of administering an antimicrobial.

Table 4

Advantages and limitations cited by respondents of injectable, in-feed, in-water and oral drench formulations of antimicrobials for use in pigs. The n value reflects the number of times each suggestion was volunteered by respondents.

	Advantages	Limitations
Injectable	Targeted individual treatment (n=133) Highly accurate dosing (n=50) Rapid speed of action (n=34)	Time taken to administer (n=49) Difficult to restrain pigs to administer (n=46) Only practical to use in small numbers of pigs (n=39) Administration causes stress for pigs (n=24) Requires skilled staff to administer (n=14)
In-feed	Practical to treat groups (n=79) Easy to administer as does not require the pigs to be restrained (n=69) Disease prophylaxis (n=14) Low stress for pigs (n=12) Does not require skilled staff to administer (n=12)	Ineffective if pigs are inappetant (n=61) Impractical to administer to individual animals (n=37) Difficult to dose accurately (n=30) High cost (n=15) Withdrawal periods (n=13)
In-water	Ease of administration (n=48) Practical to treat groups (n=47) Useful as inappetant pigs are most likely to drink water (n=31) Therapy can be started and stopped rapidly (n=24) Good efficacy (n=15) Rapid speed of action (n=11) Accurate dosing (n=11) Can be targeted to smaller groups (n=10)	Requires specialist equipment (n=31) Difficult to assess if individual pigs have received the correct dose (n=29) High cost (n=18) Cannot target individual pigs (n=18)
Oral drench	Can be used to treat individual pigs (n=29) Highly accurate dosing (n=24) Low stress for pigs (n=18)	Difficult to restrain pigs to administer (n=35) Labour intensive to administer (n=16) Time consuming to administer (n=16) High stress for pigs (n=13) Can only be used in piglets – not practical for larger pigs (n=11)

Factors influencing the decision whether to continue or discontinue the use of in-feed antimicrobials for disease prevention

Approximately half of respondents (50.4%, n=118/234) stated that they have used antimicrobials on their farms for disease prophylaxis. An open question was included in the questionnaire to explore what factors were likely to influence the decision whether to continue or discontinue their use. Clinical factors such as the presence of a disease on a farm, mortality rates and efficacy were the most common motivations for the continued use of in-feed antimicrobials whilst non-clinical factors such as a reduction in herd performance, cost effectiveness and veterinary advice were less commonly cited (Table 5). In contrast, the decision to discontinue in-feed antimicrobials was driven mainly by non-clinical features such as high cost, veterinary advice, and concerns over antimicrobial resistance with clinical features less commonly considered.

Table 5

Themes volunteered by respondents as influencing the decision to continue or discontinue in-feed antimicrobials on their farm.

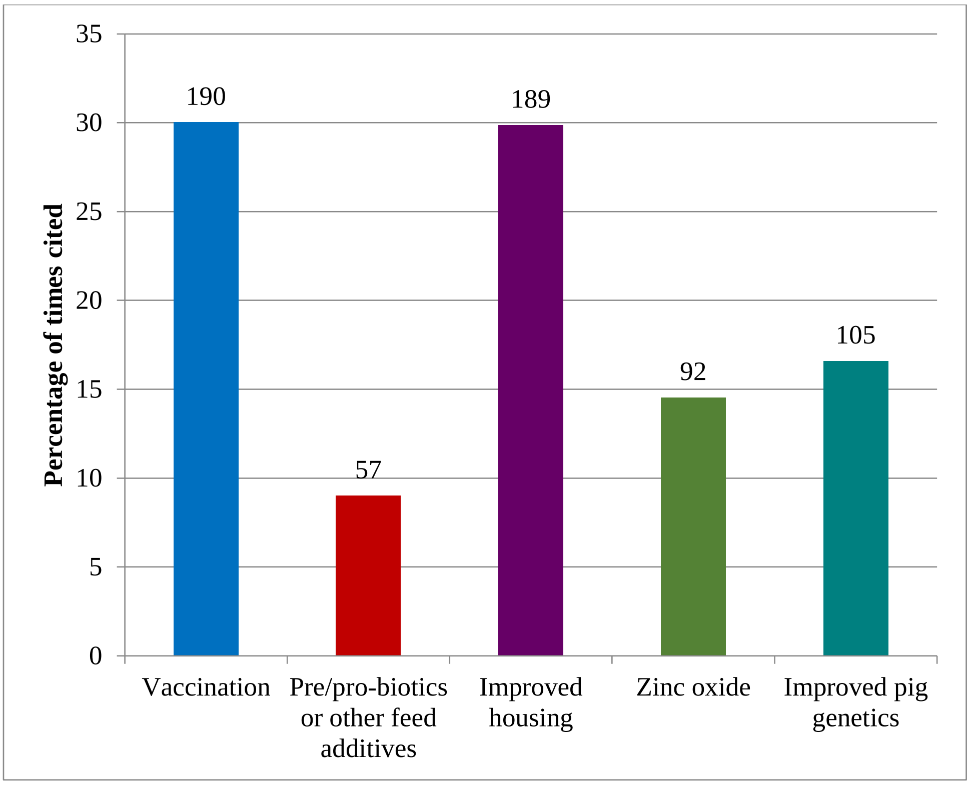
	N	**Example Quotation**
Factors identified by farmers as influencing the decision to continue in-feed antimicrobials on their farm		
Known disease issues in pigs	21	*'Had an underlying problem on farm and needed it cleared up'*
Veterinary advice	21	*'Only if vet considers this wise'*
To prevent a reduction in herd performance	16	*'Improved performance of pigs'*
Prevention of disease is better than treating disease once clinical signs are apparent	13	*'Prevention always better. Especially weaning - time of most stress'*
Good efficacy	11	*'We used it because it was easy and effective'*
Disease problems occur if in-feed is withdrawn	9	*'Having tried to withdraw antibiotic, disease re-establishes'*
To maintain a high level of welfare	8	*'Welfare of pig. If stop animal may break down'*
Cost effective to continue with medication	8	*'Prevention has good cost/benefits'*
To prevent high mortality rates	6	*'Insurance against unforeseen losses especially if disease is causing no deaths.'*
Respiratory disease problems	5	*'All of the pigs are coughing'*
Time of year when disease is common	5	*'There are certain times of year that it is unwise to stop, you stop in spring when environment is on your side.'*
Factors identified by farmers as influencing the decision to discontinue in-feed antimicrobials on their farm		
High cost	31	*'Can be costly if there are feed spillages and if over treating all pigs instead of injecting 10-20 instead.'*
Improvements in pig health	19	*'The disease burden has reduced'*
Discontinue use when clinical signs no longer present	17	*'If clinical signs have disappeared or receded it is us having the confidence to stop feed medication.'*
Veterinary advice is to discontinue in-feed antimicrobials	15	*'The vet decides about when to start and stop in feed antibiotics'*
Ineffective if used long term	9	*'Ineffective if used too often'*
Concerns over antimicrobial resistance	7	*'It helps cause resistance and it is no longer a responsible option to use them long term.'*
Improvements in weather conditions	6	*'The weather and time of year is a major factor. Pigs can be moved away on another site in summer months so shed can be washed, rested and re-furbed if needed.'*
Personal concern over the ethics of the long-term use of in-feed antimicrobials	5	*'The feeling that things have changed'*
Industry pressure to discontinue use of in-feed antimicrobials	5	*'Some companies have routinely stopped in feed to impress retailers'*

Alternatives to the use of antimicrobials in pigs

Vaccination and improved housing were identified most frequently by respondents in a closed question format to be an alternative to antimicrobial use whilst pre and probiotics were considered the least appropriate (Figure 7). An expansion open question allowed farmers to offer additional alternatives. The use of low stocking densities and outdoor systems were the most commonly cited alternatives to the use of antimicrobials. Other factors considered commonly included those relating to internal biosecurity such as improved hygiene and disinfection practices in housing and good *'stockmanship'* skills (Appendix 5, Table 5.7).

Figure 7

Respondent opinion on alternative ways of preventing disease to the use of antimicrobials.



The relationship between antimicrobial use and management features and systems

The majority of respondents identified that pig units with high health status pigs and that are well managed would have lower or the lowest antimicrobial use. In contrast, pig units with high stocking densities were identified by over three quarters of respondents as being either higher or the highest antimicrobial users (Figure 8).

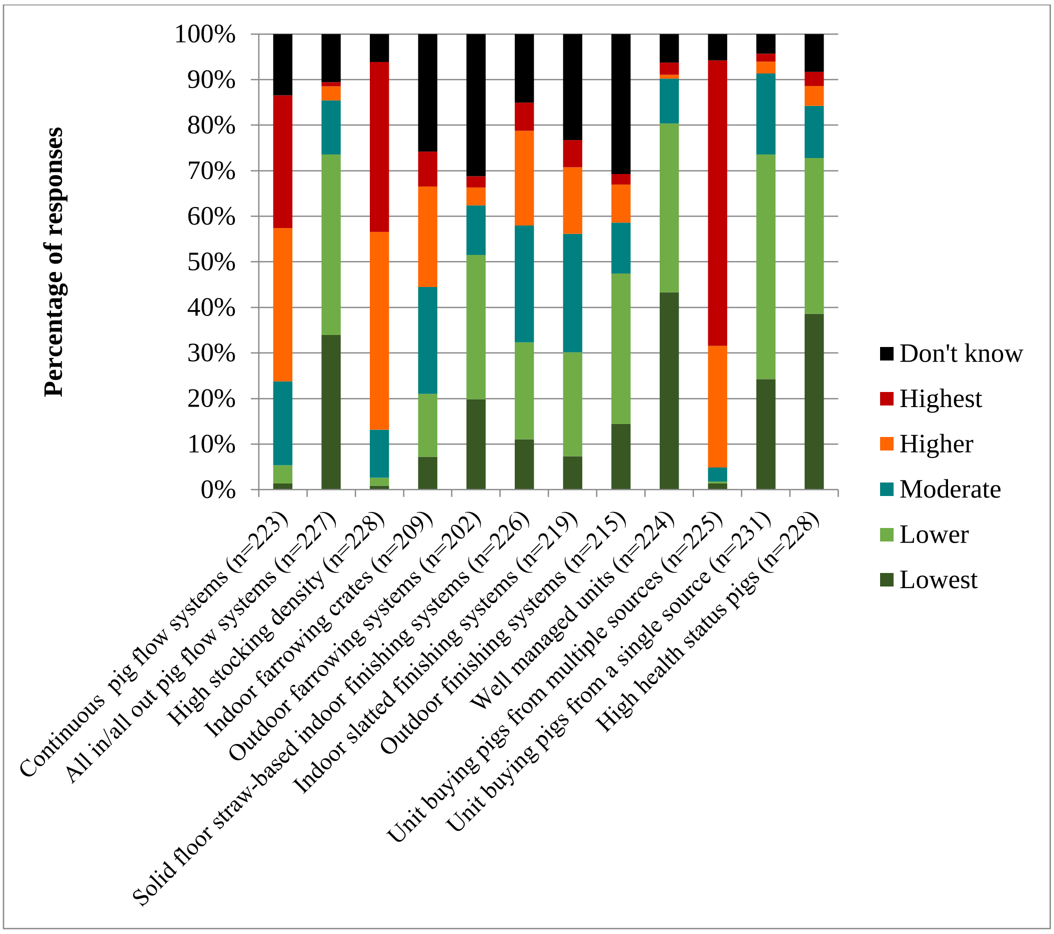
Continuous flow pig movement systems were associated with higher or the highest antimicrobial use by over half of the respondents. Conversely, over half of respondents linked all-in/all-out pig movement systems with lower use. In parallel, the practice of sourcing pigs from a single source was considered to lower antimicrobial use requirements when compared to sourcing pigs from multiple sources.

Respondent opinion on the relationship between housing characteristics and antimicrobial use was divided. Overall, farmers more frequently considered outdoor farrowing systems to be lower or the lowest antimicrobial users when compared with indoor farrowing systems. There was a division of farmer opinion on the relationship between finishing systems and antimicrobial use with similar divided opinions shown for straw-based and slatted floor finishing systems. The majority of respondents felt that outdoor finishing systems resulted in either lower or the lowest antimicrobial use.

Analysis revealed no significant associations between the management system employed on the respondents' farm and their opinion on which management features were low or high antimicrobial use systems (Appendix 5, Table 5.8).

Figure 8

Respondent opinion on the antimicrobial use requirements of different management features and systems



Management features and facilities associated with low antimicrobial use

An open question was used to elicit views of low antimicrobial use systems (Table 6). Internal and external biosecurity were commonly cited by farmers as integral in minimising the antimicrobial requirements on a farm. The specific characteristics of housing and facilities resulted in a spectrum of responses. However, the importance of good ventilation was frequently associated with low antimicrobial use. Management features such as all-in/all-out pig flow, high health status herds and low stocking densities were frequently associated with low antimicrobial use by participants. The importance of having highly skilled staff on pigs units was also commonly identified as being associated with low antimicrobial use.

Table 6

Management features and facilities associated with low antimicrobial use volunteered by respondents. Total number of responses n=107.

Management Feature/Facilities associated with low antimicrobial use	**Respondent quotations**
Biosecurity	
Good biosecurity (12)	*'Good biosecurity, quality of clean down and disinfectant, rest between batches, quality of stock entering unit'*
Efficient vermin control (8)	*'Pro-active approach to rodent control'*
Isolation of sick pigs in hospital pens (2)	*'Good stockmanship - regular checking and separating of sick pigs before it is too late. Good use of hospital pens.'*
Efficient disinfection procedures (25)	*'Cleaning and disinfectant after each batch'*
Farm Characteristics	
Closed herd (6)	*'Totally closed herd is essential.'*
Outdoor (4)	*'Low usage: use of outdoor systems based on pigs natural to this country - not hybrids'*
Straw-based systems (1)	*'Straw based systems with good natural ventilation and good air flow within the building leads to lower disease pressure and the lowered use of antibiotics.'*
Good quality straw (2)	*'Quality of straw- I think mouldy straw can lead to respiratory disease. It certainly causes coughing through either dust irritation or mycotoxins'*
Organic systems (1)	*'Organic - no antibiotics used or required'*
High quality modern housing (5)	*'Good modern buildings with high health status pigs'*
Good ventilation (14)	*'Quality of building controlling ventilation'*
High quality feed (4)	*'Use good products to feed'*
Wet feeding systems (3)	*'Wet feed finisher seem to have less salmonella problems'*
Clean water supply (2)	*'clean water'*
Correct temperature control (4)	*'Keeping pigs at an appropriate temperature. This all prevents pigs getting sick and therefore reduce the need for antibiotics.'*
Husbandry and management procedures	
Multi-site production (2)	*'As part of an integrated multi-site operation we depopulate here every 7 years and replace with high health stock. Improve performance and reduced medications required'*
Single source (1)	*'Single source and single sex'*
Low stocking density (15)	*'Extensive free range, low stock density'*
Minimising pig stress (5)	*'Probably the most important thing would be low stress levels in the animals. We have seen various conditions which would often be treated with antibiotics recover without their use if the animal is given individual attention and easy access to water, feed, warmth, company and allowed to express the most natural behaviour i.e. digging!'*
Highly skilled stockpeople (16)	*'Good stockperson with time to observe deterioration of individual/batches and reduce the extent to which antibiotics are used through early and accurate diagnosis and treatment'*
All-in-all-out pig flow (5)	*'All in all out and prevention of spread on unit will lower antibiotic usage.'*
Batch farrowing (1)	*'For low use batch farrowing'*
High health status (9)	*'high health status'*
De-population of low health status stock (3)	*'De-pop to lower usage through disease elimination.'*
Breeding disease resistant pigs (4)	*'Emphasis on health when selecting genetics.'*
Extensive use of vaccination for disease prevention (8)	'*Low use = good robust vaccination program with sows, gilts and progeny'*
Later weaning (1)	*'Wean at 5-6 weeks old.'*
Advice	
Routine veterinary surgeon advice (2)	*'routine vet monitoring'*

Perceptions on the responsibility of antimicrobial use in pigs

Justifications for the use of antimicrobials in pigs

There was shared opinion amongst respondents that the use of antimicrobials for the treatment of disease in pigs was usually or always justified. However, opinion was divided on whether their use for disease prevention was justified (Table 7). The majority were in agreement with the current EU legislation that the use of antimicrobials for growth promotion is never justified, however 22.1% felt that such use was rarely justified whilst 7.2% felt that it was usually justified. The majority of farmers also held the opinion that the use of in-feed antimicrobials was usually or always justified. There were no significant associations between respondent opinion on what is a justified use of antimicrobials in pigs and respondent farm characteristics (Appendix 5, Table 5.9).

Table 7

Respondent opinion on whether different types of antimicrobial use in pigs are considered to be justifiable.

		Never justified	Rarely justified	Usually justified	Always justified	Don't know
Antibiotic use for treatment of pigs with disease	n	1	5	104	128	0
	%	0.4%	2.1%	43.7%	53.8%	0.0%
Antibiotic use for disease prevention	n	43	68	101	16	9
	%	18.1%	28.7%	42.6%	6.8%	3.8%
Antibiotic use for growth promotion	n	151	52	17	0	15
	%	64.3%	22.1%	7.2%	0.0%	6.4%
The use of in-feed antibiotic formulations in pigs	n	37	53	102	18	22
	%	15.9%	22.8%	44.0%	7.8%	9.5%

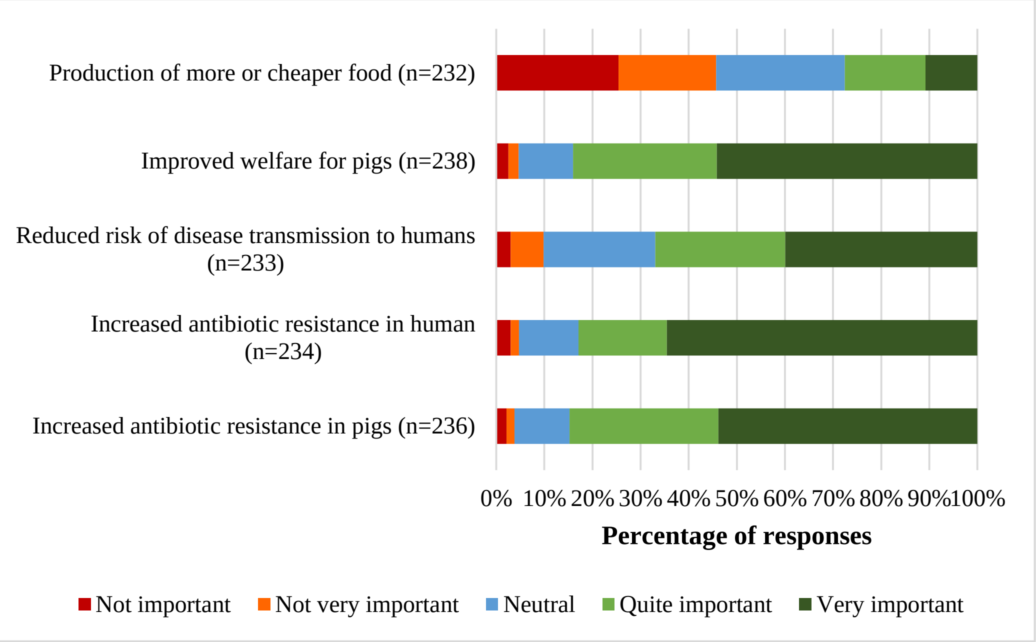
Consequences from the use of antimicrobials in pigs

Respondent opinion on the consequences from the use of antimicrobials in pigs revealed that three quarters felt that their use was either quite or very important for offering improved welfare for pigs, however, the production of more or cheaper food was considered not to be important by the majority. The majority of respondents identified that the use of antimicrobials in pigs was quite or very important in affecting antimicrobial resistance levels in pigs whilst over half of respondents also felt that it was very important in the development of resistance in humans (Figure 9). Additionally, over half of respondents felt that the use of antimicrobials were quite or very important in reducing the risk of disease transmission to humans.

Analysis on respondent opinion on the consequences from the use of antimicrobials in pigs and farm characteristics revealed no significant associations. (Appendix 5, Table 5.10).

Figure 9

Respondent opinion on the importance of different consequences from the use of antimicrobials in pigs

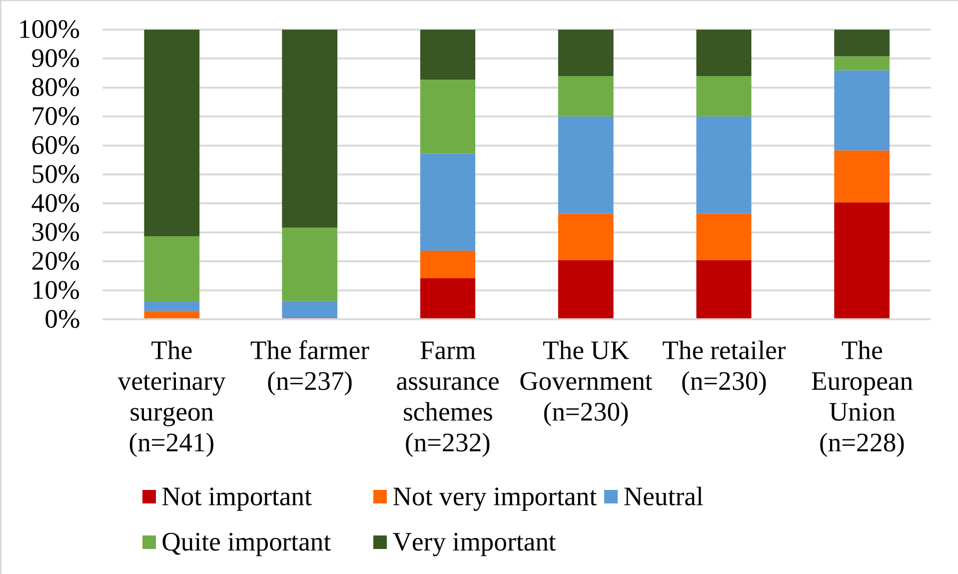


Monitoring the prudent use of antimicrobials in pigs

The majority of respondents considered both the veterinary surgeon and the farmer to be quite or very important in monitoring the prudent use of antimicrobials in pigs. However, opinion was divided on the importance of farm assurance schemes and the retailer (Figure 10). Overall, the UK government was considered to be more important in monitoring the use of antimicrobials in pigs when compared with the European Union. Analysis revealed no significant associations between respondent opinion and farm characteristics (Appendix 5, Table 5.11).

Figure 10

The importance that respondents placed on different individuals and organisations for monitoring the prudent use of antimicrobials.

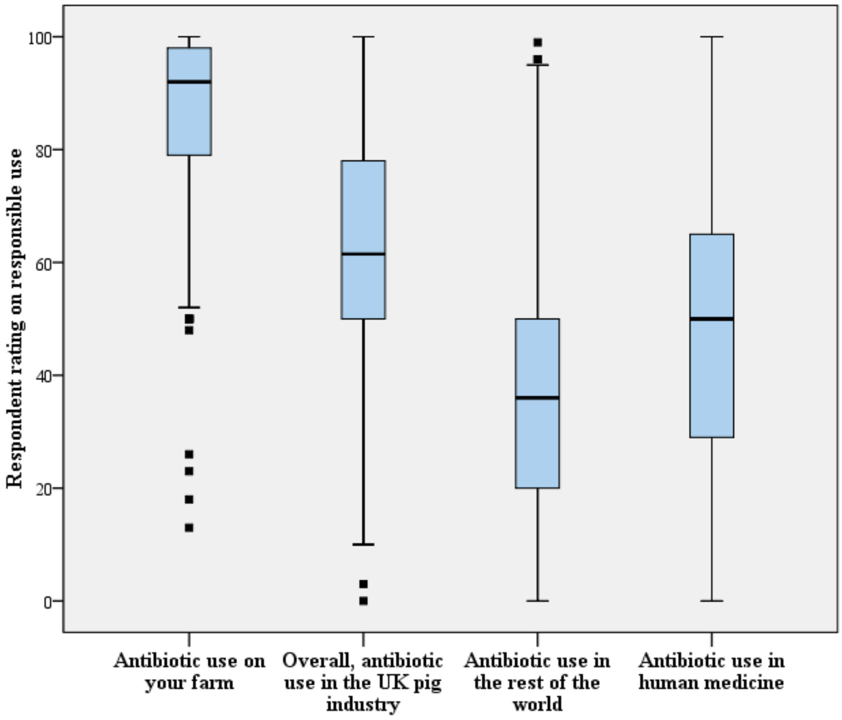


Perceptions on the responsibility of antimicrobial use in pigs

The attitudes of respondents to antimicrobial use on their own farms, in the UK pig industry, in pigs in the rest of the world and in human medicine was assessed by use of a continuous rating scale where participants marked the level of responsible use from ‘totally irresponsible use’ (identified as 0 on the scale), through ‘neutral’ (identified as 50 on the scale), to ‘totally responsible use’ (identified as 100 on the scale). Overall, respondents considered antimicrobial use to be the most responsible on their own farms with a mean score of 85.8 when compared with a mean of 61.8 for antimicrobial use in the UK pig industry. Farmers rated antimicrobial use in pigs in the rest of the world as being the least responsible with a mean score of 34.7, whilst antimicrobial use in human medicine had a mean score of 48.6 (Figure 11) .

Figure 11

Box-and-whisker plot depicting quantified respondent attitudes on the responsibility of antimicrobial use



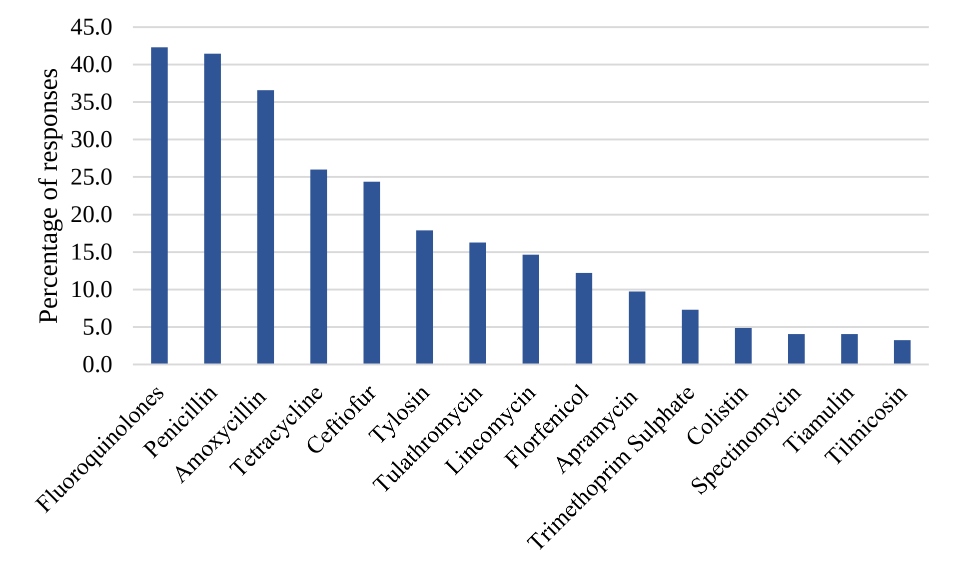
Perceptions on critically important antimicrobials

60.2% of (n=147/244) respondents stated that they were aware of the issue of critically important antimicrobials in pigs. The majority of these cited that their veterinary surgeon (36.8%, n=103/280), or the farming press (31.8%, n=89/280) had informed their level of awareness on critically important antimicrobials (Appendix 5, figure 5.10). Analysis revealed that respondents from farms with a greater median number of breeding sows (p=0.04) and feeding pigs (p=0.01) more frequently reported awareness of the issues of critically important antimicrobials in comparison to respondents from units with fewer breeding sows or feeding pigs (Appendix 5, Table 5.12).

From a list of antimicrobials (including common trade names of products used in pigs) respondents were asked which they believed were classified as critically important antimicrobials. Of 123 respondents less than 50% identified any of the antimicrobials listed as critical. Fluoroquinolones, penicillin and amoxicillin were most frequently identified whilst less than 5% believed Colistin, Spectinomysin, Tiamulin and Tilmicosin to be critical antibiotics (Figure 12).

Figure 12

Frequency that respondents identified listed antimicrobials as critically important antimicrobials (n=123).



Perceptions of farmers on the importance of the use of macrolides,fluoroquinolones and the third and fourth generation cephalosporins for the health and welfare of pigs showed that just under half of respondents considered the macrolide and fluoroquinolone classes to be either quite or very important. In contrast, the third and fourth generation cephalosporins were considered to be much less important with half of respondents considering them not to be important (Figure 13). Analysis included some additional variables relating to the respondents' reported behaviours around critically important antimicrobials; their awareness and frequency of use of these (Appendix 5, Table 5.13, 5.14 and 5.15).

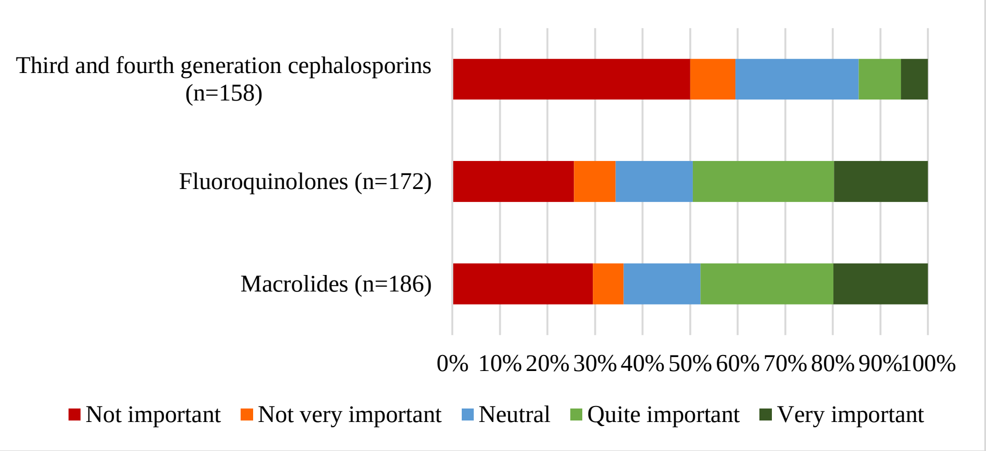
For the macrolide class of antimicrobials respondents from indoor breeding units (p=0.004) and units with a greater median number of feeding pigs (p=0.04) more frequently considered their use to be either quite or very important than respondents from outdoor breeding units or with fewer breeding sows. In addition, respondents that had used macrolides in either sows (p=0.05), weaners (p=0.005) or finishers (p=<0.001) in the year preceding the questionnaire more frequently considered its use to be either quite or very important compared to those that had not used macrolides.

There was a signficiant association between breeding (p=<0.001) and feeding (p=<0.001) units with larger herd sizes and respondents identifying that fluoroquinolones were important. Additionally, respondents who had used fluoroquinolones in their piglets (p=<0.001) and finishers (p=0.014) in the year preceding the questionnaire more frequently identified that fluoroquinolones were either quite or very important compared to farmers who had not used that class of antimicrobials.

Respondents that had used third and fourth generation cephalosporins in piglets in the year preceding the questionnaire more commonly held the opinion that the third and fourth generation cephalosporins were either quite or very important significantly more frequently compared to farmers who had not used them (p=0.003).

Figure 13

Respondent perceptions on the importance of the fluoroquinolones, macrolides and third and fourth generation cephalosporins for the health and welfare of pigs on their farm.



Beneficial measures and barriers to the reduction of antimicrobial use in pigs

Respondent opinion was sought on whether potential policy measures, management factors, economic factors or surveillance on antimicrobial resistance would be considered beneficial, a barrier or neutral to reducing the total amount of antimicrobials used in pigs in the UK (Table 8).

Factors relating to policy

The majority of respondents felt that a penalty system whereby farmers are penalised for high antimicrobial use and benchmarking antimicrobial use between farms would be beneficial in reducing antimicrobial use in pigs. Conversely, the majority considered banning in-feed antimicrobials and legislation that veterinary surgeons are no longer allowed to sell antimicrobials directly to farmers would be a barrier to reducing total antimicrobial use in pigs. There were no significant associations related to policy measures and farm demographics (Appendix 5, Table 5.16).

Factors relating to management

There was widespread agreement amongst respondents that eradicating swine dysentery, modernising pig accommodation, more effective vaccinations and a wider range of vaccinations would be beneficial in reducing the total amount of antimicrobials used in pigs. Conversely, respondents identified that a poor availability of highly skilled stockpeople was a barrier to reducing total antimicrobial use in pigs. There was a wide spectrum of opinions on the effects of whether increased use of outdoor breeding systems and straw-based finishing systems were beneficial, barriers or had no effect on reducing antimicrobial use in pigs.

There was one significant association between management factors and respondent characteristics (Appendix 5, Table 5.17). Respondents from farms with a larger number of feeding pigs more commonly identified that a wider range of vaccinations would be beneficial in reducing overall antimicrobial use ($p=0.01$).

Factors relating to economics

There was shared agreement amongst the majority of farmers that increased profitability in pig meat prices and reducing importation from high antimicrobial use countries would be beneficial in reducing the total amount of antimicrobials used in pigs. There was a range of opinions on the effects should the cost of antimicrobials be increased or decreased for farmers, however, the majority felt that it would have no effect on total antimicrobial use in pigs. Analysis revealed no significant associations between economic factors and respondent characteristics (Appendix 5, Table 5.18).

Factors relating to antimicrobial resistance surveillance

The majority of respondents identified that reporting of both regional and national surveillance would be beneficial in reducing the total amount of antimicrobials used in pigs in the UK. Respondents from farms with a greater median number of both breeding sows (p=0.005) and feeding pigs (p=0.003) more frequently held a neutral opinion over the effects of regional reporting of antimicrobial resistance on reducing the total amount of antimicrobial used in pigs in the UK. A parallel pattern was seen for respondent opinion on the effect of national reporting individuals from farms with a greater median number of breeding sows (p=0.002) and feeding pigs (p=0.002) more commonly holding a neutral opinion. Respondents from outdoor feeding systems more frequently identified that both regional (p=0.027) and national (p=0.013) reporting of antimicrobial resistance in pigs would be beneficial in reducing the total amount of antimicrobials used in pigs in comparison with respondents from indoor feeding herds (Appendix 5, Table 5.19).

Table 8

Farmer opinion on whether different measures would be considered to be a barrier, beneficial or have no effect on the total amount of antimicrobial used in pigs in the UK.

		Barrier	Neutral, no effect	Beneficial
Banning in-feed antibiotics	n	113	19	52
	%	61.4%	10.3%	28.3%
A benchmarking system whereby antibiotic usage is benchmarked between farms	n	27	55	98
	%	15.0%	30.6%	54.4%
Antibiotics would no longer be sold by vet practices and a prescription would have to be obtained from the vet and taken to a pharmacy to get antibiotics	n	126	54	24
	%	61.8%	26.5%	11.8%
A penalty system for high antibiotic usage in pigs such as the 'yellow card' system in Denmark	n	43	38	114
	%	22.1%	19.5%	58.5%
Eradicating swine dysentery from the UK	n	23	17	170
	%	11.0%	8.1%	81.0%
Modernising indoor pig accommodation	n	9	34	163
	%	4.4%	16.5%	79.1%
Increased use of straw-based finishing systems	n	34	71	99
	%	16.7%	34.8%	48.5%
Increased use of outdoor breeding systems	n	25	85	66
	%	14.2%	48.3%	37.5%
More effective vaccines	n	6	13	195
	%	2.8%	6.1%	91.1%
A wider range of vaccines	n	8	23	174
	%	3.9%	11.2%	84.9%
De-population and re-populating low health status pig herds with higher health status stock	n	5	37	158
	%	2.5%	18.5%	79.0%
Increased profitability of pig meat prices	n	10	58	148
	%	4.6%	26.9%	68.5%
Increasing the cost of antibiotics for farmers	n	103	85	21
	%	49.3%	40.7%	10.0%
Decreasing the cost of antibiotics for farmers	n	39	106	57
	%	19.3%	52.5%	28.2%
Reducing imports from other countries with high antibiotic use	n	15	26	176
	%	6.9%	12.0%	81.1%
Regional reporting of antibiotic resistance problems in pigs	n	10	40	160
	%	4.8%	19.0%	76.2%
National reporting of antibiotic resistance problems in pigs	n	13	42	155
	%	6.2%	20.0%	73.8%
Poor availability of highly skilled stockpeople	n	137	33	26
	%	69.9%	16.8%	13.3%

Discussion

This study explored the perceptions and behaviours of a sample of UK pig farmers on antimicrobial use practices, the responsibility of use and the issue of antimicrobial resistance; from both an animal and public health perspective.

When indoor and outdoor systems were compared by respondents there was a wide spectrum of opinions over which systems would result in lower or higher antimicrobial requirements. Although the majority of farmers felt that outdoor finishing systems resulted in either lower or the lowest antimicrobial use, this view needs to be considered within the context of the UK pig industry as 97% of the finishing herd are housed indoors. Thus, outdoor finishing systems are a small minority of commercial pig production (Anon, 2013e).

In contrast to the general principle of a vaccination, as protective against disease, this study found piglets from sows vaccinated against PRRSv had an increased risk of requiring antimicrobial treatment for gastrointestinal disease in comparison to non-vaccinated herds and farrowing sows had an increased risk of requiring antimicrobial treatment for lameness if they were vaccinated against influenza. These findings are echoed in the literature as Stevens and others (2007) concluded that pig herds which vaccinated their sows had a higher frequency of antimicrobial use in their weaner groups. Additionally, Stärk and others showed that vaccination against enzootic pneumonia was associated with an increased incidence of pleuropneumonia lesions in sow herds in New Zealand (Stärk et al., 1998). Thus, it seems likely that these results reflect that pig herds with a higher prevalence of disease, a lower health status and higher antimicrobial use are more likely to vaccinate. Further research to determine the true advantages of vaccination in terms of reducing antimicrobial use and economic benefit are required.

Antimicrobials belonging to the penicillin class were reportedly used across all of the groups of pigs in the year preceding the questionnaire. Similarly, a study quantifying antimicrobial use in farrow-to-finish farms in Belgium, France and Sweden found penicillins to be the most frequently used class of antimicrobials in pigs (Sjölund et al., 2016). Whilst there are no current quantitative antimicrobial use data for the UK, the overall higher sales of tetracyclines and in-feed antimicrobials (Borriello et al., 2015), coupled with the large number of tetracycline products authorised for use in-feed for pigs (Anon, 2013a), suggest that tetracyclines are likely to significantly contribute to UK on-farm use in pigs. Thus, it is possible that these data do not reflect actual use and respondents may have excluded in-feed preparations in their responses. Sjölund and others (2016) showed that the fluoroquinolones were the most frequently used class of antimicrobial in suckling piglets whilst macrolides were used most frequently in the weaned pig category. Similarly, respondents reported that fluoroquinolones were the most commonly used antimicrobial class in piglets in the year preceding the questionnaire study; however, macrolides were most commonly described as having been used in finisher pigs.

Overall, respondents valued the advice of their veterinary surgeon on antimicrobial use in pigs above other information sources and in the clinical disease scenarios respondents reported that their preferred treatment option was to treat with antimicrobials previously prescribed by their veterinary surgeon for the same condition. Similarly, the literature describes the high importance and reliance pig farmers place on their veterinary surgeon for advice on disease and antimicrobial use (Visschers et al., 2014, Visschers et al., 2015).

Awareness of the critically important antimicrobials was reported by 60% of respondents, however, these individuals considered a spectrum of antimicrobials to fall within this category. Such uncertainty is reflected in the wide range of definitions as to which classes of antimicrobials should be considered to be critical to human medicine or a priority for veterinary use (Anon, 2015d, f, 2014d). For example, macrolides, fluoroquinolones and third and fourth generation cephalosporins are identified as highest priority critically important antimicrobials in the WHO guidelines (Anon, 2012d) and as veterinary critically important antimicrobials by the OIE (Anon, 2015f). Whilst the PVS prescribing guidelines class the fluoroquinolones and third and fourth generation cephalosporins as class 3 antimicrobials, or ‘products of last resort’, macrolides are only considered as class 2 antimicrobials; which may be used based on sensitivity testing or clinical experience if the antimicrobial of first choice is ineffective. Thus, with such a wide spectrum of definitions and understandings of the term ‘critically important antimicrobial’ it is unsurprising that there is confusion in the farmers’ responses; less than 45% of respondents selected fluoroquinolones and third and fourth generation cephalosporins as antimicrobials of critical importance to human medicine and less than 20% considered macrolides. There is a need for greater clarity over the definition and meaning of what classifies as a critically important antimicrobial including agreement across the human medicine and veterinary sectors. Thus, it is clear that there is also a need for improved knowledge exchange between veterinary surgeons and farmers over concerns relating to certain classes of antimicrobials to ensure that farmers are aware of the need to reserve such classes for use in cases where no other antimicrobial classes are effective.

Across the clinical scenarios respondents from indoor systems and units with a greater median number of breeding sows more frequently reported that they were motivated to use antimicrobials left on farm by the veterinary surgeon when compared with outdoor producers and units with fewer breeding sows. This suggests that the type of farm may influence antimicrobial use decision making. Stevens and others (2007) identified higher overall antimicrobial costs for injectable and premix formulations on indoor breeding units when compared with outdoor units. In addition, larger herd sizes have been associated with a higher disease risk, and therefore, a greater antimicrobial requirement when compared with smaller units (Maes et al., 2001, Smith et al., 1998, Mortensen et al., 2002).

Farmers infrequently reported that diagnostic testing was carried out at routine veterinary visits; however this behaviour was more frequent when faced with a new disease outbreak. In agreement, diagnostic testing has been shown to be an uncommon practice for routine disease surveillance by farm animal veterinary surgeons however, novel disease outbreaks were considered to be a driver for its use (Sheehan, 2013, De Briyne et al., 2013). Respondents reported an increased frequency of diagnostic testing on larger pig units. This is in-line with previous conclusions which associate larger herd sizes with a higher disease risk and thus higher antimicrobial use. It is also possible that larger pig units have more regular veterinary input and may be in a better position to invest in diagnostic testing. In addition, respondents from closed herds reported carrying out diagnostic testing more frequently than respondents from open herds; closed herds are more likely to have a higher health status and therefore may conduct routine diagnostic testing to ensure that this high health status is maintained. Furthermore the literature shows that open herds are at an increased risk of disease, and therefore exhibit higher antimicrobial use, when compared to closed herds (Nathues et al., 2013, Mortensen et al., Maes et al., 2000, Backhans et al., 2016).

A common thread throughout the questionnaire responses was the concept that irresponsible antimicrobial use practices were an issue associated with other individuals distant and unrelated to the respondents; a concept termed ‘othering’ (Johnson et al., 2004). This opinion was shown most clearly on the continuous rating scale whereby respondents rated the responsibility of antimicrobial use on their own farms as being higher than in the UK pig industry in general, elsewhere in the world or in human medicine. A similar perception has been described in human medicine whereby physicians identify that other medical professionals display irresponsible prescribing behaviours and place themselves as being within a separate group who show responsible antimicrobial use behaviours (Barden et al., 1998, Butler et al., 1998, Kotwani et al., 2010, Rodrigues et al., 2013, Simpson et al., 2007).

To date the consequences from the zoonotic transfer of resistant bacteria from animals to humans have not been quantified (Chang et al., 2015, Cantas and Suer, 2014). Human prescribers have associated indiscriminate prescribing and the overuse of antimicrobials in livestock with resistance profiles in humans (McCullough et al., 2015, McIntosh and Dean, 2015), however the view of veterinary surgeons remains divided (Speksnijder et al., 2015b, Cattaneo et al., 2009, Visschers et al., 2016, Postma et al., 2016). Around half of respondents held the opinion that antimicrobial use in pigs may have an effect on antimicrobial resistance levels in humans. Similar farmer perceptions are shown in other studies (Visschers et al., 2014, Visschers et al., 2015, Stevens et al., 2007).

The introduction of a penalty system whereby high antimicrobial use farms are identified, and penalised if they are not successful at decreasing use, has been effective in reducing overall antimicrobial use in pigs in Denmark and the Netherlands (Aarestrup, 2012, Taverne et al., 2015). Respondents felt that such regulation would be successful in reducing overall antimicrobial use in pigs in the UK. Similarly, farmers identified that an antimicrobial use benchmarking system between farms would also be beneficial. Conversely, respondents considered regulation, such as banning the use of in-feed formulations, would be a barrier to reducing total antimicrobial use in pigs. This may reflect that the use of in-feed antimicrobials was considered to be justifiable by the majority of respondents and was described as a frequent behaviour both in this study and the published literature (Chauvin et al., 2002, Rajic et al., 2006, Stevens et al., 2007).

Disease prophylaxis was considered by the majority of respondents to be prudent antimicrobial use behaviour; a situation in which in-feed antimicrobials are commonly employed (Callens et al., 2012, Stevens et al., 2007). However, increasing pressure on the pig industry has resulted in a move to seek alternative methods of preventing disease to antimicrobial use (Anon, 2015d, Postma et al., 2015b). Vaccination was considered to be a significant alternative to the use of antimicrobials in pigs which is reflected in other publications (Postma et al., 2015b, Anon, 2015d, Buller at al., 2015). In agreement respondents felt that availability of more effective vaccinations and a wider range would be beneficial in reducing overall antimicrobial use. This is an area where further research is warranted as increased availability of effective vaccinations would offer an alternative method of preventing disease to the use of antimicrobials.

Respondents felt that other potential management changes such as modernising pig housing and de-populating low health status pigs and re-stocking with higher health status pigs were beneficial in reducing antimicrobial use on farm. Maintaining a high health status in a pig herd is considered to be essential in minimising the antimicrobial requirements of the herd (Anon, 2015d, Postma et al., 2015b). Additionally, the inability to reinvest in improved and modern pig housing has been identified as a barrier to reducing antimicrobial use in pigs (Speksnijder et al., 2015b, Stevens et al., 2007). Laanen and others found that poor internal biosecurity levels were correlated with older pig buildings (Laanen et al., 2013) and therefore, it may be that respondents considered modern buildings would allow for the maintenance of higher biosecurity levels than existing older facilities. Good biosecurity was considered to be a key characteristic of a low antimicrobial use system, a concept which is echoed in the literature (Laanen et al., 2013, Postma et al., 2015a, b, Speksnijder et al., 2015, Rojo-Gimeno at al., 2016), and is a major focus of efforts to reduce the burden of disease and antimicrobial use in the UK.

The useable response rate for this study was 21.4% which is lower than the 25.5% response rate from a questionnaire study on antimicrobial use in pigs which was sent to UK farmers in 2000 (Stevens et al., 2007). However, overall 35% of the questionnaires which were sent out were returned but 13.6% of these were from respondents who were not eligible to be included in the study, most commonly because they no longer kept pigs. Therefore, it is likely that there were also a considerable proportion of individuals within the non-response group who were also not eligible for inclusion in the sample population but did not respond to the questionnaire to declare their current circumstances.

Other questionnaire studies with European pig farmers have prompted higher response rates (greater than 60%) (Visschers et al., 2015, Visschers et al., 2014) however, these studies used convenience samples which may not be representative of the pig farming population of each country and may be biased towards pig farmers with a greater interest in antimicrobial use and resistance. The low response rate in this study may also have introduced bias as the responders may be different in terms of antimicrobial use and perceptions.

Potential reasons for non-response may be related to the sensitivity of the issue of antimicrobial use in pigs. There has been increasing pressure from the general public, politics and media relating to antimicrobial use in food producing animals and it is possible that this scrutiny may have resulted in a reluctance of farmers to discuss their current practices for fear of negative consequences (Speksnijder et al., 2015b, McCullough et al., 2015, Morris et al., 2016) Additionally, there are an increasing number of requests for farmers to complete questionnaires and non-response may be related to the limited time available for pig farmers to contribute to such studies.

There are limitations to self-reported behaviours as participants may respond to questions in the manner in which they perceive the authors expect, rather than report their true perceptions and motivations (Bowling, 2005, Foddy, 1993). Thus, there is a potential in this study that respondents may report antimicrobial use behaviours that they consider the researchers perceive as being optimal and responsible rather than their actual practices. In order to try and minimise this effect open questions were included as they require respondents to propose novel ideas or perceptions not motivated by closed question options (O'Cathain and Thomas, 2004). Additionally, expansion open questions were used following some of the closed questions in order to allow respondents to add additional perceptions and ideas not covered in the limited number of answer options (Bryman, 2006).The univariable analysis approach used did not adjust for multiple comparisons and hence should be considered exploratory.

Conclusions and Implications

This study presents the views of a sample of UK pig farmers on their perceptions on antimicrobial use in pigs, current practices and views on the responsibility of antimicrobial use. The diverse spectrum of farm systems, management factors and biosecurity practices was shown in the wide range of responses reported by farmers. Further research to explore optimal management and biosecurity practices to minimise antimicrobial use would place veterinary surgeons and farmers in a superior position to reduce antimicrobial use. A tendency towards higher antimicrobial use in larger pig herds was evident from respondents and as such research should focus on commercial units with a greater number of pigs which represent typical UK units. Farmers identified vaccination as an important disease prevention strategy; however, further work is required in order to provide a wider range of effective vaccinations against key pathogens in pigs. For example, there is currently no commercially available vaccination against swine dysentery, a disease of significant economic concern (Mirajkar and Gebhart, 2014). Almost half of farmers were unaware of the issue of critically important antimicrobials in pigs and there was a wide spectrum of farmer understanding of what constituted responsible antimicrobial use behaviours. These are areas requiring clarification and there is a need for further farmer education. The trust and value placed by farmers on their veterinary surgeon for antimicrobial use advice shows the importance of good communication between veterinary surgeons and farmers. Thus, the veterinary surgeon - farmer relationship offers an excellent opportunity for further knowledge exchange on the importance of responsible antimicrobial use.

Appendix 5

Appendix to chapter 6

Pig farmers perceptions and attitudes on antimicrobial use in pigs in the UK: A questionnaire study

Appendix 5 – Appendix to Chapter 6 Pig farmers' perceptions and attitudes on antimicrobial use in pigs in the UK: A questionnaire study

Table 5.1 - Regional breakdown of pigs per thousand head in the UK by region and the proportion of the farms required in the sample population from each region.

Region	Thousand head pigs	% of total	Of 1500 sample farms number required in each region
England	4066	92%	1380
Scotland	314	7%	105
Wales	25	1%	15
Total	4405	100%	1500

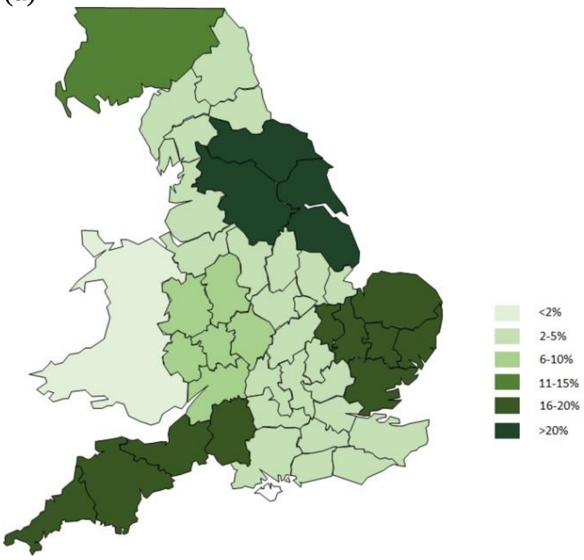
(Source – Defra, 2013 (Anon, 2013l))

Table 5.2 - Sampling frame for the questionnaire study based on sampling the farms proportional to the total number of pigs represented by that farm size group (such that large farms that represent the majority of pig numbers in UK were not underrepresented) for holdings with female breeding and fattening pigs, fattening pigs only and breeding sows only. The same stratified random sampling methodology, based on type and farm size, was employed to select farmers as was used for the qualitative interviews (Chapter 4).

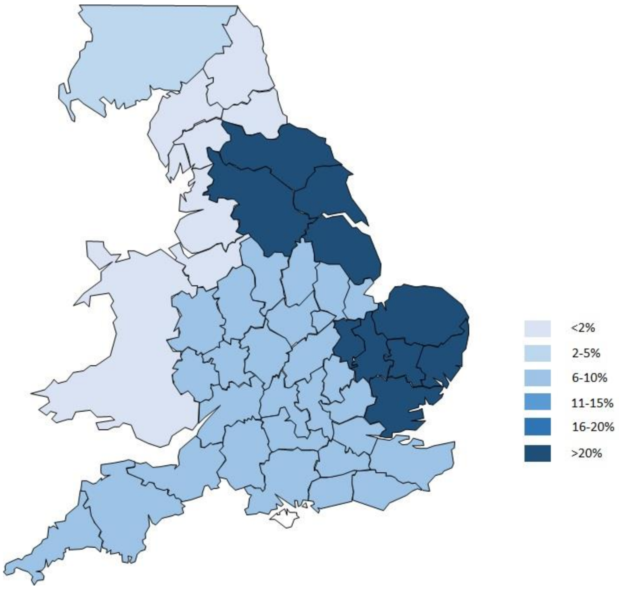
	The number of sows/pigs on holdings		
Holdings with both female breeding and fattening pigs	**5-24 female sow breeding herd**	**25-99 female sow breeding herd**	**100 and over female sow breeding herd**
Percentage for questionnaire sample	4%	8%	88%
Fattening-only holdings	**50-299 fattening pigs**	**300-999 fattening pigs**	**1000 and over fattening pigs**
Percentage for questionnaire sample	3%	17%	80%
Breeding-only holdings	**5-24 female sow breeding herd**	**25 to 99 female sow breeding herd**	**100 and over female sow breeding herd**
Percentage for questionnaire sample	7%	7%	86%

Figure 5.2 - Map to show (a) the geographic distribution of responding farms and b) the regional breakdown of the UK breeding. Percentage of total responses per region is shown in the key (n=257).

(a)



(b)



Data source - UK regional breakdown of breeding herd, Defra, 2013 (Anon, 2013,l)

Figure 5.3 - Flooring characteristics on respondent farms for different groups of pigs

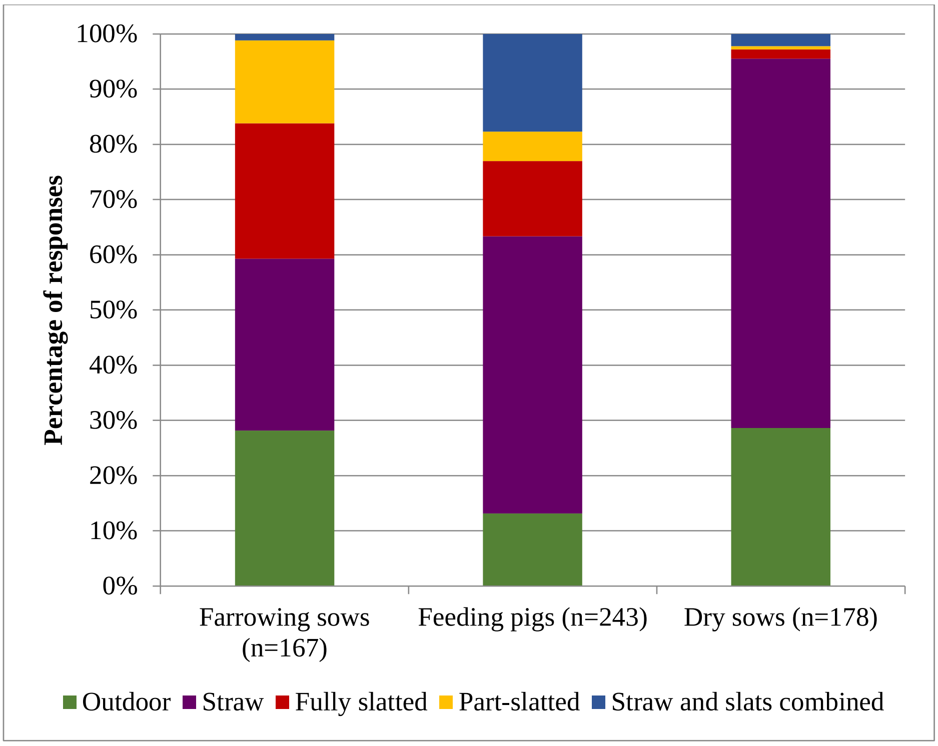


Figure 5.4
Pig movement characteristics on respondent farms for different groups of pigs

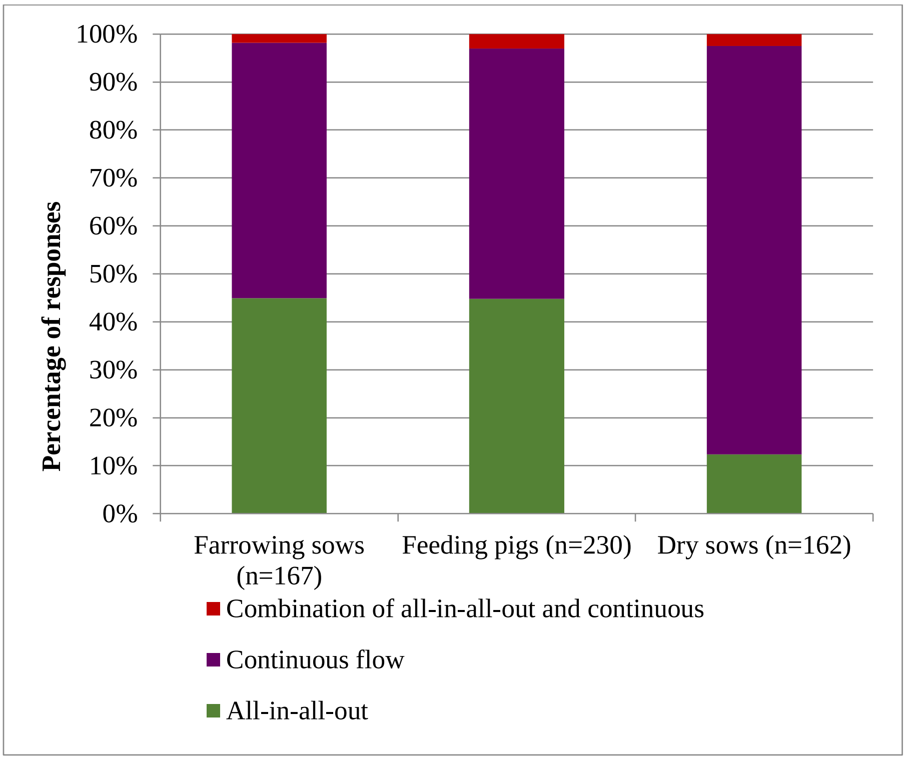


Figure 5.5
Pig feeding practices on respondent farms for different groups of pigs

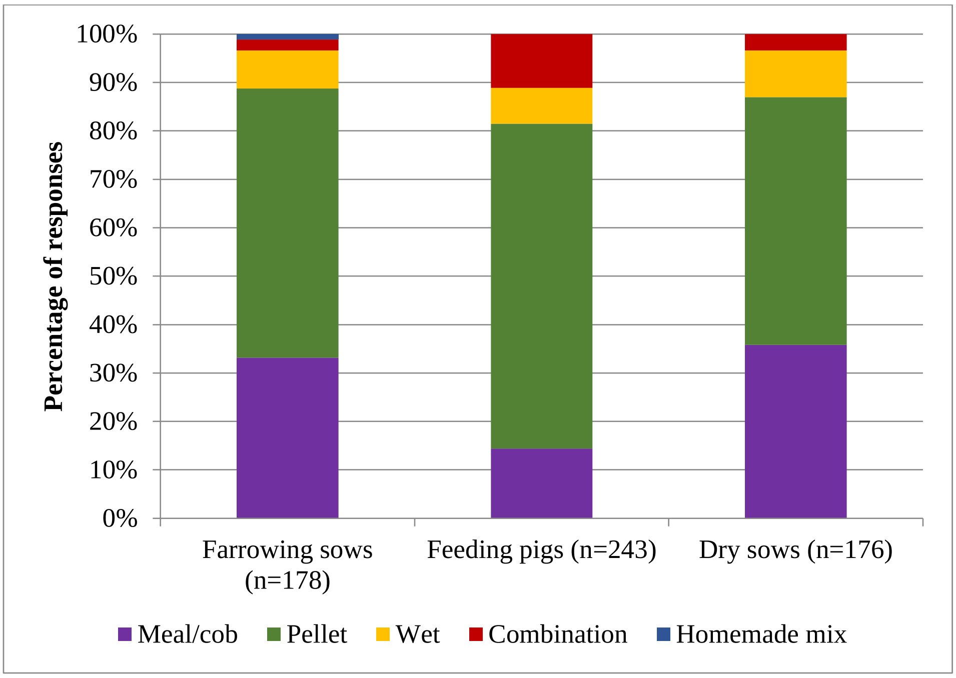


Figure 5.6 - Procedures for buying in semen or breeding stock on breeding and breeding and feeding units

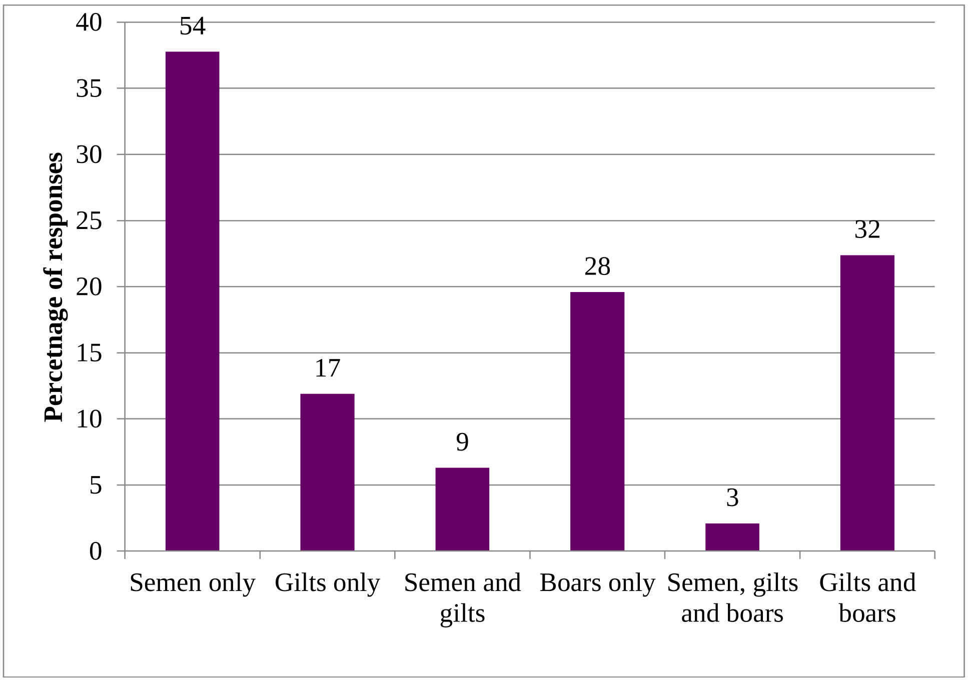


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Table 5.3 - Univariable analysis on respondent opinion on clinical factors that might drive antimicrobial use and respondent and farm characteristics.

		You are confident that bacterial disease is present				**Disease is causing pig welfare to be adversely affected**				**The pig appears to have a high temperature**			
		Less likely	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**
Type of production - breeding	**Outdoor**	2 (5%)	7 (17.5%)	31 (77.5%)	0.355	0 (0%)	1 (2.4%)	41 (97.6%)	0.828*	4 (8.7%)	16 (34.8%)	26 (56.5%)	**0.008***
	Indoor	6 (5.3%)	10 (8.8%)	97 (85.8%)		2 (1.7%)	7 (5.9%)	109 (92.4%)		4 (3.5%)	19 (16.5%)	92 (80%)	
Type of production - feeding	**Outdoor**	2 (11.1%)	4 (22.2%)	12 (66.7%)	0.086*	0 (0%)	1 (4.5%)	21 (95.5%)	0.665*	2 (9%)	10 (45.5%)	10 (45.5%)	**0.041***
	Indoor	4 (3.5%)	13 (11.7%)	94 (84.7%)		6 (5.3%)	4 (3.5%)	104 (91.2%)		10 (9%)	23 (20.9%)	77 (70.1%)	
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	45 11 450 105	55 2 6800 284	220 2 40000 535	**0.006**	75 40 110	127.5 6 600 378	18- 2 40000 476	0.603	140 4 2700 968	300 2 3000 632	150 2 40000 408	0.614
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	45 11 450 105	55 2 6800 284	220 2 40000 535	0.06	75 40 110	127.5 2 600 378	180 2 40000 476	0.747	140 4 2700 968	300 2 3000 632	150 2 40000 408	0.774

** Univariable analysis was based on a Fisher's Exact Test*

*** Univariable analysis was based on a Kruskal-Wallis Test*

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Table 5.3 continued

		The pig is not eating				The pig has been in close contact with other pigs showing signs of an infection				There is concern that clinical signs may worsen if an antibiotic is not used			
		Less likely	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**
Type of production - breeding	**Outdoor**	10 (22.7%)	23 (52.3%)	11 (25%)	**0.001**	8 (18.6%)	19 (44.2%)	16 (37.2%)	0.56	1 (2.3%)	4 (9.1%)	39 (88.6%)	0.927*
	Indoor	13 (11.6%)	34 (30.4%)	65 (58%)		28 (24.1%)	41 (35.3%)	47 (40/6%)		5 (4.3%)	13 (11.3%)	97 (84.4%)	
Type of production - feeding	**Outdoor**	5 (23.8%)	11 (52.4%)	(23.8%)	0.094	3 (15%)	8 (40%)	9 (45%)	0.587*	1 (4.8%)	3 (14.3%)	17 (80.9%)	0.406*
	Indoor	15 (14.3%)	38 (36.2%)	52 (49.5%)		30 (26.8%)	39 (34.8%)	43 (38.4%)		3 (2.6%)	11 (9.6%)	100 (87.7%)	
Number of sows**	Median Minimum Maximum IQ range	175 2 7000 595	200 2 40000 625	155 2 6800 6798	0.916	225 4 40000 550	157.5 2 6800 475	180 2 6800 460	0.75	180 4 580 398	150 2 7000 445	180 2 40000 503	0.691
Number of pigs**	Median Minimum Maximum IQ range	175 2 7000 595	200 2 40000 625	155 2 6800 404	0.936	225 4 40000 550	157.5 2 6800 465	180 2 6800 460	0.617	180 4 580 398	150 2 7000 445	180 2 40000 503	0.806

** Univariable analysis was based on a Fisher's Exact Test*

*** Univariable analysis was based on a Kruskal-Wallis Test*

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Table 5.3 - Univariable analysis on respondent opinion on external pressures that might drive antimicrobial use and respondent and farm characteristics.

		The feed company representative offers advice that an antibiotic may be needed and veterinary input may be required				**There is pressure from the retailer to lower antibiotic use**				**There is pressure from the veterinary surgeon to lower antibiotic use**			
		Less likely	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**	**Less likely**	**Neutral, no effect**	**More likely**	**P value**
Type of production - breeding	**Outdoor**	18 (43.9%)	16 (39%)	7 (17.1%)	0.327	15 (36.6%)	24 (58.5%)	2 (4.9%)	0.613*	13 (31.7%)	21 (51.2%)	7 (17.1%)	0.218
	Indoor	34 (30.4%)	54 (48.2%)	24 (21.4%)		45 (40.2%)	57 (50.9%)	10 (8.9%)		45 (40.2%)	40 (25.7%)	27 (34.1%)	
Type of production - feeding	**Outdoor**	11 (57.9%)	6 (31.6%)	2 (10.5%)	0.115*	6 (33.3%)	11 (61.1%)	1 (5.56%)	0.923*	5 (27.8%)	11 (61.1%)	2 (11.1%)	0.167*
	Indoor	37 (34.3%)	41 (38%)	30 (27.7%)		42 (38.9%)	57 (52.8%)	9 (8.3%)		46 (42.6%)	40 (37%)	22 (20.4%)	
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	165 2 40000 535	220 2 6800 535	100 5 330 475	0.339	145 5 6800 484	220 2 40000 539	20 10 3300 639	0.531	180 5 7000 420	134.5 2 40000 501	300 10 3300 589	0.516
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	165 2 40000 535	220 2 6800 535	100 5 3300 475	0.259	145 5 6800 484	220 2 40000 539	20 10 3300 639	0.389	180 5 7000 420	134.5 2 40000 501	300 10 3300 589	0.967

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Figure 5.7
Frequency of diagnostic testing on respondents’ farms on routine visits and after a new disease outbreak

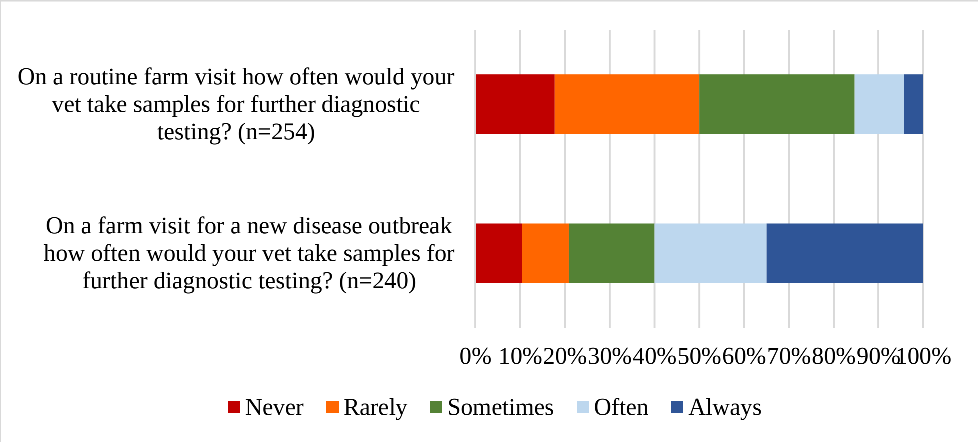

Figure 5.8
Respondent opinion on treatment failure and antimicrobial resistance

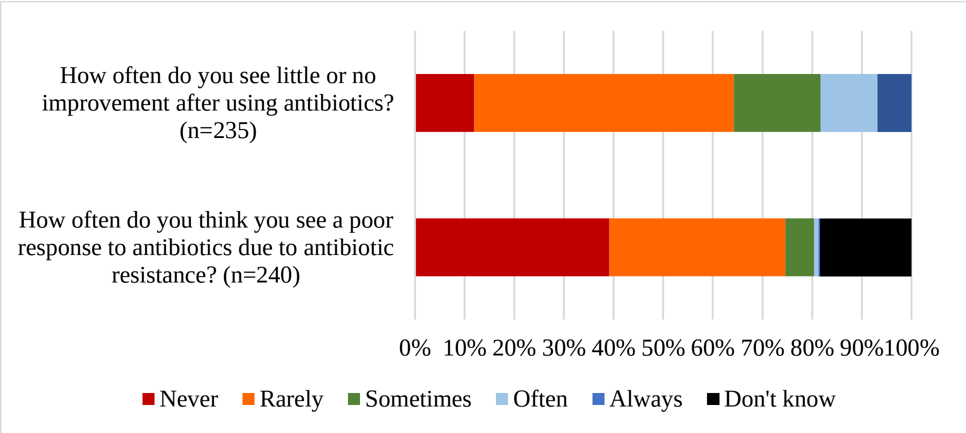

Table 5.4 - Univariable analysis on the frequency of diagnostic testing on respondents' farms and the farm characteristics.

Frequency of diagnostic testing on routine farm visit					
		Never or rarely	**Sometimes**	**Often or always**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	25 5 1200 98	355 11 6800 585	540 12 40000 829	**<0.001**
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	400 1 8000 1100	2315 40 75000 3250	3500 300 300000 5600	**<0.001**
Production type - breeding	**Indoor**	50 (42.4%)	46 (39%)	22 (18.6%)	0.209
	Outdoor	28 (57.1%)	15 (30.6%)	6 (12.3%)	
Production type - feeding*	**Indoor**	59 (48.4%)	43 (35.2%)	20 (16.4%)	0.018
	Outdoor	18 (78.3%)	5 (21.7%)	0 (0%)	
Geographic pig density*	**Low**	9 (39.1%)	10 (43.5%)	4 (17.4%)	0.217
	Moderate	70 (57.4%)	34 (17.9%)	18 (24.7%)	
	High	47 (44.8%)	41 (39%)	17 (16.2%)	
Closed herd	**No**	91 (49.5%)	73 (39.7%)	20 (10.8%)	**0.002**
	Yes	35 (51.5%)	15 (22.1%)	18 (26.4%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.4 continued

Frequency of diagnostic testing after a new disease outbreak					
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	22 7 200 83	112.5 5 950 250	320 4 40000 650	**<0.001**
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	270 2 4800 860	1017.5 7 8000 2060	2000 8 300000 3444	**<0.001**
Production type - breeding	**Indoor**	21 (17.9%)	22 (18.8%)	74 (63.3%)	0.52
	Outdoor	12 (25.5%)	9 (19.1%)	26 (55.4%)	
Production type - feeding*	**Indoor**	22 (19.6%)	18 (16.1%)	72 (64.3%)	0.072
	Outdoor	9 (40.9%)	4 (18.2%)	9 (40.9%)	
Geographic pig density	**Low**	5 (22.7%)	6 (27.3%)	11 (50%)	0.189
	Moderate	14 (14.1%)	19 (19.2%)	66 (66.7%)	
	High	49 (20.7%)	45 (19%)	143 (60.3%)	
Closed herd	**No**	35 (20.1%)	38 (21.8%)	101 (58.1%)	0.25
	Yes	12 (19.4%)	8 (12.9%)	42 (67.7%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.5 - Univariable analysis on the frequency with which respondents identified treatment failure and associated treatment failure with antimicrobial resistance and associated such a lack of response with antimicrobial resistance.

		Never or rarely	Sometimes	Often or always	p-value
Frequency with which respondents' identify treatment failure					
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	180 2 40000 450	290 5 40000 450	164.5 5 7000 601	0.556
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1200 1 300000 2623	1800 45 26000 2775	1200 28 80000 3286	0.867
Production system - breeding	**Outdoor**	27 (69.2%)	12 (30.8%)	0 (0%)	**0.001***
	Indoor	77 (67%)	17 (14.8%)	21 (18.2%)	
Production system - feeding	**Outdoor**	11 (68.8%)	3 (18.8%)	2 (12.4%)	0.602*
	Indoor	79 (67.5%)	14 (12%)	24 (20.5%)	
Frequency with which respondents' associate treatment failure with antimicrobial resistance					
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	181 2 40000 410	71 10 1400 560	550 100 750	0.452
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	12005 5 300000 2650	1800 50 17000 3350	2150 800 3500	0.815
Production system - breeding	**Outdoor**	31 (96.9%)	0 (0%)	1 (3.1%)	0.144*
	Indoor	89 (88.1%)	10 (9.9%)	2 (2%)	
Production system - feeding	**Outdoor**	13 (92.9%)	1 (7.1%)	0 (0%)	0.55*
	Indoor	96 (95%)	5 (5%)	0 (0%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.6 - Themes volunteered by respondents as alternative methods of preventing disease in pigs to the use of antimicrobials.

	Frequency (n)	**Example Quotation**
Lower stocking rates	13	*'Lower stocking densities.'*
Outdoor system	7	*'Extensive outdoor management.'*
Good stockmanship	4	*'Good stockmanship to nip problems in the bud. Good nutrition to improve overall health.'*
Improved hygiene practices	4	*'Improved hygiene and isolation of sick/poor pigs .'*
High health status pigs	4	*'Improved health status.'*
Improving nutrition	4	*'Good nutrition to improve overall health.'*
Selecting appropriate genetics for pig herd	4	*'Breed disease resistant pigs.'*
Reduce pig stress levels	3	*'Freedom to express natural behaviour is one of the most important things…'*
Organic acids in water	3	*'Organic acids in water.'*
All-in-all-out pig flow systems	2	*'All in all out with rigorous cleaning between batches.'*
Less economic pressure on pig farmers	2	*'Less economic pressures.'*

Table 5.7 - Univariable analysis on respondent opinion on the management features/systems of pig units and the relationship with the management features/systems employed on the respondents' farms.

		Lowest or lower	Moderate	Highest or higher	P value
Continuous pig flow systems					
Pig movement system - feeding pigs*	**All-in-all-out**	5 (6.6%)	16 (21.1%)	55 (72.3%)	1
	Continuous	7 (7.7%)	19 (20.9%)	65 (71.4%)	
Pig movement system - farrowing sows*	**All-in-all-out**	4 (7.8%)	8 (15.7%)	39 (76.5%)	0.75
	Continuous	6 (8.6%)	15 (21.4%)	49 (70%)	
Pig movement system -dry sows*	**All-in-all-out**	2 (14.3%)	3 (21.4%)	9 (64.3%)	0.49
	Continuous	8 (7.8%)	17 (16.5%)	78 (75.7%)	
All-in-all-out pig flow systems					
Pig movement system - feeding pigs	**All-in-all-out**	69 (86.3%)	7 (8.8%)	4 (4.9%)	0.4
	Continuous	74 (78.7%)	15 (16%)	5 (5.3%)	
Pig movement system - farrowing sows*	**All-in-all-out**	46 (85.2%)	5 (9.3%)	3 (5.5%)	0.3
	Continuous	57 (79.2%)	13 (18.1%)	2 (2.7%)	
Pig movement system -dry sows*	**All-in-all-out**	11 (78.6%)	2 (14.3%)	1 (7.1%)	0.58
	Continuous	89 (81.7%)	16 (14.7%)	4 (3.6%)	
Indoor farrowing crates					
Farming system	**Indoor breeding**	25 (32.9%)	19 (25%)	32 (42.1%)	0.16
	Outdoor breeding	5 (16.7%)	12 (40%)	13 (43.3%)	
Outdoor farrowing systems					
Farming system*	**Indoor breeding**	55 (80.9%)	7 (10.3%)	6 (8.8%)	0.71
	Outdoor breeding	20 (70.1%)	3 (11.1%)	4 (18.8%)	
Solid floor straw-based indoor finishing systems					
Flooring type for feeding pigs	**Slatted**	15 (46.9%)	10 (31.3%)	7 (21.8%)	0.56
	Straw	36 (37.1%)	29 (29.9%)	32 (33%)	
	Outdoor	6 (28.6%)	6 (28.6%)	9 (42.8%)	
Indoor slatted finishing systems					
Flooring type for feeding pigs*	**Slatted**	8 (32%)	8 (32%)	9 (36%)	0.39
	Straw	36 (41.8%)	31 (36%)	19 (22.2%)	
	Outdoor	10 (47.6%)	4 (19%)	7 (33.4%)	
Outdoor finishing systems					
Flooring type for feeding pigs*	**Slatted**	17 (68%)	6 (24%)	2 (8%)	0.13
	Straw	47 (64.4%)	11 (15.1%)	15 (20.5%)	
	Outdoor	15 (88.2%)	2 (11.8%)	0 (0%)	
Well managed units					
Role of respondent	**Management**	16 (88.9%)	0 (0%)	2 (11.1%)	0.091
	Non-management	159 (85.9%)	20 (10.8%)	6 (3.3%)	
Unit buying pigs from multiple sources					
Policy for buying in feeding pigs*	**Single source**	1 (1.2%)	2 (2.5%)	78 (96.3%)	0.21
	Multiple source	1 (3.5%)	2 (6.9%)	26 (89.6%)	
Unit buying pigs from a single source					
Policy for buying in feeding pigs*	**From a single source farm**	71 (82.6%)	12 (14%)	3 (3.4%)	0.68
	From multiple source farms	22 (75.9%)	5 (17.2%)	2 (6.9%)	

** Univariable analysis was based on a Fisher's Exact Test*

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Table 5.8- Univariable analysis of respondent opinion on what is considered to be a justifiable use of antimicrobials in pigs and respondent and farm characteristics.

		Antimicrobial use for treatment of pigs with disease			Antimicrobial use for disease prevention in pigs			Antibiotic use for growth promotion			The use of in-feed antibiotic formulations in pigs		
		Never are rarely justified	**Usually or always justified**	**p-value**	**Never are rarely justified**	**Usually or always justified**	**p-value**	**Never are rarely justified**	**Usually or always justified**	**p-value**	**Never are rarely justified**	**Usually or always justified**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	1350 60 3500 3065	1000 1 300000 2715	0.609	1000 1 26000 2730	1050 5 300000 3294	0.562	1125 1 300000 2715	850 8 6000 2470	0.889	901.5 2 300000 1980	1000 5 75000 2800	0.385
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1350 60 3500 3065	1000 1 300000 2715	0.829	1000 1 26000 2730	1050 5 300000 3294	0.604	1125 1 300000 2715	850 8 6000 2470	0.5	901.5 2 300000 1980	1000 5 75000 2800	0.404
Production system - breeding	**Outdoor**	1 (2.2%)	45 (97.8%)	1*	19 (46.3%)	22 (53.7%)	0.928	38 (88.4%)	5 (11.6%)	0.37	17 (42.5%)	23 (57.5%)	0.882
	Indoor	4 (3.6%)	107 (96.4%)		50 (47.2%)	56 (52.8%)		92 (92.9%)	7 (7.1%)		45 (45%)	55 (55%)	
Production system - feeding	**Outdoor**	0 (0%)	22 (100%)	1*	8 (38.1%)	13 (61.9%)	0.22	19 (95%)	1 (5%)	0.69*	6 (28.6%)	15 (71.4%)	0.318
	Indoor	3 (2.7%)	110 (97.3%)		59 (52.7%)	53 (47.3%)		96 (89.7%)	11 (10.3%)		41 (40.2%)	61 (59.8%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Mann-Whitney Test*

Table 5.9 - Univariable analysis to show respondent opinion on the consequences from the use of antimicrobials in pigs and respondent and farm characteristics. N or NV I – Not or not very important, Ne – Neutral, Q or V - Quite or very important

		Increased antibiotic resistance in pigs				Increased antibiotic resistance in humans				Reduced risk of disease transmission to humans			
		N or NV I	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**
Number of sows**	**Median**	65	140	180	0.736	27.5	140		0.225	49	172.5	110	0.296
	Minimum	15	2	4		5	2			4	3	3	
	Maximum	40000	6800	1050		40000	6800			6800	40000	40000	
	IQ range	11941	432	656		10050	426			390	424	488	
Number of pigs**	**Median**	525	1200	1000	0.933	452.5	12000	1100	0.254	1025	1200	900	0.693
	Minimum	45	1	30		28	1	6		16	1	11	
	Maximum	300000	75000	9000		300000	75000	51000		73500	75000	300000	
	IQ range	30210	2723	2340		2471	2685	2959		3080	2650	3300	
Production system - breeding	**Outdoor**	2 (4.4%)	35 (77.8%)	8 (17.8%)	0.44*	1 (2.3%)	38 (86.4%)	5 (11.3%)	0.629*	4 (9.1%)	31 (70.5%)	9 (20.4%)	0.534*
	Indoor	4 (3.6%)	94 (85.5%)	12 (10.9%)		6 (5.5%)	87 (79.1%)	17 (15.4%)		7 (6.4%)	71 (65.1%)	31 (28.5%)	
Production system - feeding	**Outdoor**	0 (0%)	20 (90.9%)	2 (9.1%)	0.762*	0 (0%)	20 (90.9%)	2 (9.1%)	0.757*	1 (4.5%)	13 (59.1%)	8 (36.4%)	0.315*
	Indoor	7 (6.1%)	98 (85.2%)	10 (8.7%)		6 (5.3%)	98 (86%)	10 (8.7%)		11 (9.7%)	79 (69.9%)	23 (20.4%)	

** Univariable analysis was based on a Fisher's Exact Test,*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.10 - continued

		Improved welfare of pigs				Production of more or cheaper food			
		N or NV I	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	120 8 2500 135	150 2 40000 472	40 3 3300 339	0.776	116.5 2 40000 506	140 2 2500 315	195 2 2700 539	0.604
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1000 65 10000 1175	1200 1 300000 2890	570 20 4500 1885	0.673	1000 1 300000 2738	1200 5 51000 2424	1000 2 30674 30672	0.723
Production system - breeding	**Outdoor**	3 (6.5%)	41 (89.1%)	2 (4.4%)	0.26*	16 (36.4%)	16 (36.4%)	12 (27.2%)	0.318
	Indoor	6 (5.4%)	90 (81.1%)	15 (13.5%)		51 (46.8%)	27 (27.8%)	31 (25.4%)	
Production system - feeding	**Outdoor**	2 (9.1%)	18 (81.8%)	2 (9.1%)	0.806*	10 (45.5%)	7 (31.8%)	5 (22.7%)	0.959
	Indoor	7 (6%)	95 (81.9%)	14 (12.1%)		52 (46.8%)	32 (28.8%)	27 (24.4%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Figure 5.9 Frequency that respondents identified different sources of information on critically important antimicrobials.

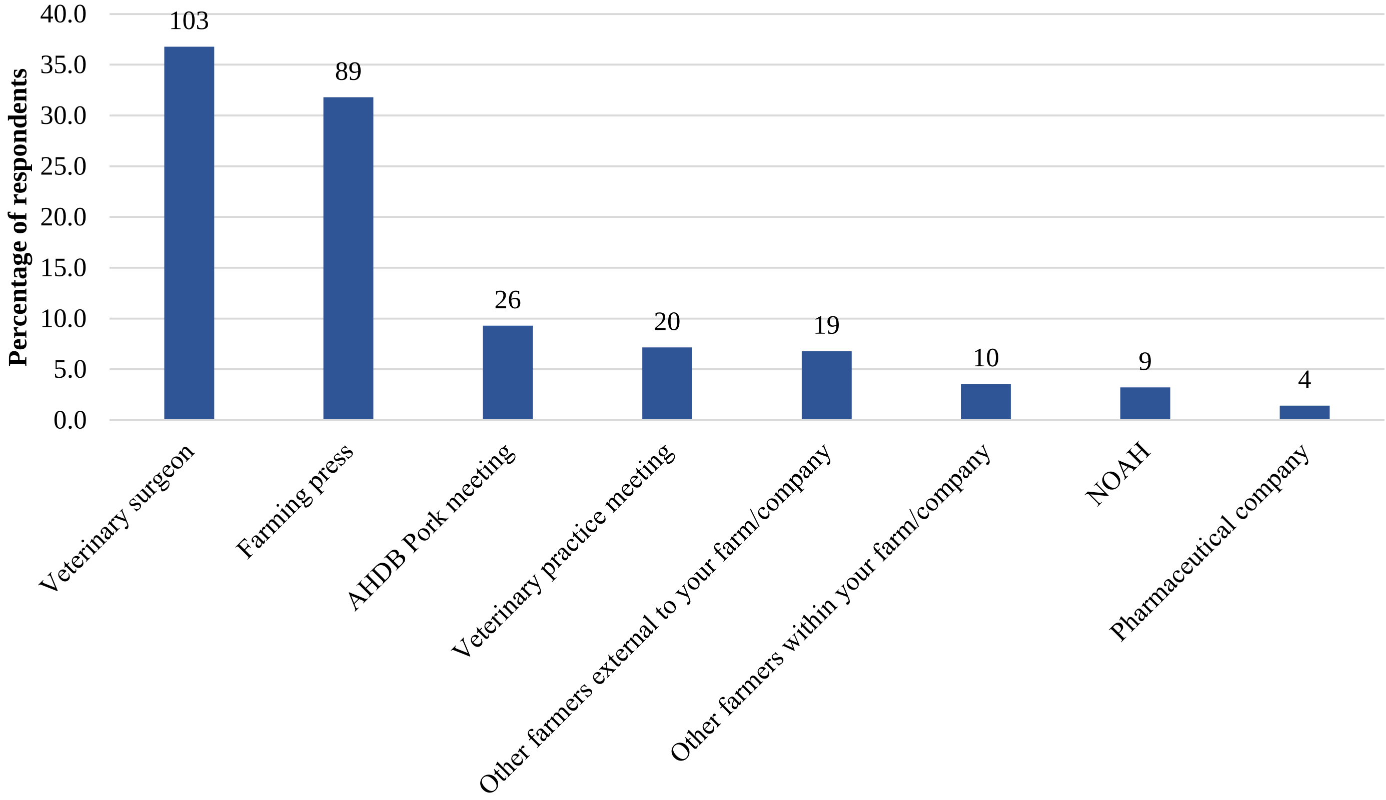


Table 5.11 – Univariable analysis of the importance respondents placed on individuals and organisations for the monitoring of the prudent use of antimicrobials in pigs and respondent and farm characteristics. N or NV I – Not or not very important, Ne – Neutral, Q or V - Quite or very important

		The veterinary surgeon				The farmer				Farm assurance schemes			
		N or NV I	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	120 10 350 290	300 2 840 744	140 2 400000 428	0.681		20 5 750 294	140 2 40000 440	0.676	87.5 4 6800 480	115 2 40000 427	150 2 2700 425	0.421
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	750 50 51000 2180	2000 2 6500 3493	1100 1 300000 2720	0.791		850 30 4000 2668	1100 1 300000 2700	0.796	870 7 75000 2750	1000 1 300000 1908	1500 2 300000 1908	0.111
Production system - breeding	**Outdoor**	1 (2.2%)	3 (6.5%)	42 (91.3%)	0.683*	0 (0%)	3 (6.5%)	43 (93.5%)	0.806*	11 (25%)	12 (27.3%)	21 (47.7%)	0.778
	Indoor	4 (3.5%)	4 (3.5%)	105 (92.9%)		1 (0.9%)	6 (5.5%)	103 (93.6%)		22 (20.2%)	34 (31.2%)	53 (48.6%)	
Production system - feeding	**Outdoor**	1 (4.5%)	0 (0%)	21 (95.5%)	1*	0 (0%)	1 (4.5%)	21 (95.5%)	1*	7 (31.7%)	5 (22.7%)	10 (45.5%)	0.212
	Indoor	5 (4.3%)	3 (2.6%)	108 (93.1%)		0 (0%)	8 (7%)	107 (93%)		23 (20.5%)	47 (42%)	42 (37.5%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.11 continued

		UK government				Retailer				The European Union			
		N or NV I	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**	**N or NV I**	**Ne**	**Q or V I**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	97.5 2 40000 428	129 4 4000 425	140 2 3300 386	0.507	120 2 40000 461	170 4 6800 450	110 2 2700 305	0.441	145 2 40000 527	134.5 2 1350 343	105 2 2700 272	0.678
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1000 1 300000 2750	1200 8 51000 2925	1200 2 30672 2228	0.691	1000 1 300000 2720	1350 8 73500 3213	1000 2 51000 2660	0.863	1000 1 300000 2300	1500 2 51000 2681	1000 5 30674 2681	0.447
Production system - breeding	**Outdoor**	14 (31.8%)	13 (29.5%)	17 (38.6%)	0.868	21 (48.8%)	10 (23.3%)	12 (27.9%)	0.721	28 (65.1%)	8 (18.6%)	7 (16.3%)	0.416
	Indoor	38 (35.2%	33 (30.6%)	37 (32.2%)		47 (43.5%)	32 (19.5%)	29 (26.9%)		58 (54.2%)	30 (28%)	19 (17.8%)	
Production system - feeding	**Outdoor**	7 (31.8%)	6 (27.3%)	9 (40.9%)	0.26	13 (59.1%)	3 (13.6%)	6 (27.3%)	0.61	15 (68.2%)	4 (18.2%)	4 (18.2%)	0.323
	Indoor	37 (33%)	47 (42%)	28 (25%)		43 (38.7%)	44 (39.6%)	24 (21.6%)		59 (53.2%)	38 (34.2%)	38 (34.2%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.12 - Univariable analysis on the respondent awareness of critically important antimicrobials and the characteristics of respondents and their farms.

		Aware of CIAs		p-value
		No	**Yes**	
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	222.5 4 6800 628	113 2 40000 382	0.037
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1700 6 73500 3615	1000 1 300000 1933	0.013
Type of production - breeding	**Outdoor**	19 (40.4%)	28 (59.6%)	0.585
	Indoor	51 (45.1%)	62 (54.9%)	
Type of production - feeding	**Outdoor**	5 (22.7%)	17 (77.3%)	0.096
	Indoor	49 (41.5%)	69 (58.5%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Mann-Whitney Test*

Table 5.13 - Univariable analysis on respondents' perceived importance of the macrolides and the characteristics of respondents and their farms.

		Not important or not very important	Neutral	Quite important or very important	p-value
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	220 2 7000 551	200 20 110 900	320 15 40000 469	0.419
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1100 5 80000 2150	1500 100 10000 3100	1900 45 300000 3700	**0.042**
Type of production - breeding	**Outdoor**	29 (67.4%)	7 (16.3%)	7 (16.3%)	**0.004**
	Indoor	31 (32.3%)	14 (14.6%)	51 (53.1%)	
Type of production - feeding*	**Outdoor**	7 (58.3%)	2 (16.7%)	3 (25%)	0.055
	Indoor	27 (29%)	13 (14%)	53 (57%)	
Aware of CIAs	**No**	23 (33.3%)	13 (18.8%)	33 (47.9%)	0.496
	Yes	40 (38.8%)	13 (12.6%)	50 (48.6%)	
Macrolide use in sows in last year*	**No**	65 (35.7%)	28 (15.4%)	89 (48.9%)	**0.049**
	Yes	2 (50%)	2 (50%)	0 (0%)	
Macrolide use in piglets in last year*	**No**	66 (37.3%)	30 (16.9%)	81 (45.8%)	0.065
	Yes	1 (11.1%)	0 (0%)	8 (88.9%)	
Macrolide use in weaners in last year*	**No**	66 (39.3%)	27 (16.1%)	75 (44.6%)	**0.005**
	Yes	1 (5.6%)	3 (16.7%)	14 (77.7%)	
Macrolide use in finishers in last year*	**No**	66 (40.7%)	30 (18.6%)	66 (40.7%)	**<0.001**
	Yes	1 (4.2%)	0 (0%)	23 (95.8%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.14 - Univariable analysis on respondents' perceived importance of the fluoroquinolones and the characteristics of respondents and their farms.

		Not important or not very important	Neutral	Quite important or very important	p-value
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	82.5 2 6800 271	230 20 4000 352	445 11 7000 630	**<0.001**
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	500 5 75000 2085	1700 100 26000 3044	2200 100 80000 3710	**<0.001**
Type of production - breeding*	**Outdoor**	16 (51.6%)	4 (12.9%)	11 (35.5%)	0.13
	Indoor	28 (31.1%)	15 (16.7%)	47 (52.2%)	
Type of production - feeding*	**Outdoor**	7 (58.3%)	1 (8.3%)	4 (33.4%)	0.193
	Indoor	25 (30.1%)	14 (16.9%)	44 (53%)	
Aware of CIAs	**No**	21 (32.3%)	14 (21.5%)	30 (46.2%)	0.337
	Yes	33 (35.1%)	12 (12.8%)	49 (52.1%)	
Fluoroquinolone use in sows in last year*	**No**	58 (34.5%)	28 (16.7%)	82 (48.8%)	
	Yes	1 (25%)	0 (0%)	3 (75%)	0.659
Fluoroquinolone use in piglets in last year*	**No**	59 (39.1%)	28 (18.5%)	64 (42.4%)	**<0.001**
	Yes	0 (0%)	0 (0%)	21 (100%)	
Fluoroquinolone use in weaners in last year*	**No**	49 (31.2%)	28 (17.8%)	80 (51%)	0.084
	Yes	0 (0%)	0 (0%)	5 (100%)	
Fluoroquinolone use in finishers in last year*	**No**	59 (36%)	28 (17.1%)	77 (46.9%)	**0.014**
	Yes	0 (0%)	0 (0%)	8 (100%)	

** Univariable analysis was based on a Fisher's Exact Test*

*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.15 - Univariable analysis on respondents' perceived importance of the third and fourth generation cephalosporins and the characteristics of respondents and their farms.

		Not important or not very important	Neutral	Quite important or very important	p-value
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	227.5 2 7000 598	280 20 2500 845	300 80 1000 248	0.548
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1440 5 80000 3000	1800 100 17000 3463	3000 270 51000 2885	0.118
Type of production - breeding*	**Outdoor**	21 (67.7%)	8 (25.8%)	2 (6.5%)	0.77
	Indoor	51 (62.2%)	21 (25.6%)	10 (12.2%)	
Type of production - feeding*	**Outdoor**	8 (72.7%)	2 (18.2%)	1 (9.1%)	0.898
	Indoor	45 (59.2%)	20 (26.3%)	11 (14.5%)	
Aware of CIAs	**No**	32 (52.5%)	20 (32.8%)	9 (14.7%)	0.204
	Yes	55 (65.5%)	17 (20.2%)	12 (14.3%)	
3rd/4th cephalosporin use in piglets in last year*	**No**	94 (60.6%)	41 (26.5%)	20 (12.9%)	**0.003**
	Yes	0 (0%)	0 (0%)	3 (100%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Appendix 5, Appendix to Chapter 6

Table 5.16 - Univariable analysis of respondent opinion on whether potential policy measures would be a barrier, beneficial or have a neutral effect on total antimicrobial use in pigs and association with respondent characteristics

		Banning in-feed antimicrobials				**Benchmarking antimicrobial use on farms**			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median**	101.5	165	165	0.899	120	102.5	140	0.949
	Minimum	2	5	2		4	4	2	
	Maximum	6800	1100	4000		2500	40000	6800	
	IQ range	390	557	413		538	423	418	
Number of pigs**	**Median**	1000	1650	1200	0.672	850	870	1600	0.441
	Minimum	8	16	5		8	16	1	
	Maximum	7350	10000	26000		25000	300000	75000	
	IQ range	2740	4113	2100		2630	2700	3240	
Production type - breeding	**Outdoor**	21 (56.8%)	2 (5.4%)	14 (37.8%)	0.245*	10 (26.3%)	9 (23.7%)	19 (50%)	0.407*
	Indoor	55 (61.8%)	12 (11.2%)	22 (27%)		13 (15.7%)	24 (28.9%)	46 (55.4%)	
Production type - feeding	**Outdoor**	12 (60%)	1 (5%)	7 (35%)	0.621*	3 (13.6%)	6 (27.3%)	13 (59.1%)	0.948*
	Indoor	56 (65.9%)	8 (9.4%)	21 (24.7%)		14 (16.7%)	25 (29.8%)	45 (53.5%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.16 continued

		Veterinary surgeons no longer able to sell antimicrobials				Penalty system for high antimicrobial use			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median**	150	116.5	140	0.976	120	180	190	0.671
	Minimum	2	5	5		2	5	2	
	Maximum	40000	2700	3300		2200	6800	40000	
	IQ range	526	405	322		480	526	450	
Number of pigs**	**Median**	1100	1075	1900	0.679	1000	1545	1490	0.282
	Minimum	1	16	60		1	16	2	
	Maximum	300000	30674	10000		25000	73500	300000	
	IQ range	2885	2790	3075		2040	3106	3215	
Production type - breeding	**Outdoor**	24 (63.2%)	10 (26.3%)	4 (10.5%)	0.822*	8 (22.9%)	6 (17.1%)	21 (60%)	0.813
	Indoor	55 (56.7%)	29 (29.9%)	13 (13.4%)		22 (23.4%)	12 (12.8%)	60 (63.8%)	
Production type - feeding	**Outdoor**	10 (52.6%)	6 (31.6%)	3 (15.8%)	0.529*	5 (26.3%)	4 (21.1%)	10 (52.6%)	0.945*
	Indoor	62 (63.9%)	24 (24.7%)	11 (11.4%)		21 (22.5%)	22 (23.7%)	50 (53.8%)	

**Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.17 - Univariable analysis of respondent opinion on whether potential management measures would be a barrier, beneficial or have a neutral effect on total antimicrobial use in pigs and association with respondent characteristics

		Eradicating swine dysentery from the UK				**Modernising indoor pig accommodation**			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median**	55	240	145	0.346	40	65	140	0.458
	Minimum	4	4	2		6	2	2	
	Maximum	40000	4000	6800		40000	4000	6800	
	IQ range	260	788	426		20092	591	425	
Number of pigs**	**Median**	525	1895	1200	0.298	380	975	1150	0.307
	Minimum	8	39	1		8	1	2	
	Maximum	300000	26000	75000		300000	51000	75000	
	IQ range	2340	5555	2695		1740	2775	2650	
Production type – breeding	**Outdoor**	5 (12.2%)	2 (9.8%)	33 (78%)	0.517*	3 (7.1%)	11 (26.2%)	28 (66.7%)	0.029*
	Indoor	14 (14.1%)	11 (11.1%)	74 (74.8%)		4 (4.4%)	9 (10%)	77 (85.6%)	
Production type – feeding	**Outdoor**	0 (0%)	1 (5%)	19 (95%)	0.277*	0 (0%)	7 (35%)	13 (65%)	0.12*
	Indoor	13 (12.5%)	7 (6.7%)	84 (80.8%)		2 (2%)	15 (15%)	83 (83%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.17 continued

		Increased use of straw-based finishing systems				Increased use of outdoor breeding			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	130 5 2000 324	150 2 6800 565	107.5 2 4000 388	0.903	120 5 3000 220	181 2 6800 610	100 2 4000 409	0.21
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1350 8 6000 1775	1650 11 7350 3342	1000 1 51000 1723	0.208	1000 16 6000 1500	1500 20 75000 3200	900 2 51000 2850	0.306
Production type – breeding	**Outdoor**	8 (20.5%)	8 (20.5%)	23 (59%)	0.055	7 (20.6%)	12 (35.3%)	15 (44.1%)	0.195
	Indoor	13 (14.6%)	38 (42.7%)	38 (42.7%)		10 (12.3%)	43 (53.1%)	28 (34.6%)	
Production type – feeding	**Outdoor**	1 (5.3%)	5 (26.3%)	13 (68.4%)	0.162*	3 (16.7%)	6 (33.3%)	9 (50%)	0.267*
	Indoor	18 (17.8%)	38 (37.6%)	45 (44.6%)		10 (11.8%)	46 (54.1%)	29 (34.1%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.17 continued

		More effective vaccines				A wide range of vaccines			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	45 4 165 115	40 6 750 534	140 2 40000 430	0.265	28.5 2 165 98	50 4 4000 619	140 2 40000 445	0.091
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	310 60 1500 709	365 7 4500 2338	1200 1 300000 2683	0.058	310 5 1500 690	380 7 26000 1950	1200 1 300000 2683	**0.012**
Production type – breeding	**Outdoor**	0 (0%)	3 (7.5%)	37 (92.5%)	0.374*	2 (5.3%)	4 (10.5%)	32 (84.2%)	1*
	Indoor	5 (5.1%)	5 (5.1%)	89 (89.8%)		5 (5.2%)	11 (11.5%)	80 (83.3%)	
Production type – feeding	**Outdoor**	1 (4.3%)	0 (0%)	22 (95.7%)	0.71*	2 (8.3%)	0 (0%)	20 (91.7%)	0.12*
	Indoor	3 (2.9%)	2 (1.9%)	98 (95.2%)		2 (2.1%)	7 (7.2%)	88 (90.7%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.17 continued

		De-population and re-population with high status pigs				Poor availability of highly skilled stockpeople			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	210 12 350	72.5 4 40000 280	145 2 6800 458	0.683	120 2 4000 389	140 2 40000 738	67.5 2 6800 585	0.98
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	850 120 4500 3065	1000 28 300000 2243	1440 1 75000 3175	0.495	1000 1 30674 2680	1200 2 300000 2610	975 5 73500 2218	0.809
Production type - breeding	**Outdoor**	0 (0%)	5 (13.2%)	33 (86.8%)	0.489*	27 (71.1%)	4 (10.5%)	7 (18.4%)	0.645*
	Indoor	3 (3.2%)	18 (19.1%)	73 (77.7%)		69 (86.3%)	4 (5%)	7 (8.7%)	
Production type - feeding	**Outdoor**	0 (0%)	4 (21.1%)	15 (78.9%)	0.871*	14 (70%)	2 (10%)	4 (20%)	0.407*
	Indoor	3 (3.1%)	24 (24.7%)	70 (72.2%)		65 (69.1%)	18 (19.1%)	11 (11.8%)	

** Univariable analysis was based on a Fisher's Exact Test, ** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.18 - Univariable analysis of respondent opinion on whether potential economic measures would be a barrier, beneficial or have a neutral effect on total antimicrobial use in pigs and association with respondent characteristics

		Increased profitability of pig meat prices				Increasing the cost of antimicrobials for farmers			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	62.5 6 4000 484	202.5 2 40000 559	140 2 6800 370	0.615	105 2 40000 375	220 2 6800 465	50 3 1400 414	0.233
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	662.5 8 26000 2835	1000 20 300000 2740	1229.5 1 75000 2650	0.698	950 1 300000 2345	1650 20 75000 3004	800 7 17000 2063	0.136
Production type - breeding	**Outdoor**	3 (7.3%)	13 (31.7%)	25 (61%)	0.739*	22 (51.2%)	16 (37.2%)	5 (11.6%)	0.788
	Indoor	5 (5%)	28 (28%)	67 (67%)		45 (47.4%)	41 (43.2%)	9 (9.4%)	
Production type - feeding	**Outdoor**	1 (5%)	9 (45%)	10 (50%)	0.142*	8 (38.2%)	11 (52.4%)	2 (9.4%)	0.439*
	Indoor	5 (4.8%)	26 (24.8%)	74 (70.4%)		54 (53.5%)	40 (39.6%)	7 (6.9%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Appendix 5, Appendix to Chapter 6

Table 5.18 continued

		Decreasing the cost of antimicrobials for farmers				Reducing imports from high antimicrobial use countries			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	125 4 4000 422	140 2 40000 425	150 2 6800 760	0.86	78.5 2 1050 375	320 6 40000 595	120 2 6800 385	0.227
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1600 7 26000 2338	1200 1 300000 2925	1000 2 73500 2470	0.757	1000 9 9000 2350	1600 39 300000 2825	1050 1 75000 2740	0.718
Production type - breeding	**Outdoor**	9 (21.4%)	19 (45.2%)	14 (33.4%)	0.29	1 (2.5%)	6 (15%)	33 (82.5%)	0.476*
	Indoor	14 (15.2%)	55 (59/8%)	23 (25%)		7 (6.9%)	10 (9.9%)	84 (83.2%)	
Production type - feeding	**Outdoor**	4 (22.2%)	10 (55.6%)	4 (22.2%)	0.581*	1 (5.6%)	2 (11.1%)	15 (83/3%)	1*
	Indoor	17 (17%)	50 (50%)	33 (33%)		10 (9.5%)	10 (9.5%)	85 (81%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Test*

Table 5.19 - Univariable analysis of respondent opinion on whether disease surveillance for antimicrobial resistance would be a barrier, beneficial or have a neutral effect on total antimicrobial use in pigs and association with respondent characteristics

		Regional reporting of antimicrobial resistance in pigs				**National reporting of antimicrobial resistance in pigs**			
		Barrier	**Neutral**	**Beneficial**	**p-value**	**Barrier**	**Neutral**	**Beneficial**	**p-value**
Number of sows**	**Median** **Minimum** **Maximum** **IQ range**	151 5 300 252	440 15 40000 700	107.5 2 4000 400	**0.005**	151 5 280 247	450 40 40000 700	102.5 2 4000 378	**0.002**
Number of pigs**	**Median** **Minimum** **Maximum** **IQ range**	1650 120 3100 1743	2000 180 300000 3500	1000 2 30674 2810	**0.003**	930 120 3100 1850	20000 350 300000 3275	1000 2 30674 2810	**0.002**
Production type - breeding	**Outdoor**	2 (4.7%)	6 (14%)	35 (81.3%)	0.82*	2 (4.7%)	6 (14%)	35 (81.3%)	0.935*
	Indoor	4 (4%)	18 (18.2%)	77 (77.8%)		4 (4.1%)	17 (17.5%)	76 (78.4%)	
Production type - feeding	**Outdoor**	0 (0%)	1 (4.5%)	21 (95.5%)	**0.027***	0 (0%)	1 (4.5%)	21 (95.5%)	**0.013***
	Indoor	8 (7.8%)	25 (24.5%)	69 (67.7%)		11 (10.3%)	27 (25.2%)	69 (64.5%)	

** Univariable analysis was based on a Fisher's Exact Test*
*** Univariable analysis was based on a Kruskal-Wallis Tetstt*

Figure 5.9 – Accompanying letter sent to farmers with questionnaire

UNIVERSITY OF LIVERPOOL

Dear

We would like to invite you to take part in a study on the use of antibiotics in pig farming in the UK. This is a national study seeking the views of both veterinary surgeons and farmers. We are now asking farmers to complete a questionnaire about antibiotic use in pigs and you have been randomly selected to take part in the study.

Antibiotics are at the forefront of tackling infectious disease both in humans and animals, offering very effective ways of rapidly combating a wide range of pathogens. However, the rise in resistance, and lack of development of new compounds, is of concern to both human and animal health. Gaining in-depth insight and understanding into the influences behind antibiotic use is essential in maintaining the effectiveness of antibiotics for use in pigs as well as other animals, including humans. Your participation in this study will help us to better understand antibiotic use in pigs in the UK. This project is funded by the Veterinary Medicines Directorate (Defra executive agency) and agreement for use has been obtained from the devolved administrations.

This letter is being sent to you using an address list compiled from information collected as part of the Defra June Survey of Agriculture and Horticulture.

The questionnaire consists of four sections. Section A asks for information about you and your farm/pig production company, section B covers opinion on antibiotic use in pigs, section C covers your opinion on pig disease and the role that antibiotics play in combating and managing disease, and section D discusses responsibility of antibiotic use. There are no right or wrong answers to the questions, their purpose is to gather opinion on the benefits and potential drawbacks of antibiotics and how this relates to the health and welfare of the UK pig herd.

All responses are completely confidential. The information that you provide will be maintained and analysed at the University of Liverpool. Participation in this study is entirely voluntary. The questionnaire should take approximately 20 minutes to complete. Once the study is completed we will make our general, anonymised findings available to the industry via BPEX and the NPA.

The study is being led by researchers at Liverpool University and Mr Richard Pearson, a partner at the George Veterinary Group in Wiltshire, who specialises in pig work. If you have any questions concerning this study please don't hesitate to contact us by email at l.a.coyne@liv.ac.uk or phone at 01517956011. A version of the questionnaire in the Welsh language is available upon request.

Once completed please return the questionnaire to us using the enclosed pre-paid envelope.

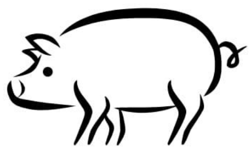
Thank you for your time and interest in this project.
Yours sincerely,

L. Coyne

Lucy Coyne, Gina Pinchbeck, Sophia Latham, Nicola J Williams, Rob Smith, Susan Dawson

Department of Epidemiology and Population Health, University of Liverpool, Leahurst, Chester High Road, Neston, Cheshire, CH64 7TE

Figure 5.10 – Farmer questionnaire



Antibiotic Use in Pigs in the UK

We are conducting a confidential survey of farmers who work in the pig industry in order to gain a better understanding of the use of antibiotics in pigs. We wish to seek opinions on the benefits and potential drawbacks of antibiotic use and how this relates to the health and welfare of the UK pig herd.

We are hoping for a high response to demonstrate the engagement of the UK pig sector with the wider issues surrounding antibiotic use. Your willingness to share your views in this area will help to do this.

Completing the questionnaire should take no longer than <u>20 minutes.</u>

Your participation in this study will help us to understand antibiotic use better in pigs in the UK. All responses will remain completely confidential. The information that you provide will be maintained and analysed at the University of Liverpool. Participation in this study is entirely voluntary.

This questionnaire consists of four sections:

Section A: About you and the farm/pig production company.
Section B: Your opinion on antibiotic use in pigs.
Section C: Pig disease and antibiotics.
Section D: Responsible antibiotic use.

Please select the box (□) for the answer that you consider is most appropriate from the multiple choice answer options given. Please select one option unless otherwise stated. When the term ‘feeding pigs’ is used please consider weaners, growers and finishers.

A – About you and the farm/pig production company

A1. What is your role on the farm/within the pig production company?

☐ Manager of multiple units, if so how many? ……………………………………………………...

☐ Manager of a single unit

☐ Senior stockperson

☐ Stockperson

☐ Other, please specify……………………………………………………………………………

A2. How many members of staff are employed on the farm/pig unit(s) you are responsible for? Please indicate the number of members of staff employed in each position.

☐ Manager

☐ Senior stockperson

☐ Stockperson

☐ Nutritionist

Others, please specify………………………………………………………………………………………

A3. How many sows and pigs are on your farm(s)?

☐ Sows

☐ Pigs

A4. How many sows and pigs are you personally responsible for?

☐ Sows

☐ Pigs

A5. What would best describe the vet that most regularly attends the farm/ pig units?

☐ The vet is a specialist pig vet within a pig production company

☐ The vet is a specialist pig vet within a private Veterinary Practice

☐ The vet is a farm animal vet within a private Veterinary Practice

☐ The vet is a mixed practice vet (farm animal and pets) within a private Veterinary Practice

☐ Other, please specify…………………………………………………………………………..

Name of Veterinary Practice (optional)……………………………………………………………………………………………...

A6. What would best describe the role of this vet on your farm/within the pig production company?

- ☐ The vet attends for routine visits more often than every 3 months and any emergencies or other requirements as they arise
- ☐ The vet attends for a quarterly visit and any emergencies or other requirements as they arise
- ☐ The vet attends for emergency visits only
- ☐ The vet has not attended the farm in the last year

A7. Do you use any other vets, veterinary practices or consultants, other than the one described in A5 above?

- ☐ No
- ☐ Yes, please give any details ……….……………………………………………………………

A8. What geographic region is the farm located in? <u>If multiple units, please state where the majority are located.</u>

- ☐ East Midlands
- ☐ Eastern
- ☐ North East
- ☐ North West
- ☐ South East
- ☐ England – other…………………
- ☐ South West
- ☐ West Midlands
- ☐ Yorkshire and the Humber
- ☐ Scotland
- ☐ Wales

A9. What type of pig production system is employed <u>on your farm</u>? <u>Please tick all that apply.</u>

- ☐ Indoor breeding
- ☐ Outdoor breeding
- ☐ Indoor feeding only
- ☐ Outdoor feeding
- ☐ Breeding company
- ☐ Organic
- ☐ Other……………………………………… ………………………………

A10. What production system do you employ for farrowing sows; feeding pigs; and dry sows? <u>Please tick which system is employed.</u>

	Farrowing sows	Feeding pigs	Dry sows
All-in-all-out	☐	☐	☐
Continuous	☐	☐	☐
Combination, please specify	☐ ………………... ………………...	☐ ………………... ………………...	☐ ………………... ………………...

A11. What feed type do you use for farrowing sows; feeding pigs; dry sows? <u>Please tick which feed type you use.</u>

	Farrowing sows	Feeding pigs	Dry sows
Meal/cob	☐	☐	☐
Pellet	☐	☐	☐
Wet	☐	☐	☐
Combination, please specify	☐	☐	☐
	………………... ………………...	………………... ………………...	………………... ………………...

A12. What type of flooring is used for farrowing sows; feeding pigs; dry sows? <u>Please tick which flooring type is used.</u>

	Farrowing sows	Feeding pigs	Dry sows
Outdoor	☐	☐	☐
Straw	☐	☐	☐
Fully slatted	☐	☐	☐
Part-slatted	☐	☐	☐
Straw and slats combined	☐	☐	☐
Other, please specify	☐	☐	☐
	……………….. ………………..	……………….. ………………..	……………….. ………………..

A13. What type of ventilation system is employed for sows; feeding pigs; dry sows? Please tick which system is employed.

	Farrowing sows	Feeding pigs	Dry sows
Outdoor	☐	☐	☐
Natural ventilation (including ACNV)	☐	☐	☐
Artificial ventilation	☐	☐	☐

A14. What is the average group size for weaner pigs; fattening pigs; dry sows?

☐ Weaner pigs

☐ Fattening pigs

☐ Dry sows

A15. Are you a member of any pork quality assurance schemes? <u>Please tick any that apply.</u>

- ☐ Red Tractor Farm Assured
- ☐ Quality Meat Scotland Assurance Scheme
- ☐ RSPCA Freedom Foods
- ☐ Soil Association
- ☐ Organic farms and growers association
- ☐ Other ……..……………………..

A16. What is the policy for introducing new pigs onto the unit? <u>Please tick all that apply.</u>

☐ Closed herd
☐ Buy in gilts
☐ Buy in boars
☐ Only buy in semen
☐ Pigs from a single source
☐ Pigs from multiple sources

A17. Do you, or your vet, check or know the health status of all incoming stock?

Yes ☐ No ☐

A18. What measures do you use to improve biosecurity? <u>Please tick all that apply.</u>

☐ Physical barriers at the farm entrance (eg. gates and signage)
☐ Shower in/shower out system
☐ Quarantine of new animals
☐ All deliveries at the farm periphery
☐ Strict visitor policy, please specify…………………………………………………...
…………………………………………………………………………………………..
…………………………………………………………………………………………..

Any others, please specify

A19. Do you routinely use any vaccinations in animals on your farm? <u>Please list any vaccinations routinely used and state which animal for example sows, piglets, fattening pigs.</u>

Animal	Vaccinations

B – Opinion on antibiotic use in pigs

B1. What are your main sources of information on antibiotics and their use in pigs? Please list all main sources below.

B2. Are there any situations where you feel your antibiotic choices are limited?

B3. On a routine farm visit how often would your vet take samples (e.g. post mortem, blood, or faecal samples) for further diagnostic testing?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

B4. On a farm visit for a new disease outbreak situation how often would your vet take samples (e.g. post mortem, blood, or faecal samples) for further diagnostic testing?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

B5. How often do you see little or no improvement after using antibiotics?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

Please give any examples where there has been a poor response to antibiotics observed on your unit(s). For example, have you ever been required to change antibiotics as the first choice of drug was ineffective?

B6. How often do you think you see a poor response to antibiotics due to antibiotic resistance?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐ Don't know ☐

B7. Which of the following factors are likely to influence your decision to administer an antibiotic on farm? Please indicate whether you would be less likely to use an antibiotic, neutral, or more likely to use an antibiotic.

	Less likely	Neutral, no effect	More likely
You are confident that bacterial disease is present	☐	☐	☐
Disease is causing pig welfare to be adversely affected	☐	☐	☐
The pig appears to have a high temperature	☐	☐	☐
The pig is not eating	☐	☐	☐
The pig has been in close contact with other pigs showing signs of an infection	☐	☐	☐
There is concern that clinical signs may worsen if an antibiotic is not used	☐	☐	☐
The feed company representative offers advice that an antibiotic may be needed and veterinary input may be required	☐	☐	☐
There is pressure from the retailer to lower antibiotic use	☐	☐	☐
There is pressure from the vet to lower antibiotic use	☐	☐	☐

B8. Please indicate what you consider are the main advantages and limitations of different routes of administering antibiotics (in-feed, in-water, injectable and oral drench). Please list any advantages or limitations you consider are important.

	Advantages	Limitations
Injectable		
In-feed		
In-water		
Oral drench		

B9. Have you ever had to use in-feed antibiotics for disease prevention? If no please move to B11.

Yes ☐ No ☐ Don't know ☐

B10. The decision to stop or continue in-feed antibiotics for disease prevention is always problematic. This decision requires the consideration of many factors between the vet and farmer.

(a) What factors have influenced the decision to continue in-feed antibiotics on your farm?

(b) What factors have influenced the decision to stop in-feed antibiotics on your farm?

B11. In your opinion which management features/systems have the highest and lowest use of antibiotics in general? Please tick one of the following for each system lowest, lower, moderate, higher, highest for each system.

	Lowest	Lower	Moderate	Higher	Highest	Don't know
Continuous pig flow systems	☐	☐	☐	☐	☐	☐
All-in/all-out pig flow systems	☐	☐	☐	☐	☐	☐
High stocking density	☐	☐	☐	☐	☐	☐
Indoor farrowing in crates	☐	☐	☐	☐	☐	☐
Outdoor farrowing systems	☐	☐	☐	☐	☐	☐
Solid floor straw-based indoor finishing systems	☐	☐	☐	☐	☐	☐
Indoor slatted finishing systems	☐	☐	☐	☐	☐	☐
Outdoor finishing systems	☐	☐	☐	☐	☐	☐
Well managed units	☐	☐	☐	☐	☐	☐
Unit buying pigs from multiple sources	☐	☐	☐	☐	☐	☐
Unit buying pigs from a single Source	☐	☐	☐	☐	☐	☐
High health status pigs	☐	☐	☐	☐	☐	☐

B12. Are there any other management features and facilities that you think might be associated with high or low antibiotic usage? Please describe any management features or facilities below.

B13. What would you consider to alternatives to the use of antibiotics in pigs? <u>Please select all those you consider to be important.</u>

☐ Vaccination

☐ Improved housing

☐ Improved pig genetics

☐ Other alternatives, please give examples

☐ Pre/Pro-biotics or other feed additives

☐ Zinc oxide

C – Pig diseases and antibiotics

C1. On your farm which of the following types of disease have required treatment with antibiotics in the last year? Please leave blank any animal groups that do not apply.

	Farrowing sows	Piglets	Feeding pigs	Dry sows
Gastrointestinal disease/scour	☐	☐	☐	☐
Respiratory	☐	☐	☐	☐
Reproductive	☐	☐	☐	☐
Lameness	☐	☐	☐	☐
Other, please specify	☐	☐	☐	☐

C2. What would be the two most common antibiotics used in the different groups in the last year? Please state the formulation of each antibiotic eg.in-feed, in-water or injectable. Please leave blank any animal groups that do not apply.

	Sows	Piglets	Weaners/ growers	Finishers
1. Antibiotic				
2. Antibiotic				

C3. Please rate the following classes of antibiotics in terms of how important they are for the health and welfare of pigs on your farm.

	Not important	Not very important	Neutral	Quite important	Very important
Macrolides (Tylan, Pulmotil)	☐	☐	☐	☐	☐
Fluoroquinolones (Baytril, Marbocyl, Forcyl)	☐	☐	☐	☐	☐
Third and fourth generation cephalosporins (Naxcel, Excenel)	☐	☐	☐	☐	☐

For the disease conditions listed below please state your likely initial response(s) if you were to encounter the disease situations on farm. Please tick all that apply.

If your farm is breeding only then please complete C4
If your farm is feeding only then please complete C5
If your farm is breeding and feeding then please complete both C4 and C5

C4. Breeding sows and piglets

	Scour in a litter of piglets	Mastitis in an individual sow	Infertility problems in the sow herd
Diagnostics			
Send sample to the lab for testing and await results before using an antibiotic	☐	☐	☐
Send sample to the lab for testing and use an antibiotic whilst awaiting results	☐	☐	☐
Send an animal for post mortem examination	☐	☐	☐
Treatment options			
Treat with an antibiotic available on farm	☐	☐	☐
Treat with an antibiotic previously prescribed by the vet for the same condition	☐	☐	☐
Expert advice			
Seek telephone advice from vet	☐	☐	☐
Request a visit from the vet	☐	☐	☐
Review at next routine veterinary herd health visit	☐	☐	☐
Request a prescription for in-feed antibiotic treatment	☐	☐	☐
Seek advice from feed company representative/nutritionist	☐	☐	☐

C5. Weaners and growers

	Post-weaning scour	Respiratory disease in feeding pigs	Sporadic meningitis in feeding pigs	Lameness in individual pigs
Diagnostics				
Send sample to the lab for testing and await results before using an antibiotic	☐	☐	☐	☐
Send sample to the lab for testing and use an antibiotic whilst awaiting results	☐	☐	☐	☐
Send an animal for post mortem examination	☐	☐	☐	☐
Treatment options				
Treat with an antibiotic available on farm	☐	☐	☐	☐
Treat with an antibiotic previously prescribed by the vet for the same condition	☐	☐	☐	☐
Add zinc oxide to the feed ration in consultation with the vet and feed company representative/nutritionist	☐	☐	☐	☐
Add a pre/probiotic to the feed ration in consultation with the feed company representative/nutritionist	☐	☐	☐	☐
Request a prescription for in-feed antibiotic treatment	☐	☐	☐	☐
Expert advice				
Seek telephone advice from the vet	☐	☐	☐	☐
Request a visit from the vet	☐	☐	☐	☐
Review at next routine veterinary herd health visit	☐	☐	☐	☐
Seek advice from feed company representative/nutritionist	☐	☐	☐	☐

D – Responsible antibiotic use

D1. There is diverse opinion on what is considered to represent responsible antibiotic use in pigs. Please indicate whether or not you consider the following to be a justified use of antibiotics in pigs. Please select from: never justified, rarely justified, usually justified, always justified, Don't know.

	Never justified	Rarely justified	Usually justified	Always justified	Don't know
Antibiotic use for treatment of pigs with disease	☐	☐	☐	☐	☐
Antibiotic use for disease prevention	☐	☐	☐	☐	☐
Antibiotic use for growth promotion	☐	☐	☐	☐	☐
The use of in-feed antibiotic formulations in pigs	☐	☐	☐	☐	☐

D2. Please rate the importance of the following when considering what you believe the likely or possible consequences are of the use of antibiotics in pigs. Not important, not very important, neutral, quite important, very important.

Consequences of antibiotic use:

	Not important	Not very important	Neutral	Quite important	Very important
Increased antibiotic resistance in pigs	☐	☐	☐	☐	☐
Increased antibiotic resistance in humans	☐	☐	☐	☐	☐
Reduced risk of disease transmission to humans	☐	☐	☐	☐	☐
Improved welfare for pigs	☐	☐	☐	☐	☐
Production of more or cheaper food	☐	☐	☐	☐	☐

D3. Please rate the importance of the following when considering who should be responsible for monitoring antibiotic usage in pigs? Not important, not very important, neutral, quite important, very important.

	Not important	Not very important	Neutral	Quite important	Very important
The vet	☐	☐	☐	☐	☐
The farmer	☐	☐	☐	☐	☐
Farm assurance schemes	☐	☐	☐	☐	☐
The UK government	☐	☐	☐	☐	☐
The retailer	☐	☐	☐	☐	☐
The European Union	☐	☐	☐	☐	☐

D4. Please consider each of the factors below and consider whether they would be beneficial, have no or neutral effect, or be a barrier to controlling the total amount of antibiotics used across the UK pig industry?

	Barrier	Neutral, no effect	Beneficial	Don't know
Banning in-feed antibiotics	☐	☐	☐	☐
A benchmarking system whereby antibiotic usage is benchmarked between farms	☐	☐	☐	☐
Antibiotics would no longer be sold by vet practices and a prescription would have to be obtained from the vet and taken to a pharmacy to get antibiotics	☐	☐	☐	☐
A penalty system for high antibiotic usage in pigs, such as the 'yellow card' system in Denmark	☐	☐	☐	☐
Eradicating swine dysentery from the UK	☐	☐	☐	☐
Modernising indoor pig accommodation	☐	☐	☐	☐
Increased use of straw-based finishing systems	☐	☐	☐	☐
Increased use of outdoor breeding systems	☐	☐	☐	☐
More effective vaccines	☐	☐	☐	☐
A wider range of vaccines	☐	☐	☐	☐
De-population and re-populating low health status pig herds with higher health status stock	☐	☐	☐	☐
Increased profitability of pig meat prices	☐	☐	☐	☐
Increasing the cost of antibiotics for farmers	☐	☐	☐	☐
Decreasing the cost of antibiotics for farmers	☐	☐	☐	☐
Reducing imports from other countries with high antibiotic use	☐	☐	☐	☐
Regional reporting of antibiotic resistance problems in pigs	☐	☐	☐	☐
National reporting of antibiotic resistance problems in pigs	☐	☐	☐	☐
Poor availability of highly skilled stockpeople	☐	☐	☐	☐

D5. With concern over antibiotic resistance in human medicine some antibiotics have been classified as being critical to human medicine ('critically important antibiotics') and therefore only used in animals when there are no alternatives. Is the issue of the use of 'critical antibiotics' in pigs something you have been made aware of before?

Yes ☐ No ☐

D6. If yes, where have you previously heard about 'critical antibiotics'?

- ☐ Your vet on a visit to your farm
- ☐ A meeting organised by your veterinary practice
- ☐ A BPEX meeting
- ☐ An NPA meeting
- ☐ The farming press
- ☐ The media
- ☐ Pharmaceutical company
- ☐ National Office for Animal Health (NOAH) Compendium
- ☐ Other farmers within your farm/pig production company
- ☐ Other farmers from outside your farm/pig production company
- ☐ Other, please specify……………………………………………………………………………………………

D7. From the list of drugs below can you identify any antibiotics that you believe may be classified as 'critical antibiotics'? Some common trade-names are included as examples in brackets.

- ☐ Amoxycillin (Amoxinsol, Stabox)
- ☐ Apramycin (Apralan)
- ☐ Ceftiofur (Excenel, Naxcel)
- ☐ Colistin (Coliscour)
- ☐ Florfenicol (Nuflor Swine)
- ☐ Fluoroquinolones (Baytril, Marbocyl, Forcyl)
- ☐ Lincomycin (Lincocin, Linco-spectin)
- ☐ Penicillin (Duphapen, Ultrapen LA)
- ☐ Spectinomycin (Spectam)
- ☐ Tetracyclines (Terramycin, Engemycin, Aurofac)
- ☐ Tiamulin (Denagard)
- ☐ Tilmicosin (Pulmotil)
- ☐ Trimethoprim sulphate (Trimediazine, Tribrissen, Norodine 24)
- ☐ Tulathromycin (Draxxin)
- ☐ Tylosin (Tylan)
- ☐ Other, please specify…………………………………………………………………………………….

D8. If you were to consider how responsibly antibiotics are used in pigs where would you rate the following on a continuous scale from totally irresponsible use to totally responsible use. Make a mark on the scale to indicate your rating.

i. Antibiotic use on your farm

Totally irresponsible use | Neutral | Totally responsible use

ii. Overall, antibiotic use in the UK pig industry

Totally irresponsible use | Neutral | Totally responsible use

iii. Antibiotic use in pigs in the rest of the world

Totally irresponsible use | Neutral | Totally responsible use

iv. Antibiotic use in human medicine

Totally irresponsible use | Neutral | Totally responsible use

Please use space below to provide any other information you think is relevant to antibiotic use in pigs or to provide have any comments regarding this study:

Thank you for your time. Your participation in the study is greatly appreciated.
Please return the questionnaire using the pre-paid envelope provided.

Reference:

Chapter 7

Concluding discussion

Concluding Thesis Discussion

This thesis describes the findings from mixed methodological studies to explore the behavioural influences behind antimicrobial use decisions by farmers and veterinary surgeons working in the UK pig industry. This is the first study of its kind to combine both qualitative and quantitative research methods to gain a detailed understanding of the respondents' perceptions and views on antimicrobial resistance, the responsible use of antimicrobials and the motivations surrounding antimicrobial use decisions in pigs. The following discussion explores the shared and contrasting perceptions on antimicrobial use decisions in pigs by the two distinct respondent groups of veterinary surgeons and farmers.

Comparative discussion

There was an overarching sense of personal confidence in the antimicrobial prescribing decisions of both veterinary surgeons and farmers, accompanied by the shared opinion that such choices were responsible and justifiable. Veterinary surgeons identified a social responsibility to reserve the use of the critically important antimicrobial classes for use in clinical cases where there were no effective alternatives; such behaviours have been identified in other veterinary surgeons (De Briyne et al., 2013). Farmer awareness of the critically important antimicrobials was variable. Whilst the majority proposed that their use in pigs was minimal and only used when necessary, farmers were infrequently able to identify the fluoroquinolones, third and fourth generation cephalosporins and macrolides as antimicrobial classes of critical importance to human medicine. Farmers identified veterinary surgeons as their most consistently consulted and trusted source of information on antimicrobials, as well as the actors with the responsibility for ensuring use is prudent and for finding alternative treatments should resistance develop, or a product be restricted. Hence there is an opportunity for further knowledge exchange, and for influencing antimicrobial use practices, between veterinary surgeons and farmers, particularly with regards to the critically important antimicrobials.

There were contrasts in the way in which veterinary surgeons and farmers perceived their relationship. Farmers commonly identified a partnership where antimicrobial use decisions are made mutually and, whilst some veterinary surgeons shared this view, many identified pressure from clients to prescribe antimicrobials; a situation recognised within veterinary medicine (Gibbons et al., 2013, Speksnijder et al., 2015b). There were some differences between the species caseload of veterinary surgeons and how they perceived client behaviour influenced prescribing. Overall, mixed species veterinary surgeons were more likely to prescribe based on client characteristics, such as expectation and perceived responsibility when compared with specialist pig practitioners. More effective communication and improved relationships may enable increased farmer awareness of the pressures veterinary surgeons face in prescribing decisions.

At odds with the sense of individual responsible antimicrobial use there was some concern that antimicrobial use in pigs by other veterinary surgeons and farmers may be less responsible. The ‘habitual’ use of in-feed antimicrobials for disease prevention was used by respondents to exemplify irresponsible use. This prophylactic use of in-feed antimicrobials is a common practice in pig production (Chauvin et al., 2002, Visschers et al., 2014, Sheehan, 2013), but is not consistent with the current guidelines on the responsible use of antimicrobials in pigs (Anon, 2013g, Anon, 2014d, Anon, 2015b). The concept whereby respondents associated irresponsible antimicrobial use with other veterinary surgeons or farmers, that were separate from themselves, is termed ‘othering’ (Johnson, 2004). This culture of blaming others for irresponsible antimicrobial use behaviours has also been described in human medicine (Rodrigues et al., 2013).

There were some contrasts in the farmer perceptions on the responsibility of prophylactic antimicrobial use. Whilst many interviewed described this practice as an undesirable and irresponsible behaviour practiced by some individuals, others believed that overall the use of antimicrobials for disease prevention was a responsible behaviour. This was confirmed in the questionnaire study where half considered such use to be justified, whilst the other half did not. This belief was also shared by veterinary surgeons in the study and is shown in the literature (Callens et al., 2012, Guardabassi and Prescott, 2015). Additionally, only half of farmers stated that they have used antimicrobials on their farms for disease prophylaxis. Both respondent groups identified that it was important to maintain the availability of antimicrobials for targeted disease prophylaxis in situations where alternative methods of disease control are not practical or feasible; such targeted use was considered to be an example of prudent use by respondents.

Another example of irresponsible behaviour described the concept that antimicrobials were used in some situations as a ‘management tool’, where improvements in the management practices and housing would allow this use to be reduced. Similarly, Stevens and others found that 79% of UK pig farmers considered ‘improved housing’ as an alternative to antimicrobial use (Stevens et al., 2007). A small proportion of interview respondents felt that antimicrobials are still used by a minority of irresponsible individuals for their positive effects on growth and production; a common example given was tylosin a macrolide; a class which is frequently used in pigs in Europe (De Briyne et al., 2014).

Veterinary surgeons and farmers equally identified that the act of discontinuing in-feed antimicrobials could be problematic, as withdrawal when there is no viable alternative method to prevent disease can be detrimental to the health and welfare of pigs. In such cases respondents commonly identified that economic constraints may restrict the feasibility of alternative methods of preventing disease. In agreement, other studies describe the ethical dilemma between desired responsible behaviours and actual practices (Morley et al., 2005). For example, the moral responsibility to reduce antimicrobials via management improvements, coupled with the ethical obligation to ensure that pig health and welfare is maintained. In some situations such improvements are not economically feasible or the farmer may be unwilling or unable to make changes. Additionally, both veterinary surgeons and farmers recognised the moral difficulty in withdrawing antimicrobials if endemic disease is present (Sheehan, 2013). This situation was commonly given as an example of client pressure by veterinary surgeons; a phenomenon recognised by other farm animal prescribers (Gibbons et al., 2013, Speksnijder et al., 2015b).

Veterinary surgeons and farmers expressed a desire to seek alternative methods to prevent disease to antimicrobial use, such as improved internal and external biosecurity measures, more effective vaccination strategies, improved housing and enhanced herd health through health status and genetic improvements. These conclusions are supported by the literature which reflects that creating an optimal environment for pigs through high quality hygiene, biosecurity and management practices were associated with low antimicrobial use in pigs (Laanen et al., 2013, Stevens et al., 2007) and therefore can be considered as routes through which antimicrobial requirements can be minimised (Anon, 2015d, Postma et al., 2015b). The definitions of what an optimal environment consisted of, in terms of housing or flooring type, were diverse (Scott et al., 2006, Stevens et al., 2007, Berriman et al., 2013). One predominant opinion was that outdoor systems were lower antimicrobial users and that there were differences in the clinical drivers for antimicrobial use in outdoor and indoor systems. Thus, further research on the association between different housing and management characteristics, antimicrobial use and bacterial and resistance loads, would allow further deductions to be made on optimum accommodation and husbandry features to minimise disease burden and antimicrobial requirements.

The high cost required to make housing and facility improvements juxtaposed with the poor economic return on pig meat were cited by veterinary surgeons and farmers as a barrier to reducing antimicrobial use in some situations; a perception echoed in other studies (Speksnijder et al., 2015b, Alarcon et al., 2014, Postma et al., 2015b). A detailed cost-benefit analysis of making facility improvements in typical UK pig production systems may be beneficial in identifying any long-term financial gains from such investment.

Many factors intrinsic to the prescriber such as the responsibility, and consequences of decisions for patients, and extrinsic factors such as pressure from clients, colleagues and policy have been identified in human medicine (Rodrigues et al., 2013) and were considered by veterinary surgeons and farmers to motivate antimicrobial use decisions. Such parallels suggest that an integrated human health/animal health or ‘one health’ approach to antimicrobial use and prescribing may be beneficial.

Although veterinary surgeons and the majority of farmers were aware of the issue of antimicrobial resistance both shared the opinion that antimicrobial resistance in human medicine was mainly driven by indiscriminate prescribing practices and use in humans. The perception that there was limited evidence linking antimicrobial use in livestock or pig production to the development of resistance in human pathogens contributed strongly to veterinary surgeon and farmer opinion that any link was not currently a major public health threat (Cattaneo et al., 2009, Speksnijder et al., 2015b). Hence respondents felt there was an unjustified sense of pressure on the livestock industry from the human medical profession (McCullough et al., 2015) and the UK Government (O'Neill, 2015, Anon, 2013j). In fact many respondents felt that reducing antimicrobial use could lead to increased zoonotic disease transmission risks to humans. Thus, this highlights a potential barrier to a ‘one health’ approach to reducing antimicrobial use. This idea was reflected in respondents’ views that suggested interventions for reduction of use, or restrictions in the use of critically important antimicrobials, would have little or no impact on resistance levels in humans.

Furthermore, antimicrobial resistance was seldom seen as a clinical issue in the veterinary surgeons’ caseload or the farmers’ herd, however it was commonly considered to be an issue for others and in other geographic areas; again demonstrating this concept of ‘othering’(Johnson, 2004). Despite resistance being seldom cited as a concern, respondents acknowledged that incidents of treatment failure were fairly frequent, though the cause of this was rarely associated with resistance. The respondents’ disconnect between treatment failure and antimicrobial resistance is an area of concern, as it seems likely that many cases of treatment failure are not investigated further to determine if antimicrobial resistance has occurred. Overall, indoor breeding systems more frequently identified treatment failure when compared to those from outdoor systems.

At present surveillance of veterinary resistance relies on voluntary submissions to the Animal Health and Plant Agency (APHA) and EU-harmonised monitoring surveillance of isolates from healthy animals (Borriello et al., 2015); thus representative data at either a national or regional level are not available. Respondents identified that the availability of such data would be beneficial in reducing the total amount of antimicrobials used in pigs. National surveillance of resistance would also allow veterinary surgeons to make informed decisions on antimicrobials based on likely sensitivities and resistances; such national data are collated and published for human medicine (Anon, 2015e). A unified one health approach to antimicrobial resistance surveillance, in human and veterinary medicine, would offer superior data to better understand the transfer of resistance for zoonotic pathogens between humans and animals.

Maintaining the health and welfare of pigs was a constant recurring priority throughout the studies for farmers and veterinary surgeons alike. Any discussion on restrictions on use, for example banning in-feed antimicrobials or restricting critically important antimicrobials led to strong concerns of potential negative welfare consequences, with increasing morbidity and mortality. Veterinary surgeons described major professional and moral obligations to animal health and welfare and antimicrobials were seen as essential to ensure that high welfare levels were maintained (De Briyne et al., 2013). Conversely many expressed the opinion that improvements in health and welfare would lead to a reduction in antimicrobial use and that some individuals in the industry may be using antimicrobials to overcome poor welfare. This must be considered within the context of the Royal College of Veterinary Surgeons (RCVS) declaration which states that:

" I PROMISE AND SOLEMNLY DECLARE that I will pursue the work of my profession with integrity and accept my responsibilities to the public, my clients, the profession and the Royal College of Veterinary Surgeons, and that, ABOVE ALL, my constant endeavour will be to ensure the health and welfare of animals committed to my care."

This declaration states that the primary responsibility of the veterinary surgeon is to ensure animal health and welfare above all other entities; including public responsibility. Thus, the use of a critically important antimicrobial in an animal where it offers the best option for maintaining health and welfare, over other treatments, could be considered a professional requirement by the RCVS; even if it may not be a responsible use in the context of public health.

Therefore, it is clear that animal health and welfare is a major driver and should be a priority in any proposed interventions or potential policy to restrict or limit use. This demonstrates the ethical and moral dilemmas facing veterinary surgeons; whilst public health is a consideration in prescribing decisions their primary responsibility is to the health and welfare of animals under their care. Parallel considerations have been identified in human prescribing whereby physicians consider both the interests of the individual patient and of wider public health in antimicrobial use decisions (Simpson et al., 2007). Thus, further confirming the need for harmonised initiatives to address indiscriminate prescribing and promote the prudent use of antimicrobials through a one health approach.

It is impossible to quantify the effects of antimicrobial use as a selection pressure for resistance without monitoring consumption and resistance profiles. Currently, antimicrobial use in the UK veterinary sector is only measured through tonnes of active ingredients sold and thus data on use in individual species cannot be extrapolated (Borriello et al., 2015). Veterinary surgeons and farmers commonly identified that there was a need for more detailed information on antimicrobial use in pigs and the majority felt that a move to benchmark use, possibly with penalties, would be beneficial in reducing the total amount of antimicrobials used in the UK pig population. The use of such a system with penalties for high antimicrobial users has been successful in reducing overall use in pigs in Denmark (Aarestrup, 2012). Recent initiatives such as those by Red Tractor Farm Assurance, which has required all member farms to record use since October 2014 (Anon, 2014g), and the electronic medicines book which was launched by Agricultural and Horticultural Development Board Pork (AHDB Pork) in April 2016, in collaboration with the Veterinary Medicines Directorate (VMD), will attempt to quantify use across UK pig farms (Anon, 2015c). The electronic medicines book aims to offer superior quantifiable data with the potential for benchmarking amongst similar farms.

Antimicrobial prescribing guidelines have been published by the Pig Veterinary Society since 2014 (Anon, 2014d) however, the adoption of these guidelines by respondent veterinary surgeons was low and farmer awareness of these guidelines was limited. Whilst these prescribing principles describe the recommended antimicrobial classes for first line use, and where classes should only be used after antimicrobial sensitivity testing, they do not outline which classes are appropriate for different disease conditions. These prescribing principles could be used by veterinary surgeons as a basis for discussions and communication with farmers on the importance of reserving certain classes of antimicrobials for cases where other classes have been shown to be ineffective from antimicrobial susceptibility testing.

Veterinary surgeons and farmers commonly described the benefits of antimicrobial susceptibility testing in the qualitative interviews; however the frequency of reported testing in the questionnaire study was low. Similarly, it has been found to be rarely conducted in farm animal practice (De Briyne et al., 2013, Sheehan, 2013). The behaviour was described as being more frequent in new disease outbreaks than routine disease surveillance; the high costs of diagnostics were identified as a barrier to its use for routine disease surveillance in herds. In addition, the time delay in obtaining results was identified by respondents as being problematic when immediate treatment is required, as withholding antimicrobials whilst awaiting results was considered to be a welfare concern (De Briyne et al., 2014, Speksnijder et al., 2015b). The availability of more rapid diagnostic tests to identify both disease pathogens and susceptibility profiles, which were economically viable for farmers would allow more targeted antimicrobial use in pigs. This would also offer more scope for pig units to monitor endemic disease status and tailor vaccination programs to individual requirements.

Study methodology

The studies described aimed to achieve a sample balance across different demographics and pig production systems for veterinary surgeon and farmers for the interviews with individuals from the large corporate groups as well as smaller independent businesses. The qualitative interviews lasted for long periods, a rapport was established and it appeared that participants spoke frankly and felt unhindered in highlighting important issues.

Respondents expressed diverse and extreme opinions in some cases, for example that antimicrobial use in pigs is irresponsible and may be used for growth promotion. Such honesty suggested that these data are likely to represent true opinions. The position of the interviewer as a veterinary surgeon with experience of farm animal practice placed them in a similar social and cultural environment to both the veterinary surgeons and farmers interviewed and therefore may have acted to minimise any hierarchy between the interviewer and interviewee (Coar and Sim, 2006). However, there was a potential for participants to have reported what they perceived to be socially correct, or believed the researchers expected, rather than reporting true beliefs and actual practices (Coar and Sim, 2006, Dicicco-Bloom and Crabtree, 2006). This bias may have had more effect on farmers due to the inevitable position of veterinary surgeons as the only individuals able to prescribe or dispense antimicrobials and the dependency farmers have on this relationship to access antimicrobials.

The questionnaire return rates (56.7% for the veterinary surgeon and 35% for the farmer questionnaires) were acceptable, although the useable response rates were lower due to a high proportion of those returned stating that they were no longer involved in the pig industry and thus could not complete the questionnaire. It is likely a proportion of the non-respondents also did not meet the inclusion criteria due to these reasons but opted not to inform the authors. The sensitivity surrounding antimicrobial resistance and the increasing pressure from the general public, media and politicians on use in livestock may result in a reluctance by some to be involved in the study.

When comparing the demographic data of the study participants with those in the sampling frame the respondents appeared representative, as such the responses were considered to be of sufficient value to draw meaningful conclusions on antimicrobial use in the UK pig industry. However there is a potential for bias in the respondent population, as respondents that completed the questionnaire may be those that have a personal interest in antimicrobial use. Additionally, there may be limitations in self-reported behaviours in which participants may respond to questions in a way in which they believe are expected rather than truly reporting actual practices (Bowling, 2005). The inclusion of open questions in the questionnaire attempted to reduce the effects of such bias by requiring respondents to propose novel ideas or perceptions not motivated by closed question options. The wide spectrum of opinions shown suggests that respondents were balanced in their views as there did not appear to be a bias towards an extreme viewpoint.

The mixed method approach taken in this thesis enabled both a broad and detailed investigation of the motivations behind antimicrobial use in the UK pig industry which would not have been possible had one research method been used in isolation. The initial focus group study provided a foundation for further qualitative enquiry and described general themes and subject areas which were explored in further detail in the in-depth qualitative interviews. This approach is widely accepted and considered to maximise the depth and detail of the qualitative data obtained (Morgan, 1997).

The focus group setting was advantageous in providing broad data through the interaction of group participants (Asbury, 1995, Kitzinger, 1994, 1995). However, the one-to-one nature of the qualitative interview allowed the interviewer to obtain more rich, in-depth information from individuals and offered greater control over the process in comparison to the focus group setting where groups interactions can sometimes be unpredictable (Morgan, 1997). Similarly, the qualitative interview allowed the interviewer to discuss specific ideas with particular individuals (Denscombe, 2014), for example, the association between specific management practices and antimicrobials was explored in greater detail in individuals familiar with the practice of interest. They also allowed the interviewer to explore the sensitive subject of antimicrobial use in pigs in a one-to-one setting without the influence of others; a subject which has placed the pig industry under considerable pressure from the media (Morris and others 2016).

A recognised limitation of focus group studies is the presence of dominant participants alongside those that are more reflective. The ability to minimize the effects of these extremes is highlighted as a key objective of the focus group moderator (Krueger, 1994). For example, in the initial focus group study we conducted separate veterinary surgeon and farmer discussion groups in the same meeting and then led a comparative discussion between the groups. This latter discussion had little benefit to the richness of the data as it was dominated by the veterinary surgeon group. As previously identified farmers are reliant upon veterinary surgeons for antimicrobial prescriptions, and advice on use, (Visschers et al., 2014, Visschers et al., 2015) and this relationship dynamic may have resulted in farmers feeling uneasy, or lacking confidence, in contributing towards joint discussions. Consequently, subsequent focus groups studies conducted in this study did not include a comparative discussion. The potential for dominant individuals to lead discussions and be too assertive within groups needs to be considered in any future focus group studies exploring perceptions on antimicrobial prescribing behaviours. As was demonstrated in these studies it may be advisable to have separate discussion groups for different groups of participants such as veterinary surgeons and farmers.

The qualitative studies employed a thematic analysis technique which focused on identifying the themes, perceptions and behavioural influences surrounding antimicrobial use. Analytical alternatives included a grounded theory approach which requires the gathering of qualitative data and simultaneously working out theories, concepts and hypotheses in the context of these data (Bryman, 2012). This is a more dynamic approach where analysis is undertaken in parallel with data collection and which relies upon theoretical sampling in which theories generated from data contribute towards the selection of future participants and directs the focus of the qualitative enquiry (Charmaz, 2006). In contrast, the studies presented here relied upon a purposive sampling as there was a desire to include participants who represented all aspects of the UK pig industry. Our thematic approach was not directed by pre-existing theories and instead the initial focus group study was used to describe themes and theories which were then expanded and explored in the interview studies. The depth achieved through the qualitative studies was considered to be sufficient as thematic analysis of the interview transcripts resulted in data saturation whereby no new themes were identified in the transcripts. In addition, the final questionnaire survey allowed these themes to be explored on a larger population of pig veterinary surgeons and farmers.

The qualitative approach provided in-depth and comprehensive data. However, these data only represented the views and perceptions of study participants and therefore cannot be considered to be representative of the general population of veterinary surgeons and farmers working in the UK pig industry. The purposive sampling methodology allowed the selection of a wide range of participants within the possible study population, for example individuals with experience of a wide variety of pig management systems and from different geographic locations; in order to obtain a diverse spectrum of opinions (Mays and Pope, 1995). Whilst these results may be unique to the study group population, we propose that these data may inform a more generalised theory to explain the research area (Bryman, 2012, Christley and Perkins, 2010).

The quantitative questionnaire methodology was advantageous in that it sought to provide data which was representative of the sample population of veterinary surgeons and farmers. The questionnaire content was informed by the themes generated from the qualitative studies and as such it allowed the generalisability of these themes to be tested across a wider population. The perceptions and ideas generated from the questionnaire studies were parallel to the themes identified in the qualitative enquiry (Bryman, 2012). For example, the perceptions on responsible use were a common thread across the farmer and veterinary surgeon qualitative and quantitative data sources. There was a shared confidence that their own antimicrobial use behaviours were responsible and that irresponsible practices were associated with other farmers or veterinary surgeons, other veterinary sectors, other countries or human medicine. Equally, the reservation of antimicrobials considered critical to human health, for situations when there no other alternative therapeutic strategies, was a common definition of a responsible antimicrobial use across all of the studies.

Overall, the mixed methodology united the data with the quantitative studies acting to substantiate the findings from the earlier qualitative studies. Thus, the combined approach acted to triangulate the data and clarified the results from the initial qualitative studies, such that the two methodologies complemented each other. Additionally, the questionnaire study was used to uncover contradictions in findings (Bryman, 2012, Greene et al., 1989) such as the contrasting views described by mixed species veterinary surgeons and respondents that specialised in pigs. For example, mixed species veterinary surgeons perceived antimicrobial use to be more responsible in other veterinary species sectors when compared with pig veterinary surgeons; who expressed concern that use may not be responsible in other species sectors.

Further Work

Concern over antimicrobial resistance and interest in the potential public health effects from the use of antimicrobials in livestock, have continued to augment since the studies contained within this thesis commenced. A summary of recommendation from the studies in this thesis and proposed next steps for relevant stakeholders are shown in Table 7.1. Following increased pressure on the UK pig industry the electronic Medicines Book was launched in April 2016 by AHDB Pork in collaboration with the VMD. This database allows pig producers to record antimicrobial use at a farm level (Anon, 2016d). Whilst this scheme is currently voluntary it will enable extraction of data on total antimicrobial use on UK pig farms in-line with future policy measures (O'Neill, 2016). Additionally, these data offer the opportunity to provide baseline figures on antimicrobial use in anticipation of species specific reduction targets to be defined in 2017 (Anon, 2016e). This increasing pressure to ensure that antimicrobial use in pigs is responsible, justified and minimal demonstrates the relevance, importance and timeliness of the findings from this thesis and highlights areas to target in achieving this reduction.

The recent recommendations to reduce antimicrobial use in pigs are a logical step in reducing the selection pressure on resistance. However, the role of economic drivers in pig production, as was highlighted by respondents in these studies, needs to be considered. Further research to define the economic costs of making the necessary improvements to housing and facilities to reduce antimicrobial use needs to be performed and balanced against the cost of using antimicrobials to prevent disease. Such work needs to consider typical UK pig production systems to ensure that findings will be relevant and useful to the industry. Further studies to identify alternative routes to preventing disease other than antimicrobial use are essential. This is particularly timely in light of the anticipated policy by the European Union to discontinue the use of antimicrobials for disease prevention and to tighten the residue limits in the manufacture of premixed in-feed antimicrobials (Anon, 2016c). These measures are likely to reduce the frequency with which antimicrobials are used to prevent disease in pigs.

Vaccination has proven to be an essential tool in the prevention of disease in pigs. For example, huge success has been seen in the control of porcine post-weaning multi-systemic wasting syndrome with the introduction of the Porcine Circovirus vaccination (Chae, 2012). However, this is an area where further work is needed to improve the efficacy of some vaccinations. For instance, there are concerns over the efficacy of the *Streptococcus suis* vaccination (Goyette-Desjardins et al., 2014, Smith et al., 2001, Torremorell and Trego, 1997). Additionally, there remain gaps in the current availability of vaccinations with many key bacterial pathogens in pigs not currently covered by commercial vaccinations. Thus, further work to increase the current range and efficacy of vaccinations for common pig diseases is needed.

The importance of diagnostic testing in identifying the pathogen responsible for clinical disease signs and ascertaining an appropriate antimicrobial are essential tools in ensuring that antimicrobial use is appropriate. However, the time delay in obtaining the results from such diagnostics may be a hurdle to their frequent adoption (Speksnijder et al., 2015b, De Briyne et al., 2013). There is a need for further research to identify cost effective, rapid pen-side tests to identify the pathogens responsible and so determine the appropriate antimicrobials.

Biosecurity is an area of particular interest in the pig industry with high standards of practice considered essential in the prevention of the introduction and spread of disease on pig units. A study by Rojo-Gimeno and others showed an economic advantage to increasing biosecurity measures over the use of prophylactic antimicrobials in pig farms in Belgium (Rojo-Gimeno et al., 2016). Such evidence can be used to incentivise producers to make improvements and changes to their current practices. This is an area where further work is needed particularly with regards to typical UK systems, such as outdoor production, where biosecurity practices face challenges from environmental factors and wildlife. Other factors such as different management systems, feed and water quality, stocking densities, weaning age, genetics of the pig herd and feed additives are also potential alternatives to the use of antimicrobials in pigs and warrant further research where there are gaps in knowledge.

The political pressure on the livestock sector with regards to antimicrobial use extends beyond the pig sector with increasing pressure being placed on the poultry and ruminant sectors. The British Poultry Council already collects data on antimicrobial use in broilers (Borriello et al., 2015), however, there are presently no systems in place for the collection of data from the dairy, sheep or beef sectors. Such quantitative data on antimicrobial use in these species are essential ahead of the species specific reduction targets outlined by the Government following the publication of the O'Neill Review on Antimicrobial Resistance (Anon, 2016e). As was highlighted in these studies there is a need to conduct similar research work within these sectors to identify the drivers and motivations behind antimicrobial use by veterinary surgeons and farmers from these sectors. There is also a specific need to explore antimicrobial use in sheep and game birds, species where off-label use is believed to be a frequent practice.

Conclusion

This thesis provides a detailed description and analysis of antimicrobial use practices, perceptions on antimicrobial resistance and veterinary surgeons' and farmers' views on what behaviours are considered to exemplify responsible use in the UK pig industry. Its publication is timely with increasing media interest in antimicrobial use in livestock and rising concerns over antimicrobial resistant zoonotic bacteria. The pressure on the UK pig industry has risen since the initial studies described in this thesis due sometimes to misinformed media reporting which has placed farmers and veterinary surgeons under increasing scrutiny and pressure. This pressure is coupled with high production costs, small profit margins and a drive by the industry to reduce antimicrobial requirements on farm; putting the industry under increasing economic pressure. It is essential that antimicrobial resistance is approached from a one health perspective which eliminates the current trend of human and veterinary medicine blaming one and other. A one health approach should encompass the health and welfare of humans and animals alike and consider the pressures currently facing the livestock sectors. Whilst antimicrobial resistance is a global issue and needs to be treated as such it is essential that the UK addresses indiscriminate and unnecessary antimicrobial use in human and veterinary medicine. This will allow the UK to contribute to efforts to tackle this major public health concern at a national, European and Worldwide level.

Table 7.1 Summary of Key Findings

Summary of Findings	**Conclusions and recommendations**	**Proposed next steps for relevant stakeholders**
Farmer awareness of critically important antimicrobials was variable	There is need for greater knowledge exchange with farmers on the definition and importance of critically important antimicrobials (due to the wide variation of definitions this would be best defined by the PVS prescribing guidelines).	Farmer meetings through veterinary practices, AHDB Pork, NPA and BPA which outline the critically important antimicrobials and explain the concerns over the use of these classes of antimicrobial.
Veterinary surgeons feeling pressure from farmers to prescribe antimicrobials	Strengthening relationships between farmers and veterinary surgeons may increase farmer awareness of the pressures veterinary surgeons face in prescribing decisions.	Knowledge exchange on responsible antimicrobial use practices could be delivered as outlined above.
Farmers identified veterinary surgeons as the most important source of information on antimicrobials	Veterinary surgeons as key in ensuring that antimicrobial use by farmers is prudent.	Empower veterinary surgeons in their role in ensuring that farmers are fully informed on antimicrobials they are using in their units.
Veterinary surgeons and farmers have a spectrum of opinions on what defines a responsible antimicrobial use practice.	There is a need for harmonised training and education on the correct administration of antimicrobials to pigs and what is considered prudent use.	A unified training on responsible antimicrobial use could be delivered through a collaboration of NOAH, RUMA, AHDB Pork, NPA and veterinary practices
Diagnostic testing is an underutilised tool	There is room for further uptake of antimicrobial susceptibility testing (AST) by veterinary surgeons and farmers to identify the correct antimicrobial. There is a need for economically viable pen-side rapid diagnostic tests for identifying key pig pathogens.	Veterinary surgeons should encourage AST to justify antimicrobial choice, particularly if critically important antimicrobials are being used. Further researchinto AST advancement.
Long-term in-feed antimicrobial use for	There is a place for further communication of alternative	The communication of case studies of

disease prevention may not be prudent	methods of preventing disease to in feed antimicrobial use. This is also an area for further research.	antimicrobial alternatives from commercial UK pig units through PHWC, RUMA, AHDB Pork, NPA and veterinary practices. There is the potential that UK/EU policy may restrict or ban the use of in-feed antimicrobials.
There was no consensus on what farming systems were associated with low antimicrobial use	Further research relevant to UK systems on which housing systems and management practices are beneficial in reducing antimicrobial use and antimicrobial resistance whilst optimising production which are. A review of the Minapig work in this area would be beneficial.	Further research for research institutions/AHDB Pork.
Economic constraints limit improvements in farm environment needed to reduce antimicrobial use.	A cost-benefit analysis for a typical UK system would be beneficial. A review of the Minapig work in this area would be beneficial.	Further research for research institutions/AHDB Pork.
There is a need for a united ‘One Health’ approach to antimicrobial use and resistance	With many parallel drivers between human and veterinary antimicrobial use a harmonised approach to research and communication is required.	RUMA, APHA, PHWC, NPA, AHDB Pork, retailers, veterinary surgeons and farmers need to communicate responsible use efforts in pigs. Knowledge exchange between human and veterinary medicine on successful interventions to reduce antimicrobial use for example, through multidisciplinary research teams with contributions from veterinary surgeons and doctors.
There is no national or regional surveillance for disease or antimicrobial	There is a need for harmonised national disease and antimicrobial resistance surveillance. This would	A collaboration of APHA and AHDB Pork, with the co-operation of

resistance.	be most effective if a unified approach with human medicine was adopted.	veterinary surgeons to report disease, would be best placed to build and deliver a surveillance system.
There is a need for quantitative antimicrobial use data at a farm level.	This has been addressed through the electronic medicines book (eMB) which was launched by AHDB Pork and the VMD in April 2016. There is a need to continue to collect antimicrobial use data and to encourage farmers to have 'ownership' of data so that it can be used to audit antimicrobial use on individual farms. These antimicrobial use data could be reviewed alongside antimicrobial resistance surveillance data to establish regional and national trends.	Veterinary surgeons can work with farmers in order to minimise use on farm through eMB data. The ability to benchmark against similar farms will be valuable for reviewing and optimising antimicrobial use.
Vaccination is a feasible alternative method of preventing disease to using antimicrobials	There is a need for improved availability of the range of pathogens covered by vaccination and improved efficacy in some available vaccinations.	Further research for research institutions. NOAH could encourage its members to conduct further research and development into vaccination.
Failure to perceive issues of antimicrobial resistance or irresponsible use as relevant to own situation.	This concept of 'othering' whereby farmers and veterinary surgeons did not see antimicrobial resistance and irresponsible use behaviours as relevant to their own situation can act as a barrier to behaviour change. Knowledge exchange with farmers and veterinary surgeons needs to focus on the national impact of antimicrobial resistance on the UK pig herd, public health effects and the effects on individual herds should resistant bacteria cause disease.	Knowledge exchange through APHA, PVS and AHDB Pork will better inform the industry of the scale of the antimicrobial resistance issue in pigs. In addition, the availability of superior data on antimicrobial resistance through collaboration between these stakeholders would provide superior data on antimicrobial resistance.

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