Antibiotic use in farm animals: supporting behavioural change of veterinarians and farmers

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Antibiotic use in farm animals: supporting behavioural change of veterinarians and farmers

Antibioticagebruik in landbouwhuisdieren; induceren van gedragsveranderingen van dierenartsen en veehouders

(met een samenvatting in het Nederlands)

Proefschrift

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door

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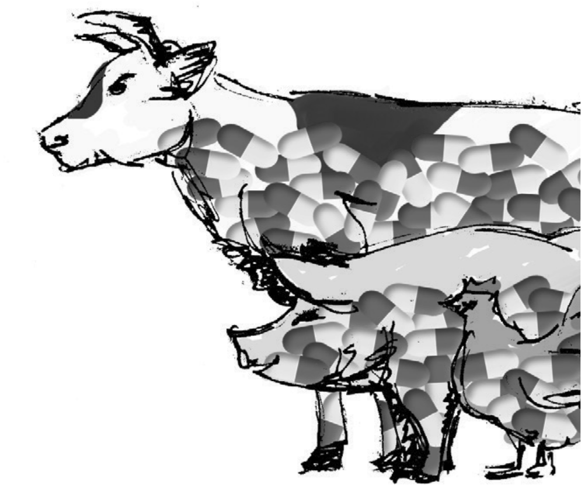

Chapter 1

General Introduction

This general introduction is an adaptation of the following manuscript:

Reduction of veterinary antimicrobial use in the Netherlands. The Dutch success model.

D.C. Speksnijder
D.J. Mevius
C.J.M. Bruschke
J.A. Wagenaar

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Abbreviations

AHP:	Animal Health Plan
ATP:	Animal Treatment Plan
AGP:	Antimicrobial Growth Promoter
ESBLs:	Extended Spectrum Beta-Lactamase producing bacteria
HC:	Dutch Health Council
IKB:	Integrated Chain Control; private quality assurance systems in the livestock sector
KNMvD:	Royal Dutch Veterinary Association
LA-MRSA:	Livestock Associated methicillin-resistant *Staphylococcus aureus*
MoU:	Memorandum of Understanding, signed between all stakeholders in 2008
PVE:	Product Boards for Livestock, Meat and Eggs; public-private organization with legislative powers for the whole livestock sector
SDa:	Netherlands Veterinary Medicines Authority
UDD:	Administration by veterinarians only
WVAB:	Veterinary Antibiotic Policy Working Group

Historical developments of veterinary antibiotic use

The introduction of antibiotics in the second half of the 20th century has been of major importance in human and veterinary medicine. Veterinary antibiotic use increased from the 1950s onwards in the fast-developing modern livestock production systems (Manten 1963, EMEA 1999). In addition to therapeutic and preventive use, they were also applied as antimicrobial growth promotors (AGP) to increase the efficiency of animal production (McEwen, Fedorka-Cray 2002, van den Bogaard, Stobberingh 1999, McEwen 2006). The Swann Committee in 1969 was the first international body to raise serious concerns about extensive veterinary antibiotic use and increasing antibiotic resistance with related risks for human health care. Despite increasing knowledge about the potential impact of veterinary antibiotic use on public health, veterinary antibiotic use still increased during the following decades (EMEA 1999, van den Bogaard, Breeuwsma et al. 1994, Endtz, Ruijs et al. 1991). It took until 1986 when, as precautionary measure, Sweden was the first country in the world to ban all AGP use in animals (Wierup 2001). It was only in 1997 that the European Union (EU) banned the use of avoparcin as AGP in response to the finding of vancomycin resistant enterococci (VRE) in avoparcin fed pigs and poultry. The recommendations of the World Health Organization (WHO) in 1997 and the Copenhagen recommendations in 1998 regarding the use of non-therapeutic antibiotics in animals further accelerated EU policymaking which resulted in the withdrawal of specific AGPs in 1999 and a complete ban on all AGP use in animals by 2006 (Barton 2000, Cogliani C., Goossens H. et al. 2011, Mevius, Sprenger et al. 1999, World Health Organization 1997, Aarestrup 2005).

Notwithstanding these European interventions, in the Netherlands the total sales of antibiotics for therapeutic veterinary use increased from an estimated 275 tons in 1990 to almost 600 tons in 2007, with the most prominent increase during and after the withdrawal of AGPs (Figure 1) (MARAN 2009, Pijpers, Fink-Gremmels et al. 1998). In 2007, the Netherlands was ranked as the highest veterinary antibiotic consumer out of 10 EU countries from which data were available (Grave, Torren-Edo et al. 2010). Parallel to the increase in use, the Monitoring of Antibiotic Use and Resistance in Animals in the Netherlands (MARAN) reported increasing antibiotic resistance levels in commensal *E. coli* isolates from farm animals between 1998 and 2009 (MARAN 2010).

Turn of the tide

In 2005, Livestock Associated-methicillin-resistant *Staphylococcus aureus* (LA-MRSA) was reported to be widely spread in the Dutch pig population with occupational transmission to humans (farmers, veterinarians). Dutch hospitals had controlled MRSA very successfully by restricted antibiotic use and strict infection control measures in the last decades. The sudden discovery of this formerly unknown and large MRSA reservoir was followed by societal and political pressure to reduce antibiotic use in farm animals (Voss, Loeffen et al. 2005). Discussions on the future of antibiotic use in farm animals between government and stakeholders of the livestock industry resulted in 2008 in the set-up of the Taskforce Antibiotic Resistance in Animal Husbandry. This taskforce comprised representatives from all parties within the animal production chain, the Royal Dutch Veterinary Association (KNMvD), the Ministry of Agriculture [1] (MoA) and the Ministry of Health (MoH). This Taskforce developed action plans per animal production sector (cattle, veal calves, poultry, and pigs) as part of a Memorandum of Understanding (MoU) with the aim to control antibiotic resistance in livestock (Letter to the Parliament 2008). The action plans aimed at detailed monitoring of antibiotic use at herd level, the monitoring of antibiotic resistance, a clear description of responsibilities of veterinarians and farmers in antibiotic prescribing and use, and the introduction of Farm Treatment Plans and Farm Health Plans. However, no strict targets or regulations for antibiotic use were formulated yet. Although the MoU was the basis for further discussions, it did not have a direct effect on the total veterinary antibiotic use in the following year (MARAN, 2010).

The discovery of ubiquitous presence of Extended Spectrum Beta-Lactamase producing bacteria (ESBLs) on Dutch poultry meat in 2009 and a possible relationship with a human casualty was widely disseminated in the media in 2010 and led to serious public concerns (Leverstein-van Hall, Dierikx et al. 2011). A debate in parliament

[1] Agriculture was till 2010 part of the Ministry of Agriculture, Nature and Food Quality. From 2010-2012 it was part of the Ministry of Economic Affairs, Agriculture and Innovation. It is currently in the Ministry of Economic Affairs. Throughout this manuscript we use consequently 'Ministry of Agriculture'.

followed where the public health concerns of extensive use of antibiotics in farm animals were discussed. As a result, the government introduced a compulsory 20% and 50% reduction target in antibiotic use in farm animals in 2011 and 2013 respectively with 2009 as a baseline. These targets were supported by the livestock sectors (Figure 2)

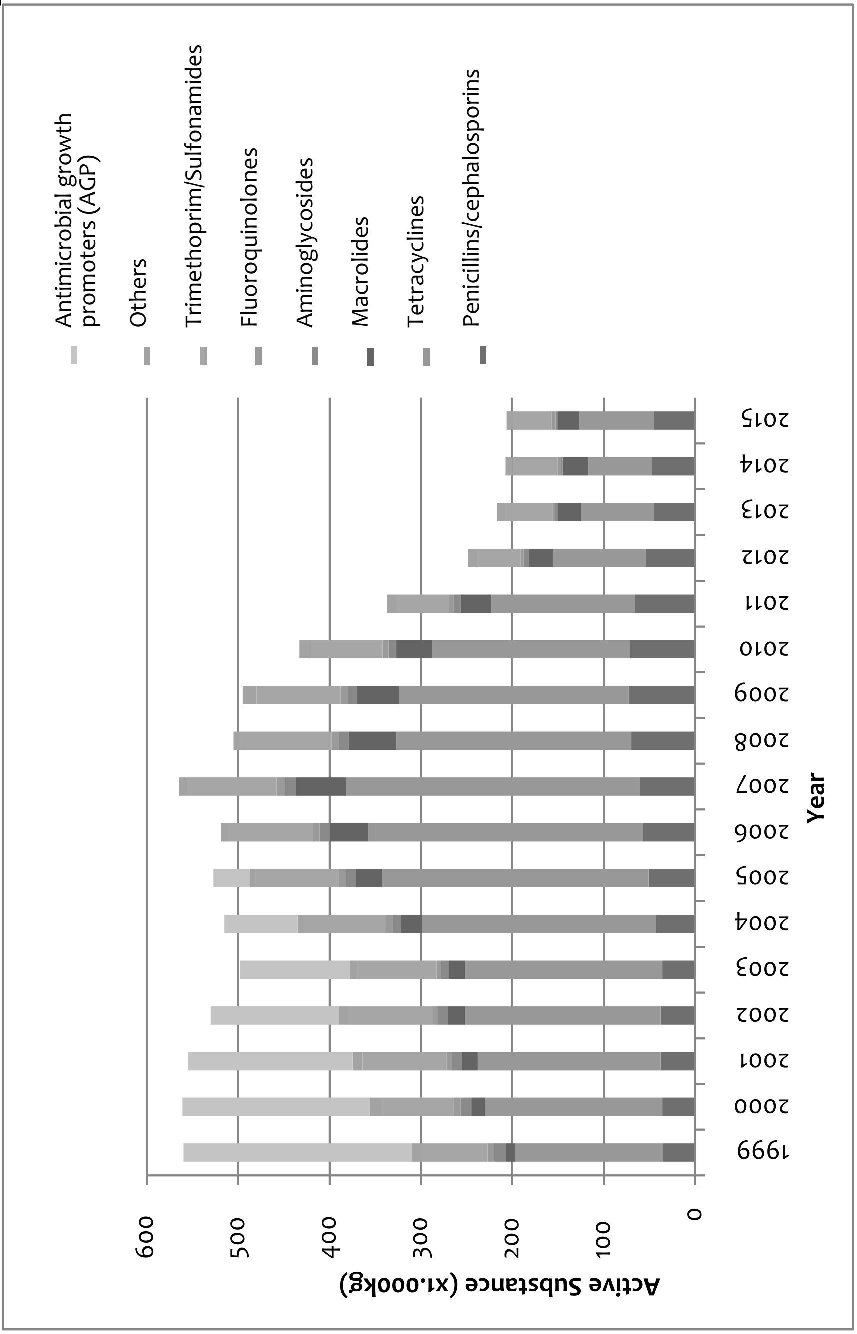


Figure 1. Sales figures for antibiotics licensed for therapeutic use in animals in the Netherlands from 1999 up to 2015. Data derived from FIDIN (http://fidin.nl/Beleid/Antibiotica) and (MARAN 2016).

Veterinary Medicines Authority

In response to the need for an independent body to monitor antibiotic use at herd level, in 2010, the independent Netherlands Veterinary Medicines Authority (SDa) was established as a public-private partnership between the government, the KNMvD and livestock industries. The task of the SDa was i) to collect and report reliable antibiotic usage and prescription data from all individual farms and veterinarians in the Netherlands, and ii) to set annual targets for antibiotic use in the different major livestock sectors, including species specific benchmark indicators that differentiate between moderate, high and very high users (farmers) and prescribers (veterinarians). Based on these benchmarks, high users and high prescribers could be subjected to disciplinary sanctions by the private IKB systems (Integrated Chain Control; quality assurance systems which involve most Dutch farmers) and the KNMvD respectively or by the Dutch Food and Consumer Product Safety Authority (NVWA) which is the governmental inspection authority (Stichting Diergeneesmiddelen Autoriteit 2013).

Restricting the use of specific antibiotic classes

In August 2011, the Dutch Health Council (HC), an independent scientific advisory body for the government and parliament, presented on request of the MoH and MoA, scientifically based recommendations to prevent further development and spread of antibiotic resistant bacteria in animal production (Health Council of the Netherlands 2011). Among the recommendations were the exclusive use of newly developed antibiotics for humans, an immediate ban on preventive and systematic therapeutic group treatments of animals with the as critically important considered 3rd and 4th generation cephalosporins and fluoroquinolones (Angulo, Collignon et al. 2009), a future ban on the use of colistin and the phasing out of all preventive and systematic veterinary use of β-lactam antibiotics and aminoglycosides in animals. The different existing private IKB systems translated these recommendations into specific regulations that radically restricted the use of 3rd and 4th generation cephalosporins and fluoroquinolones in farm animals. The Veterinary Antibiotic Policy Working Group (WVAB) of the KNMvD subsequently reclassified veterinary antibiotics into first, second and third choice for use in the existing veterinary treatment guidelines (formularies) and veterinary practice, based on the recommendations of the HC. The government took the responsibility for enforcement by incorporating these private regulations into legislation. Furthermore, the government banned all preventive use of antibiotics in animals (Letter to the Parliament 2011a).

New obligations for farmers and veterinarians

It was acknowledged that veterinarians are both entrepreneurs who earn their income from farmers, but also prescribers who should prudently prescribe antibiotics in animals. This could potentially lead to a conflict of interests when farmers put pressure on veterinarians for prescriptions. Therefore, the independent position of veterinarians had to be reinforced to be able to act as an independent professional and a gatekeeper for prudent use of antibiotics in animals (Beemer, Zunderdorp et al. 2011). From 2009 onwards, the different private IKB systems started to introduce the prerequisite for livestock farmers to only procure veterinary services and veterinary medicines from one veterinary practice (1-to-1 relationship) to reduce competition between veterinary practices and to ensure a proper knowledge of the farm of the prescribing veterinarian. This measure was already proposed in the MoU in 2008 and was in 2012 imposed for all livestock farmers in the Netherlands by the Product Boards for Livestock, Meat and Eggs (PVE; public-private organization with legislative powers for the whole livestock sector) (Beemer, Zunderdorp et al. 2011). In 2011, the KNMvD proposed the development of a quality system for veterinarians. Incorporated in this quality system are the introduction of compulsory post academic education and the development of specific treatment guidelines for veterinarians to support their clinical decision making. As these guidelines could also be incorporated in existing private quality systems for farmers, the implementation of these guidelines can be enforced. The PVE in 2011 decreed – as mentioned in the MoU - the introduction of the Animal Health Plan (AHP) and Animal Treatment Plan (ATP) and central registration of all prescribed and delivered antibiotics at farm level. The AHP and ATP are drawn up as a collaborative effort by the farmer and the farm veterinarian and evaluated annually. AHPs aim to improve the health of farm animals by identifying risk factors for diseases and documenting proposed prevention measures at the farm level. The ATP is a farm specific treatment protocol that should be used by farmers in the treatment of animals. This ATP should

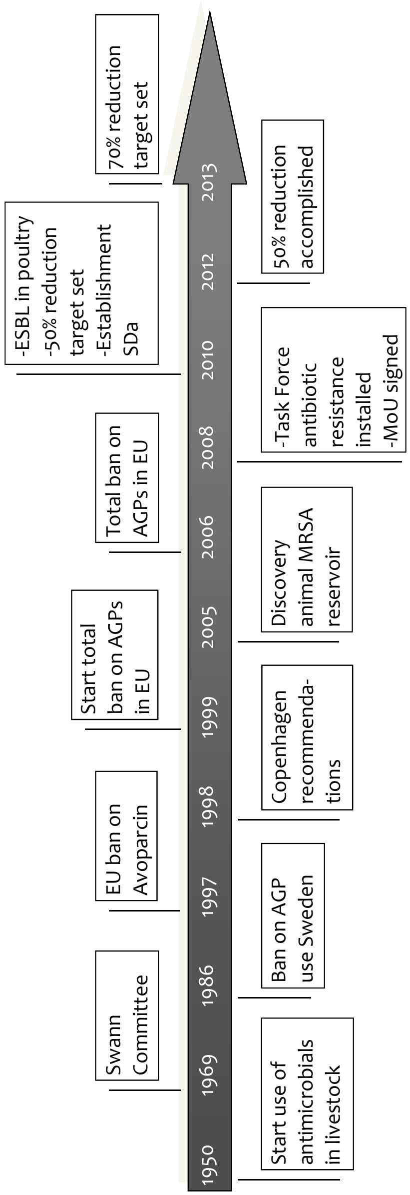


Figure 2. Timeline of events regarding introduction, major events, findings and measures influencing antibiotic use in farm animals in the Netherlands.

be in accordance with the formularies developed by the KNMvD and considering other relevant information like susceptibility patterns of cultured pathogens and historical treatment results. In principle, only first choice (non-critically important) antibiotics from the WVAB formularies are allowed in this ATP.
A potential conflict of interest to prescribe also existed at the level of veterinarians. Dutch veterinary practices hold their own veterinary pharmacy. This implies that they make a direct profit from the drugs they prescribe to farmers. Like in other countries, this became a point of concern in the public debate and at governmental level and questions arose whether the veterinary pharmacy should be separated from veterinary practices (Wegener 2006, Törneke, Torren-Edo et al. 2015). The Dutch government however concluded, based on an independent advisory report, that decoupling prescription and selling of veterinary drugs as a sole measure would not lead to the desired reduction. Instead, the economic motives to prescribe were expected to greatly be eliminated by the proposed benchmarking of antibiotic prescription and use and introduction of strict 1-to-1 relationships (Letter to the Parliament 2011b, Beemer, Zunderdorp et al. 2011).

The continuing story of the Dutch approach

The measures taken in the period 2008-2012 were not the end of the Dutch model for reduction of AMU. In 2014, new legislation (UDD measure, administration by veterinarians only) has been introduced by the government. Under this legislation, veterinarians should perform the administration of all veterinary antibiotics. Only when farmers meet specific conditions, they are permitted to apply antibiotics to their animals without physical intervention of a veterinarian. These conditions comprise the 1-to-1 relationship, mandatory periodical herd inspections by the veterinarian and annual evaluation of the FHP and FTP. Under these conditions, farmers are allowed to have first choice antibiotics in stock for treatment of at most 15% of the susceptible animals (Staatscourant 2013). Exemptions have been made for a few second-choice antibiotics that were regarded essential to treat animals for specific indications and where no first-choice alternatives are available. Farmers may apply these antibiotics to in advance identified animals for a period of maximum 14 days under the condition that their veterinarian has made a clinical diagnosis.
The KNMvD started developing and introducing specific veterinary treatment guidelines from 2013 onwards. The first one to be published was a guideline to selectively dry off dairy cows with antibiotics. This guideline was widely adopted by veterinarians and the dairy industry and resulted in an almost 30% reduction in antibiotics used for dry cow treatments in 2014 (Stichting Diergeneesmiddelen Autoriteit 2015). Other treatment guidelines soon followed such as a guideline for the diagnosis, treatment and prevention of *S. suis* infections in weaned piglets (Navis 2016).
In response to an update of the recommendations from the Dutch Health Council in 2015, the WVAB started to revise the veterinary formularies in 2016. A major adaptation is the further restriction of the use of colistin in farm animals. Other recommendations of the Health Council were to start monitoring antibiotic use in

other sectors (dairy goats, companion animals, horses) and to focus on high users and prescribers of antibiotics (Health Council of the Netherlands 2015).

Reduction and resistance

The SDa reported a 58.4% reduction in antibiotic use in farm animals in the period 2009–2015 (Stichting Diergeneesmiddelen Autoriteit 2016). In the period 2009–2012, the veterinary sales of the as critically important considered 3rd and 4th generation cephalosporins and (fluoro)quinolones decreased with 92% and 59% to 0.03% and 1.3% of the total sales respectively (Bondt, Puister et al. 2012). Already in 2012, the 50% reduction goal as set for 2013 was almost met (Figure 1). Abandoning preventive use of antibiotics, restricting therapy lengths to the SPC (Summary of Product Characteristics), replacement of antibiotic combinations by single substances and individual or partial herd treatment as replacement for whole herd treatments attributed most to this reduction (personal communication). In 2013, based on the measures that were initiated by private parties involved in animal production, the government set a new goal of 70% reduction in veterinary antibiotic use in 2015 compared to 2009 (Letter to the Parliament 2012).
The reduction targets as given by the government, were not based on any evidence based dose (antibiotic use)-effect (antibiotic resistance) relation. However, faced with increasing public pressure and concerns, decisions needed to be taken. Studies on a total ban of certain specific antibiotics used as AGP (tetracyclines, glycopeptides and macrolides) and for therapeutic purposes (cephalosporins) indicated a relation between antibiotic use and antibiotic resistance (Korsgaard, Agerso 2012, van Leeuwen, van Embden et al. 1979, Aarestrup 2005, Cleveland- Nielsen, Aarestrup et al. 2007). The effect of an overall reduction of all therapeutically used antibiotics was however still unknown and hard to predict based on the complexity of the association between antibiotic use and resistance due to e.g. co-resistance. Since 2010, in the routine monitoring an apparent trend is visible for example in commensal indicator *E. coli* isolates from broilers, veal calves and slaughter pigs towards a systematic and substantial decrease in resistance levels for a number of antibiotics. This trend is also visible in *Campylobacter* spp. for the fluoroquinolones (*C. jejuni* from poultry) and macrolides (*C. coli* from pigs) (MARAN 2016). Recent data from the Netherlands indicated that the reduction in antibiotic use in farm animals has resulted in lower *E. coli* resistance levels in swine and poultry (Dorado-Garcia, Mevius et al. 2016). However, these data should be interpreted with caution. Only long term monitoring over a period of several years might reveal robust changes in resistance patterns.

Pathways and limitations towards antibiotic reduction

Animal welfare and health could possibly negatively be affected by delayed or non-treatment with antibiotics, although evidence suggests that lower antibiotic use can be realized without deteriorating consequences for animal health and productivity (Innovatienetwerk 2011a, Innovatienetwerk 2011b, Wierup 2001, Aarestrup, Jensen et al. 2010). Optimal housing and hygiene practices, climate control, feed and water quality are believed to be major prerequisites for antibiotic reduced or free

production. Several authors concluded that a reduction in antibiotic use might probably be accompanied with higher production costs per unit (Phillips, Casewell et al. 2004, Cromwell 2002, Wierup 2001, Jensen 2006). A rise in production costs would be a challenge in a competitive international market wherein the Dutch agro-food sector highly relies on export. Others dispute this adverse economic effect (Graham, Boland et al. 2007, van der Fels-Klerx, Puister-Jansen et al. 2011). It should be noted that most aforementioned analyses only focused on the economic consequences of a ban on AGPs, not on the effects of a drastic reduction in total antibiotic use which might have different economic consequences.
Basically, two major strategies should be applied to promote prudent use of antibiotics. The first is to minimize the incidence of infectious diseases at farm level by strict biosecurity measures, eradication of infectious diseases, and vaccination as every infection prevented is one that needs no treatment (World Health Organization 2015, Wierup 2000, EFSA 2008, McEwen 2006). It is shown that the use of antibiotics for preventive or growth promoting purposes have the greatest beneficial effect on farms with poor hygiene, suggesting that improvement of overall hygiene might lead to a reduction of the added value of using antibiotics (Wierup 2000, Jensen 2006).
The second strategy is prudent application of antibiotic therapy when preventive measures have failed and treatment is indicated. Ideally, antibiotic selection should be based on proper diagnosis, preferably confirmed by susceptibility testing and knowledge of pharmacokinetics. Many general recommendations for prudent use have been proposed including the implementation of treatment guidelines to support prescribers in the choice of the right antibiotic (Wegener 2006, Ungemach, Müller-Bahrdt et al. 2006, McEwen, Fedorka-Cray 2002, Schwarz, Kehrenberg et al. 2001, FVE 2010, Avorn, Barrett et al. 2001, World Health Organization 2000).
Both strategies to reduce veterinary antibiotic use demand the adoption of new practices and behavioural changes and changing behaviour can be difficult. Many cultural, personal and psychological aspects can drive or limit the implementation of preventive measures or prudent use guidelines in practice as shown in the human domain (Arnold, Straus 2005, Butler, Rollnick et al. 1998, Grol, Wensing 2004, Cabana, Rand et al. 1999, Hulscher, van der Meer et al. 2010, McEwen 2006, Wegener 2006). The uptake of these measures can be enforced by regulators, but usually have limited sustainable effect, and only last in the presence of enforcement of rules and regulations. This enforcement requires high efforts and human capital of governments and quality systems. A more sustainable approach for behaviour change is the voluntary motivated route in which internal and external motivators (social pressure, provisions and subsidies) are addressed to induce behavioural changes (Cleveland- Nielsen, Aarestrup et al. 2007, Van Woerkum, Kuiper et al. 1999). This requires however a good understanding of current behaviour including drivers and barriers for behaviour change in order to tailor interventions aiming at the uptake of prudent use practices.
Veterinarians in the Netherlands are the only professionals responsible for prescribing and overseeing the use of antibiotics in animals. Therefore, they have a potentially leading role in modifying current antibiotic prescribing and use practices (Prescott 2008, Morley, Apley et al. 2005). However, prescribing behaviour of veterinarians has

only sporadically been researched and comprehensive insights in determinants influencing prescribing behaviour of veterinarians are still lacking (Prescott 2008, McIntosh, Schulz et al. 2009, Regula, Torriani et al. 2009, Jan, McIntosh et al. 2012). Targeting prescribing behaviour of physicians in medical healthcare has shown to be effective in reducing antibiotic prescribing (Butler, Simpson et al. 2012, McNulty, Francis 2010, Welschen, Kuyvenhoven et al. 2004, Oxman, Thomson et al. 1995). Several determinants influence this prescribing behaviour of physicians. These are related to clinical reasoning as well as non-clinical factors such as attitudes toward antibiotic resistance, perceived patient pressure to prescribe antibiotics, risk avoidance, and pressure from colleagues (Petursson 2005, Hulscher, van der Meer et al. 2010, Hulscher, Grol et al. 2010, Butler, Rollnick et al. 1998, Kumar, Little et al. 2003, Akkerman, Kuyvenhoven et al. 2005, Simpson, Wood et al. 2007). Knowledge of these prescribing determinants and categorization of health care providers into different target groups is extensively used for the purpose of sustainable implementation of tailored antibiotic stewardship programs and interventions (Hulscher, Grol et al. 2010, Hulscher, van der Meer et al. 2010, Kumar, Little et al. 2003, Walker, Grimshaw et al. 2001, Vander Stichele, De Potter et al. 1996, Simpson, Wood et al. 2007). In the same way, a thorough understanding of veterinarians' current prescribing practices, their attitude towards the newly introduced regulations and their perceived barriers and opportunities for adjusting prescribing practices, might offer leads for interventions to further reduce antibiotic use in farm animals.

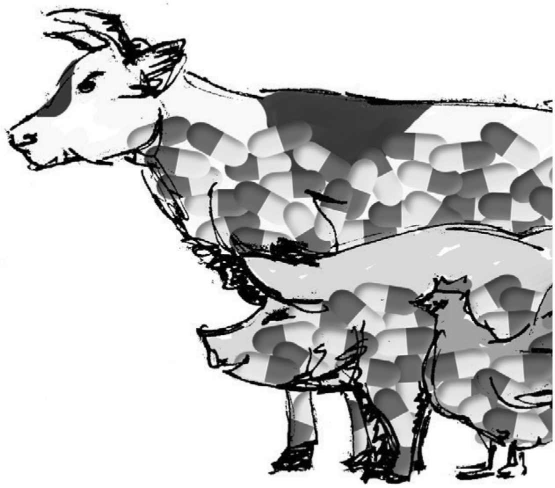
Aim and outline of this thesis

The aim of this thesis was twofold. The first objective was to identify determinants (factors) that influence the antibiotic prescribing behaviour of farm animal veterinarians and to study their opinions on measures aiming at a reduction of antibiotic use in farm animals. The second objective was to develop and implement a multi-faceted intervention aiming at reducing the amount of antibiotics prescribed by veterinarians, using the knowledge that is gathered in the first part of the thesis and experiences derived from the medical domain.

Chapter 2 describes a qualitative study in which semi-structured interviews were used to explore determinants that influence antibiotic prescribing decisions of farm animal veterinarians working with different types of farm animals. The outcomes of this study were discussed in an expert meeting and used to develop a survey which was distributed amongst all farm animal veterinarians working in the Netherlands in 2012. The results of this survey are described in Chapter 3. Subsequently, this survey was also distributed in Flanders (Dutch speaking part of Belgium) and Chapter 4 will deal with differences found between Dutch and Flemish farm animal veterinarians with regards to prescribing determinants and attitudes towards antibiotic reduction measures.

Chapter 5 and 6 present the effects on animal health parameters and antibiotic use of a trial study with a control group in which Dutch dairy farmers together with their own veterinarian and nutritionist were trained and facilitated to develop and implement their own tailor made animal health improvement program.

The main findings of this thesis will be summarized and discussed in Chapter 7. Recommendations for future research and intervention strategies aiming at promoting prudent use of antibiotics in farm animals will be presented.



Chapter 2

Determinants associated with veterinary antimicrobial prescribing in farm animals in the Netherlands: a qualitative study.

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Abstract

Antimicrobial use in farm animals might contribute to the development of antimicrobial resistance in humans and animals and there is an urgent need to reduce antimicrobial use in farm animals. Veterinarians are typically responsible for prescribing and overseeing antimicrobial use in animals. A thorough understanding of veterinarians' current prescribing practices and their reasons to prescribe antimicrobials might offer leads for interventions to reduce antimicrobial use in farm animals. This paper presents the results of a qualitative study of factors that influence prescribing behaviour of farm animal veterinarians.

Semi structured interviews with eleven farm animal veterinarians were conducted which were taped, transcribed and iteratively analysed. This preliminary analysis was further discussed and refined in an expert meeting. A final conceptual model was derived from the analysis and sent to all the respondents for validation.

Many conflicting interests are identifiable when it comes to antimicrobial prescribing by farm animal veterinarians. Belief in the professional obligation to alleviate animal suffering, financial dependency on clients, risk avoidance, shortcomings in advisory skills, financial barriers for structural veterinary herd health advisory services, lack of farmers' compliance to veterinary recommendations, public health interests, personal beliefs regarding the veterinary contribution to antimicrobial resistance and major economic powers are all influential determinants in antimicrobial prescribing behaviour of farm animal veterinarians.

Interventions to change prescribing behaviour of farm animal veterinarians could address attitudes and advisory skills of veterinarians, as well as provide tools to deal with (perceived) pressure from farmers and advisors to prescribe antimicrobials. Additional (policy) measures could probably support farm animal veterinarians in acting as a more independent animal health consultant.

Introduction

Livestock industries in industrialized countries are usually well developed and typically use large amounts of antimicrobials (Aarestrup, Wegener et al. 2008, Angulo, Collignon et al. 2009). For public health reasons, increasing attention is drawn towards a more prudent and restrictive use of antimicrobials in farm animals (McEwen 2006, Barza, Gorbach et al. 2002, Codex Alimentarius 2005, FAO/WHO/OIE 2008, Aarestrup, Wegener et al. 2008, Prescott 2008).
Since 2010, there has been an almost 50% reduction of antimicrobial use in farm animals towards 2013 in the Netherlands (Anonymous 09-04-2010, Speksnijder, Mevius et al. 2015). Veterinarians in the Netherlands are responsible for prescribing and overseeing the use of antimicrobials in animals and could therefore have a potentially leading role in modifying current practices in order to reduce antimicrobial use (Morley, Apley et al. 2005). A thorough understanding of veterinarians' current prescribing practices, their attitude towards the newly introduced regulations and their perceived barriers and opportunities for adjusting prescribing practices, might offer leads for interventions to reduce antimicrobial use in farm animals (Butler, Rollnick et al. 1998, Grol, Wensing 2004).

Targeting prescribing behaviour of physicians has shown to be effective in reducing antimicrobial use in human healthcare (Butler, Simpson et al. 2012, McNulty, Francis 2010, Welschen, Kuyvenhoven et al. 2004, Oxman, Thomson et al. 1995). Several determinants influence prescribing behaviour of physicians, such as perceived patient pressure to prescribe antimicrobials, risk avoidance, and pressure from colleagues (Petursson 2005, Hulscher, van der Meer et al. 2010, Hulscher, Grol et al. 2010, Simpson, Wood et al. 2007, Butler, Rollnick et al. 1998, Kumar, Little et al. 2003). These factors along with ones more specifically related to veterinary medicine might be important prescribing determinants for veterinarians. Prescribing behaviour of veterinarians has only sporadically been researched and comprehensive insights in determinants influencing prescribing behaviour of veterinarians are still lacking (Prescott 2008, McIntosh, Schulz et al. 2009, Regula, Torriani et al. 2009, Jan, McIntosh et al. 2012).
We conducted semi structured interviews with farm animal veterinarians to identify determinants influencing farm animal veterinarians to prescribe antimicrobials. The reported prescribing determinants can be used, after validation amongst an extended group, to develop feasible interventions aimed at the reduction of antimicrobial prescription in farm animals.

Methods

Instrument development

Qualitative techniques with semi structured interviews were used to explore reasons for veterinarians to prescribe antimicrobials (Pope, van Royen et al. 2002, Britten 1995, DiCicco-Bloom, Crabtree 2006, Collingridge, Gantt 2008, Pope, Ziebland et al.

2000). As prescribing behaviour of veterinarians is currently criticized in the public debate, individual interviews instead of group interviews were preferred to allow respondents to express controversial views. To identify different themes to be explored, a list of potential determinants influencing prescribing behaviour of farm animal veterinarians was constructed using the literature on prescribing behaviour of physicians (Petursson 2005, Hulscher, van der Meer et al. 2010, Hulscher, Grol et al. 2010, Hart, Pepper et al. 2006, Simpson, Wood et al. 2007, Butler, Rollnick et al. 1998, Kumar, Little et al. 2003, Cockburn, Pit 1997, Simpson, Butler et al. 2009) and consultations were organized with members of the advisory board of the project which consisted of veterinarians working in academia and board members of the Royal Dutch Veterinary Association (KNMvD).
The perceived roles of other actors like farmers and non-veterinary advisors, the economy, the society and the government were also explored (based on Hulscher, van der Meer et al. (2010), who describe four levels of relevant groups of prescribing determinants of physicians). An interview guide was developed based on the developed list of potential prescribing determinants (Appendix I). This interview guide was tested in three pilot interviews with practicing farm animal veterinarians.

Participants

Inclusion criteria for the selection of respondents were: (i) at least 2 years practical experience and (ii) full time working with farm animals. Participants were selected so that they represented veterinarians working in each of the four major livestock sectors (i.e. poultry, swine, veal calves and dairy) and working in different provinces of the country. Some experienced practicing farm animal veterinarians were suggested by members of the advisory board of the project, based on the personal believe that these veterinarians were able to clearly express their professional views and opinions on the role of veterinarians in antimicrobial use in farm animals. Respondents were approached by telephone to participate in an interview. The interviews were performed by DS, a researcher and practicing farm animal veterinarian. After completion of the interviews, the respondents were asked to suggest other veterinarians from other parts of the country who were expected to hold opposing views in accordance to the snowball method (Onwuegbuzie, Leech 2007, Wester, Peters 2004). These veterinarians were then approached to participate in this study, thereby enhancing the collection of various opinions and views (Malterud 2001, Collingridge, Gantt 2008, DiCicco-Bloom, Crabtree 2006).

Data collection & analysis

The interviews (duration 45-79 minutes) were recorded on tape, transcribed verbatim and analysed using Atlas.ti 6 (ATLAS.ti Scientific Software Development GmbH, Berlin.). Interviews took place between September 2011 and January 2012. This study was exempt from ethical approval according to Dutch legislation (Law on Medical Scientific Research with People) because no patients were involved. Nevertheless, signed informed consents were obtained from the participants, assuring confidential handling of the data. Concurrently with data collection, transcribed interviews were iteratively analysed. This sequential analysis during data collection made it possible to refine questions, develop hypotheses and pursue emerging themes in more depth during following interviews (Pope, Ziebland et al. 2000, DiCicco-Bloom, Crabtree 2006, Collingridge, Gantt 2008). DS reviewed the transcripts inductively. The most important themes in the data on the role of farm animal veterinarians in antimicrobial use were marked with a label, thereby enabling the categorization of the extracted themes based on the assigned labels. These categories were further analysed and refined and subsequently used to create an initial template representing the most important themes based on their mutual relationships (Pope, Ziebland et al. 2000, Wester, Peters 2004).

AG analysed 3 of the transcripts independently. These 3 double reviewed transcripts were compared to check inter-rater reliability of the analysing process. When doubts existed about the categorization in non-double reviewed transcripts, AG was consulted for discussion about these text fragments.

After 9 interviews, the categorization of themes in the template was critically evaluated in the advisory board of the project and the categorization of these themes in the template was discussed. Regular consultation with all authors took place to discuss whether formerly unmentioned themes emerged in interviews with new respondents to decide when saturation of data was reached. A preliminary report summarizing all the interviews including quotations on which conclusions were based was sent to the respondents for a final check of interpretations of the interviews (Mays, Pope 2000). Interviews were conducted in Dutch and analyses of the transcripts were also performed in Dutch. Quotations in this manuscript were translated as if they were originally said in English.

Results

All approached veterinarians accepted to participate in this study, except one due to a lack of time. All veterinarians were working in different group practices from different regions of the country and were specialized in just one or two animal species (Table 1). After eleven interviews, no new themes emerged interviewing was discontinued.

It emerged from the interviews that promoting prudent antimicrobial use in farm animals can roughly be realized at three levels; i) Prevent animal diseases through successful and consistent implementation of preventive measures for diseases; ii) Perform a correct diagnostic process to avoid unnecessary antimicrobial treatment; iii) Select antimicrobial treatments based on sensitivity of the involved pathogen(s) and pharmacological properties of the antimicrobial, followed by a correct administration of the antimicrobial. The different actors have different roles and influences at these levels which determine the opportunities and barriers that exist at each level to promote prudent use of antimicrobials in farm animals. This is graphically summarized in Figure 1. These three levels will be separately discussed below.

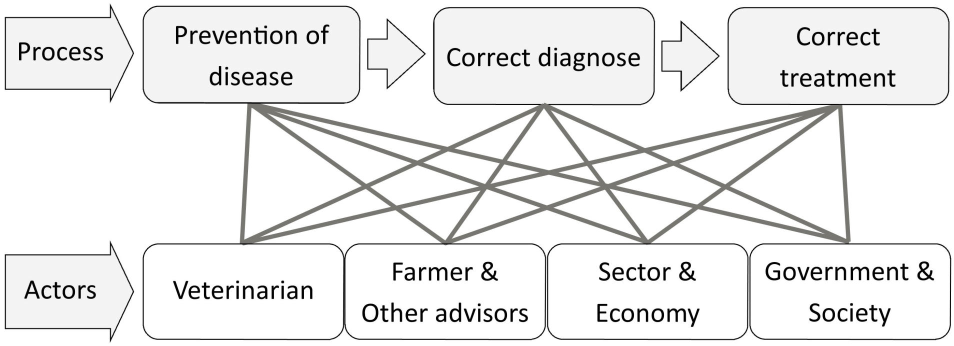

Figure 1. Different actors are related to veterinary antimicrobial use and reduction of antimicrobial use. Each of these have different interests, are interrelated and influence each other.

Prevention of animal diseases

Role of veterinarians on farms

All respondents mentioned that in addition to their traditional curative veterinary work, providing veterinary advices to farmers is increasingly part of their daily work. This advice particularly focuses on promoting animal health and welfare and improving production results.

Most respondents emphasized the importance of regular farm visits to monitor the actual health of the animals and to identify existing risk factors for animal diseases in order to timely advise farmers to take specific actions to prevent (further dissemination of) animal diseases. The availability of actual and reliable farm performance data is considered an important additional tool to assess whether or not veterinary interventions are required.

Table 1. Characteristics of the respondents

Respondent ID	Animal species of main concern	(Co-)Owner vs. payroll	Years of experience
R1	Poultry	(Co)-Owner	33
R2	Poultry	Payroll	8
R3	Veal calves	(Co)-Owner	19
R4	Poultry	(Co)-Owner	15
R5	Pigs	Payroll	10
R6	Dairy/veal calves	(Co)-Owner	26
R7	Dairy	(Co)-Owner	2
R8	Pigs	(Co)-Owner	20
R9	Dairy	(Co)-Owner	22
R10	Pigs	Payroll	17
R11	Veal calves	(Co)-Owner	10

Respondent (R)4: "My role as veterinarian is to work together with the farmer to keep an eye on animal health and everything that is related to that; nutrition, ventilation. Some sort of a management consultant, that is what it is actually."

Low tariffs for veterinary advisory services were regarded to be essential to remain or get the motivation for farmers to consult veterinarians for regular farm visits and advices. Higher tariffs for veterinary consults is expected to decrease the motivation for farmers for intensive veterinary supervision which might, according to some respondents, eventually result in more animal health problems and associated antimicrobial use.

Some respondents indicated that veterinarians have to improve their knowledge of animal nutrition and housing conditions and how they relate to animal diseases to further improve their advisory role on animal health to farmers. According to other respondents it is sufficient for a veterinarian to correctly identify problems due to inadequate feed or housing conditions and subsequently call for specialists.

Economic considerations hampering prevention of animal diseases

All respondents mentioned economic considerations as a major driver of decisions made in livestock farming. This was mentioned by all, except dairy veterinarians, to be a substantial cause of antimicrobial use in farm animals.

R4: "And it is available, eh… The 'Volwaard'-chicken. A wonderful initiative. We reduce the growth rate of those broilers and they hardly use any medicines. They just do not need them. Yeah, but it is a bit more expensive... So, the product is available. We export quite a lot to Russia, Pakistan and I do not know where. Over there, they could not care less how it is produced, as far as it is cheap. We are a bit in a quandary; the farmers rather want to do it another way, but they are left with no choice."

Cost control was realized through feeding low quality feeds and by postponing costly improvements in suboptimal housing and climate conditions which resulted in an increased sensitivity of animals for infectious diseases. Farmers also minimized the amount of hired labour to do the work at the farm, resulting in less attention for weak or diseased animals which increases the risk of disease transmission within the herd.

R4: "So the economy is a difficult one. See, a farmer might choose to order cheap feed, and then we are talking about 1 or 2 euros cheaper. You can administer a lot of medicines for that money."

R10: "I had a pig farmer in my practice with 1,000 sows, who asked me: 'Give me one single reason why I should spend more money for less result. Those antibiotics of yours, they are effective! And if I have to change practices, I have to hire another worker; just costs too much money.'"

The perceived willingness of farmers to invest in vaccinations or intensive veterinary support varied. A swine veterinarian encountered objections after suggesting vaccinations as a mean to prevent infections.

R5: "Then a farmer considers the costs and benefits. He considers whether to treat those animals with antimicrobials or to vaccinate them. That PIA-vaccine costs about 2 euros and when he treats them with antimicrobials, he only has to spend about 1 euro. If he says 'I will not vaccinate, I am going to treat them with antimicrobials', well, there is nothing to stop him doing this."

Many disease problems are believed to arise due to the "low quality" of young animals that arrive at raising farms. Veal calves often have insufficient maternal immunity and because of their diverse origin can introduce all kinds of infections to raising farms. Broilers also often suffer from (sub)clinical infections at the time of arrival according to some respondents due to cost control measures at hatcheries. This eventually increases disease risks and antimicrobial use at the raising farm.

R2: "When the chicks and the feed are of inferior quality, then you cannot expect chickens to arrive at the slaughterhouse without medicines."

Farmer skills and behaviour

According to almost all respondents, high use of antimicrobials in farm animals could partly be explained by insufficient skills of farmers to detect risk factors for diseases or early signs of upcoming diseases followed by proper management adjustments. Other farmers just lack the motivation to ban antimicrobials according to some respondents. They are accustomed to raising animals with the use of antimicrobials during periods of (perceived) high disease risks and are simply reluctant to ban antimicrobials from their working routine.

Respondents made several suggestions for improving animal health. Farmers should become better educated and supervised in caretaking of animals. Two respondents suggested a license to produce (i.e. demonstrable training or education) for farmers and their co-workers based on compulsory education and additional requirements as a prerequisite to raise and keep animals for food production. Veterinarians could potentially support farmers with insufficient management skills or motivation to improve animal health by means of more frequent veterinary supervision.

R10: "Eh… motivation, that is the most important. To tackle things structurally and to look at the farm from a different perspective. But also something as talent is important; the skills to watch over animals and to implement the right actions before a problem arises. Something else for pig farming is structure. If that is not in the farmer, then it is without prospects. Or you need to direct the farmer in such a farm protocol that he can manage it. So if this farmer is guided into a four week system [a certain management protocol –DS], it can succeed. He should be forced to take good actions."

Proper diagnosis of animal diseases

Proper history taking and clinical examination are fundamental to make a correct clinical diagnosis according to the respondents. When groups of sick animals are involved, other sources as farm history of diseases, farm inspection and data inspection are major additional contributors to the diagnostic process.

Reasons (not) to use diagnostic tests
All respondents considered diagnostic tests valuable for confirmation of diagnoses and helpful in the decision whether or not and which antimicrobials should be used. Some valued diagnostic tests as an effective tool to convince farmers with objective evidence of the presence or absence of certain infectious pathogens and the need for management adjustments.

R8: "Then you immediately start with antimicrobial group treatment. Because treating 350 piglets individually, that is not feasible at that very moment. Then you also do not await a report from the Animal Health Service [veterinary laboratory - DS] or something. Then you need to act immediately. There was mortality already. Then really something must be done, otherwise you have to drag most of them to the road [for destruction – DS]."

Despite the perceived value of diagnostic tests, they were often not used. Especially when individual diseased animals were involved, diagnostic tests were often more costly than just the empirical administration of antimicrobials. Many diagnostic tests were perceived as having results that were unavailable on a timely basis, and when faced with clinical symptoms, respondents felt an urge to treat animals immediately. During acute disease outbreaks in groups of animals, diagnostic tests were occasionally used retrospectively by respondents in order to adjust an already started therapy or to guide any future treatment at the same farm.

When diagnostic tests did not add extra information in the opinion of the farmers, they might lose their motivation to perform often expensive diagnostic tests. In these cases some respondents considered it difficult to convince farmers to perform diagnostic tests.

R10: "In fact, we have too little guidance to… Say; if you have a problem caused by Streptococci, how often will you send material for post mortem examination? So I do it regularly, but regularly… Once a year also is regularly but is insufficient to justify antimicrobial use."

DS: "So why do you not perform diagnostic tests more often?"

R10: "Because, usually there is the same finding each time and then the motivation of the farmers to do this investment is lacking. 'Yes, it is another Streptococcus, we knew that'. You really need tools and rules, with which you can say… You need a big stick; okay, we do it four times a year as part of our monitoring and then we can keep an eye on the sensitivity of the Streptococcus."

In some cases, diagnostic tests were not regarded as having added value. During outbreaks of respiratory diseases in veal calves, it is likely to find multiple pathogens and it is difficult to assign the disease to only one pathogen. In some instances (e.g. *Clostridium* spp. infections), the cultured pathogenic bacteria are also found in healthy animals, so there is very limited added value of this culture result. . In practice, it is then just a matter of empirical treatment -which is sometimes based on macroscopic post mortem examinations- and proper therapy evaluation.

Selection and administration of antimicrobials

Determinants for antimicrobial choice

Most respondents indicated that formularies (treatment guidelines) from the KNMvD and summaries of product characteristics are generally leading in their choice for an antimicrobial. However, based on their empirical experience and practice routines and the results of sensitivity testing, they deviated from formularies and product approvals. One respondent mentioned that for some indications, their experience had taught them that the results of an antimicrobial intervention in the field sometimes conflicts with the results of sensitivity testing in the laboratory and then the latter was ignored. Several respondents indicated that the administration of medicines should be as convenient as possible for the farmer to increase therapy compliance. Thus, administration route and administration interval as well as withdrawal times for slaughter or milk delivery, were also considered when choosing an antimicrobial.

Prophylactic use of antimicrobials

Some respondents mentioned that prophylactic (disease prevention) and metaphylactic (mass medication of groups of food animals when infectious diseases are incubating (Prescott 2008)) antimicrobial treatments were until recently believed to be a convenient and cheap way to control infectious diseases in farm animals. Most respondents indicated that these practices had greatly been abandoned, although some prophylactic and metaphylactic antimicrobial treatments were seen as inevitable.

Several respondents mentioned that antimicrobials were still used prophylactically to prevent problems with a high probability of occurrence. They argued that if these infections were not prevented, they could cause high morbidity and mortality rates with accompanying financial losses and subsequently had to be treated with antimicrobials which were either expensive, highly important for public health, or both.

> R9: " We have very bad experiences with selective dry cow therapy [restricting intramammary antimicrobial treatment only to cows demonstrable infected at drying-off, instead of blanket dry cow therapy for all animals-DS]. With current knowledge I consider it really dangerous to strictly introduce this practice. I think that we are running the risk of very serious accidents. If you get more mastitis due to this practice, then you just run into more problems, more antimicrobial use."

Dependency

Several respondents sometimes experienced conflicting roles. There was the pressure of working in a competitive market to deliver veterinary services to farmers. Client satisfaction was therefore important for veterinarians to remain in business. On the other hand, veterinarians felt the expectation to safeguard public health which sometimes was perceived to conflict with the interests of farmers, for example in the case of reduction of antimicrobial use. Some respondents mentioned situations in which they felt pressure from farmers or influential non-veterinary farm advisors to prescribe antimicrobials. Refusing a strong request from a farmer for antimicrobial prescription felt uncomfortable.

> R7: "Because, apart from the fact that you are convinced of something, there also still is a need to remain in business, eh… I mean… See, you may not really support some things, but you also not easily say no to a client. Because you have a certain… Because he assures your livelihood!"

R6: "And if you are going to act as a police officer, then you will lose lots of clients."

Most respondents had occasionally experienced feelings of frustration as they can only give recommendations to prevent diseases to farmers without enforcement of implementation. When farmers did not follow advices and veterinarians were again confronted with sick animals, they felt their professional obligation to prescribe to reduce animal suffering.

R3: "I guess, 10-15% of the farmers are just stubborn. That really is the biggest frustration. Too often there is, unjustified I think, administration of antimicrobials to camouflage the farmer's mismanagement."

Many respondents, however, recognized a slow change in the attitude of farmers. Farmers that had personally been confronted with isolation measures because of a potential methicillin-resistant Staphylococcus aureus (MRSA) colonization at hospital submission were increasingly motivated to reduce antimicrobial use on their farm. Political and public pressure had also slowly changed the attitude of farmers. This made it increasingly easier to talk with farmers about reducing antimicrobial use.

Antimicrobial resistance

Views differed between respondents regarding the veterinary contribution to antimicrobial resistance in humans. Some were very motivated to reduce veterinary antimicrobial use for public health reasons. Others doubted a significant contribution of veterinary antimicrobial use to antimicrobial resistance in humans. They hardly ever encountered therapy failures due to resistance problems in daily veterinary practice and considered antimicrobial resistance mainly a problem caused by inadequate prescribing practices of physicians and international traffic. Several respondents would like to see a sound scientific backing of the current Dutch policy to halve antimicrobial use in farm animals. They feared impairments of animal welfare due to non-treatment of diseased animals and were not convinced of the effectiveness of this measure in terms of reduction of antimicrobial resistance. All respondents considered it their duty as veterinarian to treat diseased animals for reasons of animal welfare and animal health, regardless of antimicrobial resistance issues.

R2: "Those animals really can be seriously diseased. Then I also think we have to safeguard animal welfare and then I prescribe."

Some veterinarians viewed the excellent registration of antimicrobial use in the Netherlands as the cause of the prevailing view that Dutch farm animals are amongst the highest antimicrobial consumers in Europe. They had the strong impression that veterinary antimicrobial use in surrounding countries was at least at the same level as in the Netherlands. Many respondents shared the opinion that policies regarding reduction of veterinary antimicrobial use should be equal in all European countries in order to prevent illegal imports of antimicrobials and to maintain a level playing field in terms of competitiveness on international markets. They doubted any effect on antimicrobial resistance if only national level measures were taken to combat antimicrobial resistance.

Practices to reduce antimicrobial use

Most respondents mentioned a high reduction in the number and extent of routine preventive antimicrobial administrations as a response to the recently introduced policy to halve veterinary antimicrobial use. Where possible, group treatments were increasingly replaced by treatment of individual animals. This approach is generally more labour intensive and more expensive than mass medication so it can therefore sometimes be difficult to convince farmers to waive a group treatment.

Mild clinical symptoms were increasingly treated by supportive therapies only, according to the respondents, although it very much depended on the willingness of the farmer whether antimicrobial therapy was omitted or postponed in such situations. When confronted with more severe symptoms, fear of complications after non prescribing usually was a strong motivator to turn to antimicrobial intervention.

Veterinary pharmacy

Where antimicrobial selling in the past substantially added to the pharmacy incomes of veterinarians, all respondents stated that pharmacy incomes from antimicrobial selling was no longer a stimulus to prescribe antimicrobials. Some respondents mentioned that pharmacy incomes from selling antimicrobials had been replaced by selling vaccines and non-steroids which they did not consider to be a threat for public health. Most respondents were reticent to increase their hourly (consultancy) tariffs for veterinary services out of concern for a negative influence on the motivation of farmers to hire them for veterinary advices. Therefore, low consultancy tariffs were regarded necessary which could only be compensated with pharmacy incomes to earn a decent income. Separating prescribing and dispensing was not expected to reduce antimicrobial prescription in farm animals. As animals continue to contract illnesses, a need to prescribe antimicrobials would remain according to the respondents.

Discussion

This is one of the first studies to identify underlying factors influencing prescribing behaviour of veterinarians working in farm animal practice. What becomes clear from this study is that veterinarians, like physicians, act in a playing field where many conflicting intrinsic beliefs and extrinsic influences like economic powers, client dependence and risk avoidance act as both drivers and barriers to changing their antimicrobial prescribing behaviour (Simpson, Wood et al. 2007, Butler, Rollnick et al. 1998). The three different levels for promotion of prudent antimicrobial use that were distracted from these results (prevention of diseases, correct diagnosis making and correct selection and administration of antimicrobials) are considered useful to structure future interventions (Callens, Persoons et al. 2012, Aarestrup, Wegener et al. 2008, Persoons, Dewulf et al. 2012, Pardon, Catry et al. 2012, Prescott 2008).

Opinions, knowledge and skills of veterinarians

Prevention of animal diseases can largely contribute to reduction of antimicrobial use in farm animals. Several respondents mentioned that veterinarians could benefit from more practical applicable knowledge about disease control at the farm; a finding that is confirmed by a study from (Gunn, Heffernan et al. 2008). Another finding is that there are opportunities for improvements in advisory skills of veterinarians (Derks, van de Ven et al. 2012, Jaarsma, Dolmans et al. 2008, Jansen, Lam 2012). It might be not a matter of just acquiring more technical knowledge, but a matter of acquiring a comprehensive set of knowledge about animal management, nutrition, environment, genetics, infectious diseases, production disorders, veterinary pharmaceuticals and farm economics; supplemented with skills and attributes to put this knowledge into practice (Mee 2007, LeBlanc, Lissemore et al. 2006).

All respondents felt a moral obligation towards society to reduce veterinary antimicrobial use although many questioned the veterinary contribution to antimicrobial resistance. The fact that serious resistance issues were not often encountered in daily veterinary practice might feed their belief that antimicrobial resistance is not a big and urgent issue which should be taken into account in their prescribing decisions at specific instances. Fear of major complications with deterioration of animal welfare, high mortality rates, economic consequences and client dissatisfaction after not prescribing seems to be more important for farm animal veterinarians than the more abstract risk of antimicrobial resistance. These findings are confirmed by Dean et al., 2011.

The trade-off between the direct interest of the individual sick animal or group of animals with fear of complications and its associated consequences after non-prescribing and the interests of the community in terms of the antimicrobial resistance threat for public health is also recognized in studies dealing with antimicrobial prescribing of physicians (Butler, Rollnick et al. 1998, Simpson, Wood et al. 2007, McNulty, Francis 2010, Hulscher, van der Meer et al. 2010, Petursson 2005). Even with quite firm evidence for non-efficacy of antimicrobials in certain clinical conditions, physicians still favor the avoidance of risks and reaching client satisfaction by prescribing antimicrobials above serving public health interests by not prescribing. The evidence for non-efficacy of antimicrobials for the most treated clinical symptoms (respiratory and gastro-intestinal disorders) in farm animals is limited or non-existent and is usually complicated by the fact that in a group of diseased animals, different clinical symptoms can be present which complicates the diagnostic process and thereby the rationality of waiving antimicrobial intervention.

In the view of some respondents, specific prophylactic and metaphylactic administrations of antimicrobials contribute to prudent veterinary antimicrobial use by lowering the amount of curative used antimicrobials and by protecting animal health and welfare. It is not known if and to what extent prophylactic and metaphylactic use of antimicrobials contributes to or jeopardizes prudent veterinary antimicrobial use and animal welfare (Morley, Apley et al. 2005). However, it has been shown that even without these practices antimicrobial reduction can be accomplished under modern circumstances without deteriorating animal health and welfare and production results (Persoons, Dewulf et al. 2012, Cromwell 2002, Wierup 2001, Bennedsgaard, Klaas et al. 2010, Vaarst, Bennedsgaard et al. 2006, Anonymous 2011, Wierup 2000).

Farmers

Ultimately, farmers are the final decision makers when it comes to whether or not effective preventive measures for infectious diseases will be implemented, diagnostic tests will be performed and whether and which therapy will be started. They are often also responsible for the administration of antimicrobials. Not all farmers are able or willing to change practices out of risk avoidance, insufficient knowledge of the benefits, or financial reasons (Klerkx, Jansen 2010, Gunn, Heffernan et al. 2008). This highly influences the necessity of treating animals with antimicrobials and confronts veterinarians with a difficult dilemma for they have the professional obligation to alleviate animal suffering as well as to protect public health interests (Morley, Apley et al. 2005). Most respondents experienced a varying level of pressure to comply with the implicit or explicit demand of farmers and other advisors, as found in other studies (McIntosh, Schulz et al. 2009, Jan, McIntosh et al. 2012). Losing a client might have serious financial consequences and therefore a stable veterinarian-farmer relationship is very valuable (Klerkx, Jansen 2010). It is interesting to know whether farmers' expectations for prescriptions or lack of motivations for management changes are correctly or wrongly perceived by veterinarians. It is known from physicians that the perceived expectation for antimicrobial therapy does not always correspond with the actual expectation of the patient (Butler, Rollnick et al. 1998). In the veterinary domain, it has been found that ostensibly unwilling farmers might in reality be willing to implement management adjustments, though they should probably be approached with different arguments (Jansen, Steuten et al. 2010). This might be related to insufficient knowledge transfer; farmers must be convinced of the efficacy and economic benefits of implementing preventive measures (Gunn et al., 2008). Compulsory continuing education for farmers as 'a license to produce' as suggested by some respondents, might be considered to improve the level of knowledge of farmers on disease prevention, although other approaches like annual development of action plans in collaboration with farm veterinarians might also be an effective way to increase disease preventing measures (Speksnijder et al., 2014). However, at the end of the day, the ultimate responsibility to produce animal derived food with high food safety, public health and animal welfare standards and to implement specific preventive measures rests with the farmer. It is up to governments or quality systems (including continuing educational systems) to enforce compliance of farmers to these high standards when these are not met, in order to protect public health interests.

Profitable Veterinary Herd Health Advisory Services

Presumably, a large reduction of antimicrobial use can be accomplished through higher emphasis on preventive measures at farm level whereby the farm veterinarian plays an important advising and supervising role. A huge constraint is the barrier to make this regular Veterinary Herd Health Advisory Service (VHHAS) profitable without being dependent on incomes from dispensing veterinary drugs or vaccines. A recent study indicated that 40% of the dairy farmers would reduce the time spent on VHHAS if the tariffs would increase (Derks, van de Ven et al. 2012). It has been shown that intensive contact between a farmer and veterinarian might increase animal health so decreasing the frequency of VHHAS might result in a deterioration of animal health (Lam, Jansen et al. 2011). This obstacle should be tackled if sustainable VHHAS without additional pharmacy incomes will become the norm.

Diagnostic tests

Many respondents described diagnostic tests as expensive and time consuming, thereby hampering their execution to refine diagnoses. In human healthcare, the introduction of new point-of-care testing devices has enhanced faster decision making and prudent antimicrobial prescribing, although these tests should be used with caution for the tests vary in their performance (Cals, Schot et al. 2010, Price 2001). The introduction of faster diagnostic tests could in some situations be beneficial in veterinarians' decision making, although when groups of animals are concerned, multiple pathogens are often simultaneously involved which might complicate the use of rapid point-of-care testing.

Global concern

The livestock sector in the Netherlands is representative of large scale livestock production systems that exist in many industrialized countries and which are highly internationally oriented. In most of these systems, farmers as well as private veterinarians work in a very competitive environment. International collaboration is needed to effectively reduce the development of antimicrobial resistance and to remain a fair and level playing field in terms of competitiveness on international markets and to prevent illegal imports of antimicrobials (Speksnijder et al., 2014). Though specific contexts may differ, we think that many of the determinants that influence antimicrobial prescribing behaviour of farm animal veterinarians in the Netherlands do also apply to veterinarians working in comparable livestock systems worldwide. This is supported by the scarce literature dealing with prescribing determinants of farm animal veterinarians (McIntosh, Schulz et al. 2009, Jan, McIntosh et al. 2012).

Implications

To increase veterinarians' and farmers' confidence in achieving a sustainable reduction in antimicrobial use in farm animals, they should be provided with evidence-based, feasible approaches and tools to help achieving this change (McNulty, Francis 2010). Clear evidence could be presented dealing with the consequences of veterinary overuse of antimicrobials and the need to reduce veterinary antimicrobial use. Existing knowledge about best practices to reduce antimicrobial use without compromising animal health and production results should be further disseminated amongst veterinarians and farmers to convince them of the feasibility of production with less use of antimicrobials. As veterinarians are seen as highly influential referents regarding biosecurity issues, there might be a huge role for veterinarians in motivating and advising farmers to implement preventive control measures (Ellis-Iversen, Cook et al. 2010). Improved advisory skills of veterinarians might well further substantiate the effect of VHHAS. Veterinarians should also learn to deal with sometimes contrasting opinions of other farm advisors and ways should be found to harmonize the advice of different consultants to improve farmers' compliance (Lam, Jansen et al. 2011).

Additional policy instruments might be needed for a better compliance to veterinary advice to control animal diseases (Klerkx, Jansen 2010, Morley, Apley et al. 2005). Disease specific guidelines that also include recommendations for performing specific diagnostic tests and preventive measures to prevent diseases might be beneficial in substantiating veterinary advice to farmers, although some farmers might not voluntarily comply and should ultimately probably be enforced by independent parties (Aarestrup, Wegener et al. 2008, Prescott 2008).

Limitations of the study

As this study is qualitative in origin, it is not possible to rank the found prescription determinants in importance nor can these results be generalized over the whole veterinary profession (Pope, Ziebland et al. 2000). For this goal, a questionnaire for dissemination in a larger group will be developed based on the results of this qualitative exploration.

The public currently holds a negative attitude towards extensive antimicrobial use in farm animals (Derks, van de Ven et al. 2012, Dijksma 2014). Interviewed veterinarians might be aware of this negative image and might have tended to give socially desirable answers. However, the fact that the interviewer is a peer of the respondents might have reduced the hierarchy between informants and researcher (DiCicco-Bloom, Crabtree 2006, Chew-Graham, May et al. 2002, Coar, Sim 2006). Respondents were very frank in describing their daily practices, leading to the impression that the participating veterinarians really expressed their true feelings and behaviour (McNair, Taft et al. 2008).

The number of respondents (eleven) is relatively low. The estimated population of private farm animal veterinarians in the Netherlands is around 1100. However, saturation of data was reached and the performance of additional interviews was not expected to provide additional information for the purpose of revealing possible prescribing determinants for farm animal veterinarians. Relatively small sample sizes can be sufficient to understand common perceptions and experiences among a group of relatively homogeneous respondents (Guest, Bunce et al. 2006, Onwuegbuzie, Leech 2007).

Conclusions

This study indicates that antimicrobial prescribing by veterinarians is influenced by a very complex set of internal attitudes and beliefs and external, often conflicting, interests. To reduce the overall use and misuse of antimicrobials in farm animals, three different challenges can be distinguished; i) the successful and consistent implementation of preventive measures at farm level, ii) the reduction of thresholds for the use of diagnostics, and iii) the prudent and accurate administration of antimicrobial treatments. All kinds of identified stakeholders have responsibilities at these challenges and have to change behaviours. International collaboration in reducing antimicrobial use is needed to maintain international competitiveness of national livestock sectors and to remain support of all stakeholders. Single, simple solutions are unlikely to alter antimicrobial prescribing of veterinarians. A comprehensive set of multiple interventions addressing different aspects of prescribing behaviour, together with flanking policy measures to enforce compliance of all the stakeholders, is needed.

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Appendix I: Interview guide

Veterinarian

Role of the veterinarian

- How do you perceive your role as a veterinarian on a farm?
- Which steps do you take when you are being confronted with (a) sick animal(s)?
    I. Way of approaching the problem
    II. How the diagnose is made
    III. Choice of therapy

Prescribing

- How do you define "prudent antimicrobial use"?
- How do you perceive your own prescribing behaviour?

Antimicrobial resistance and reduction of antimicrobial use

- How do you consider antimicrobial resistance?
    I. Current policies to reduce antimicrobial use?
    II. Influence on daily work?
    III. Barriers and opportunities for reducing antimicrobial use in farm animals?
    IV. Role of veterinarians in reducing antimicrobial uses in farm animals?
    V. What about your own knowledge and skills to reduce antimicrobial use?

Farmers and non-veterinary advisors

Relationship between veterinarian and farmer

- Expectations of farmers towards you as a veterinarian?
- Role of farmers and non-veterinary advisors in the choice for antimicrobial therapy?
    I. Pressure on you in your considerations to start a certain therapy?
    II. How do you deal with pressure to prescribe?
    III. Tools or skills to deal with pressure?

Antimicrobial use on a farm

- Important factors on a livestock farm that determine the scale of antimicrobial use?
    I. How can these factors be influenced?
- Motives of farmers (not) to apply antimicrobials on their animals?

  I. Actors or factors influencing these motives?
  II. Role of veterinarians in influencing these motives?
- Role of prophylactic and metaphylactic antimicrobial use on an average farm?

Organization of the livestock sector and animal health care

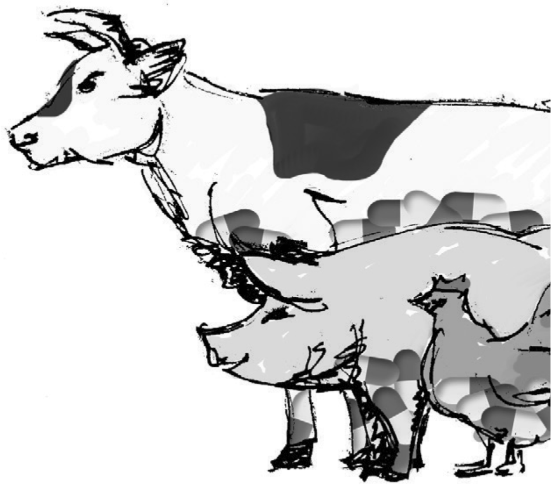
Influence of the organization of the livestock sector on animal diseases and antimicrobial use
- Influence of the current organization of the livestock sector on the scale of animal diseases?
  I. Influence on antimicrobial use in the livestock sector you are working in?
  II. Value of initiatives taken by the livestock sector to reduce antimicrobial use?
  III. Suggestions for improvements?

Organization of animal healthcare
- Coordination between colleagues in your practice in terms of therapy choices, treatment protocols etc.?
- Role of diagnostic tests in reduction of antimicrobial use?
  I. Which potential role in future? What is needed for that?
- Current veterinary infrastructure in the Netherlands?
  I. Which improvements might be possible?
- Role of formularies, guidelines etc. in healthcare for livestock?
  I. Which requirements to be effective?

Cultural & Socio-economic context

Public and political aspects
- Current public and political debate about antimicrobial use in livestock?
- Role of veterinarians in public health?
  I. Which obstacles experienced?
- Role of government in the current issue of antimicrobial use in livestock?
- What should the position of veterinarians in the livestock sector and his/her public tasks be (in terms of public health and animal welfare issues)?
  I. How can this position be strengthened?

Economic considerations of veterinarian and farmer
- Role of veterinary pharmacy for income of veterinarians?
- Financial considerations of farmer in using antimicrobials?



Chapter 3

Attitudes and perceptions of Dutch veterinarians on their role in the reduction of antimicrobial use in farm animals.

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Abstract

Little is known about attitudes of veterinarians towards antibiotic use and reduction opportunities, and their interaction with farmers herein. Therefore, a questionnaire was developed and sent out to Dutch farm animal veterinarians.
The response rate was 40%. Categorical Principal Component Analysis (CATPCA) was conducted on statements measuring attitudes towards the use of antibiotics and reduction opportunities in farm animals, the veterinary pharmacy and the interaction of veterinarians with farmers in improving animal health. This resulted in 3 underlying dimensions. Additionally, possible explanatory variables (main farm animal species working with, years of experience in practice) were added to the CATPCA to identify differences between veterinarians.
Veterinarians working with different animal species were comparable in their opinions towards the necessity to reduce veterinary antibiotic use and the current policy to halve veterinary antibiotic consumption. Veterinarians working with ruminants - “ruminant specialists” - and veterinarians working with several different animal species - “generalists” - reported to feel more uncertainty in acting independently from farmers’ and significant others’ (other advisors, colleagues) demands for antibiotics or opinions than veterinarians mainly working with intensively raised animals (pigs, poultry, veal calves) - “intensive specialists”. Years of experience in practice was negatively related to feelings of uncertainty in acting independently. At the other hand, years of experience was associated with being less concerned about the possible contribution of veterinary antibiotic use to antimicrobial resistance, considering it more important to keep the right to prescribe and sell antibiotics, and being less hesitant to apply antibiotics to prevent (further dissemination of) animal diseases. Intensive specialists expected most from improving feed quality and benchmarking of antibiotic prescribing and use in reducing veterinary antibiotic use; ruminant specialists and generalists preferred improving housing and climate conditions and benchmarking. The by veterinarians perceived main reasons for farmers not to comply to veterinary advices to improve animal health were related to financial and time restrictions, although intensive specialists stressed the importance of conflicting advices from other advisors as a cause for non-compliance.
The results showed that younger veterinarians might require additional support to act independently from farmers and significant others’. Additionally, experienced veterinarians could be educated about possible risks related to veterinary overuse of antibiotics. Alternative approaches should be identified for veterinarians to preserve a decent income without pharmacy incomes. Especially in intensive farming, ways should be found to prevent contradictory advices as a barrier not to implement veterinary advices to improve animal health.

Introduction

The emerging antimicrobial resistance in bacteria is considered to be a major threat for public health. Farm animals are regarded as high antibiotic consumers with considerable levels of avoidable antibiotic use (U.S. Department of Health and Human Services. Centres for Disease Control and Prevention. 2013). Since antibiotic use drives resistance, there is an urgent need to reduce antibiotic use in animals to the absolute minimum that is required to safeguard animal health but still compatible with a sustainable animal production (Angulo, Collignon et al. 2009, Prescott 2008, Aarestrup, Wegener et al. 2008, McEwen 2006).

The Dutch government in 2010 imposed the livestock sectors to reduce veterinary antibiotic usage with 50% in 2013 and 70% in 2015 compared to 2009. After an initial rapid decrease in reduction of antibiotic use in farm animals (56% in 2013) there is a levelling in 2014 with 58% (MARAN 2015). A 70% reduction will require additional fundamental changes in the behaviour of veterinarians and farmers towards the usage of antibiotics in farm animals (Speksnijder, Mevius et al. 2015). Tailored interventions directed to veterinarians to change antibiotic prescribing behaviour of veterinarians might be effective as they are key persons in reducing antibiotic use in farm animals (Prescott 2008, Morley, Apley et al. 2005). However, only little is known about attitudes and other influences that might influence prescribing behaviour of veterinarians.

In human medicine, prescribing decisions of physicians are influenced by clinical reasoning as well as non-clinical factors which are related to personal characteristics (e.g. years in practice, extent of medical knowledge, attitudes, relationship with patients) (Akkerman, Kuyvenhoven et al. 2005). Knowledge of these prescribing determinants and categorization of health care providers into different target groups is extensively used for the purpose of sustainable implementation of tailored antibiotic stewardship programs and interventions (Hulscher, Grol et al. 2010, Hulscher, van der Meer et al. 2010, Kumar, Little et al. 2003, Walker, Grimshaw et al. 2001, Vander Stichele, De Potter et al. 1996, Simpson, Wood et al. 2007).

Earlier qualitative research amongst Dutch farm animal veterinarians identified a broad variety of opinions regarding veterinary antibiotic use and ways to promote prudent use as well as determinants that influenced their prescribing behaviour (Speksnijder, Jaarsma et al. 2015a). Further exploration of attitudes of farm animal veterinarians and their interaction with farmers in promoting animal health and subsequent categorization of farm animal veterinarians in different groups might support targeting interventions to promote prudent use of antibiotics more precisely.

The purpose of this study was to explore differences in attitudes towards the use of antibiotics and reduction opportunities in farm animals and the interaction of veterinarians with farmers in improving animal health and reducing antibiotic use between categories of veterinarians.

Materials and Methods

Instrument

Based on our earlier qualitative research (Speksnijder, Jaarsma et al. 2015a) a questionnaire was designed. Questions consisted of general descriptives, 5-point Likert scale statements (1=completely disagree; 2=disagree; 3=neutral; 4=agree; 5=completely agree), ranking questions (ranking of items on importance) and open questions assessing attitudes, knowledge and self-reported behaviour of veterinarians regarding antibiotic use and reduction opportunities in farm animals, their interactions with significant others like other advisors and colleagues and their perceived role in antibiotic reduction. The design and content of the questionnaire was discussed in an expert meeting consisting of veterinary and medical experts. The questionnaire was subsequently piloted amongst veterinarians working at the Faculty of Veterinary Medicine, Utrecht University, the Netherlands (Rattray, Jones 2007). The questionnaire was made online available through Surveymonkey (SurveyMonkey.com, LLC, Palo Alto, California, USA).

Questionnaire distribution

In April 2012, an invitation to participate in an online survey was sent out to all practicing farm animal veterinarians in the Netherlands by email. Veterinarians working at least 1 day a week with farm animals were invited to participate. In total, 1770 email addresses of registered farm animal veterinarians were obtained from the Royal Dutch Veterinary Association (KNMvD). This list however appeared to be contaminated with double email addresses (private as well as company email addresses). It was not possible to reduce the number of email addresses without risking missing practising veterinarians. The exact population size of practicing farm animal veterinarians in the Netherlands is not exactly known and was estimated based on the species specific registers of veterinarians which consisted of around 1100 practitioners in early 2013. After 2 and 7 weeks, reminders were automatically sent to non-responders. This survey was also advertised in the monthly digital newsletter of the KNMvD. Responses were collected anonymously unless participants choose to leave contact details. A €20 voucher for participation was provided after completion of the questionnaire.

Data Analysis

Data were analysed using Microsoft Excel and SPSS Statistics version 22 (IBM Corp.). Comparisons between categories of veterinarians were performed with the appropriate tests and post hoc analyses for the different types of data (nominal, ordinal, continuous). Continuous data (years in practice, estimated achievable reduction) were visually checked for normality.

Respondents were asked how their working time was attributed to the different animal species (1-20%; 21-40%; 41-60%; 61-80%; 81-100%). Respondents working >60% with animal species belonging to either intensively raised farm animals (poultry, swine, veal calves) or ruminants (cattle and small ruminants, not veal calves) were classified as respectively intensive specialists and ruminant specialists. Veterinarians working between 0-60% with animals from the different sectors (intensive, ruminant, horses and pets) were classified as generalists.

Factor analysis was performed to reduce the attitudinal variables to a number of uncorrelated principal components (dimensions) that represent the data and could further be analysed to find differences in attitudes between veterinarians and possible explanatory variables (Linting, van der Kooij 2012). As the data in our study consisted of nominal, continuous and ordinal variables, nonlinear rather than linear analysis was chosen to analyse the data. Categorical Principal Component Analysis (CATPCA) can manage possibly nonlinearly related variables with different types of measurement level and is particularly useful to analyse Likert-type variables (Linting, van der Kooij 2012). CATPCA converts categorical variables to quantitative variables using optimal quantification and reduces the dataset to a smaller number of dimensions (Linting, van der Kooij 2012, Linting, Meulman et al. 2007). Component loadings are correlations between the variables and the dimensions and can graphically be represented as vectors in a biplot (two dimensional graphical display) (Linting, Meulman et al. 2007). In total, 31 Likert scale statements (1 = completely do not agree – 5 = completely agree) were treated as ordinal data and selected for CATPCA analysis. Additionally, 3 supplementary explanatory variables were added to the CATPCA; type of veterinarian (multiple nominal data), years of experience (numeric) and being a practice owner (nominal). For missing values, the default Passive CATPCA option of imputing the modal category after quantification was chosen. Scree plot analysis indicated that a 3-dimension solution was most suitable for analysis of this dataset. All variables with a total variance accounted for (VAF) of 0.25 or lower were excluded for the final analysis. The CATPCA procedure was repeated until no variables with a total VAF <0.25 remained. Component loadings of 0.40 or higher were regarded as sufficient to calculate object scores for each dimension and were saved for further analysis (Linting, van der Kooij 2012).

In a separate question, respondents were asked to estimate the, in their opinion, reasonably achievable reduction in veterinary antibiotic consumption (percentage) in 2015 compared to 2009 for the animal species they were working with for at least 20% of their time. This individually reported reduction estimate per animal species was divided by the mean reduction estimates per animal species to calculate the relative estimated reduction of a respondent compared to peers as a percentage (100% being the average estimated reduction; less than 100% means being less optimistic than peers in the achievable reduction in veterinary antibiotic consumption; above 100% is more optimistic than peers). The mean scores per respondent over the different animal species were then averaged into one estimation of relative reasonably achievable reduction per respondent in comparison with peers. Parametric tests (T-test, ANOVA, linear and logistic regression analysis) were used as well as non-parametric tests for proportions or ordinal data (Pearson Chi Square and Kruskal Wallis H-test) to test for differences and associations between variables. The answers to the open question regarding reasons why veterinary advices are not implemented were analysed iteratively using qualitative techniques.

Table 1. Working time attributable to different animal species (proportion of respondents)					
	Percentage of working time				
Animal species	1-20%	21-40%	41-60%	61-80%	81-100%
Poultry	35,7%	1,6%	0,2%	0,5%	1,6%
Swine	38,0%	8,2%	3,2%	3,0%	6,9%
Cattle	13,3%	13,3%	19,0%	20,8%	23,6%
Veal Calves	37,5%	2,5%	0,7%	1,6%	2,5%

Results

General descriptives

We received 437 questionnaires of which 377 were complete (response rate of 40% (34% complete) based on the estimated number of registered veterinarians working in farm animals). The respondents were on average 15.8 (range 1-41) years in practice and 90.2% of the respondents had received their veterinary training at Utrecht University, the Netherlands. Of the respondents, 62.9% were (co)owner of a practice while the others were working on payroll. Practice owners had on average 20.6 years of experience in practice (95%CI 19.6-21.7) and no-owners had on average 7.3 years of experience (95%CI 6.1-8.5; t-test p=0.000). The percentages of respondents (n=437) reporting to work with the different farm animal species and the mean percentage of working time devoted to the different animal species are shown in Table 1, indicating for example that the majority (61%) of the intensive specialists are mainly working with pigs.

The intensive specialists had significantly longer experience than ruminant specialists but not than generalists (ANOVA; F=4.279; p=0.015). Intensive specialists were significantly more often practice owner instead of working on payroll compared with the other two categories (Table 2). Besides working with farm animals, veterinarians classified as generalists attributed significantly more working time to pets (Kruskal Wallis H-test $\chi2(2)$ = 43.585, p=0.000) and horses (Kruskal Wallis H-test $\chi2(2)$ = 81.898, p=0.000) compared to the other two categories, justifying their classification as generalists.

Table 2. Distribution of respondents over the different categories of veterinarians and their characteristics			
Veterinarian category	Number of respondents (%)	Percentage practice owner	Mean years of experience; 95% CI (N)
Intensive specialist	70 (16.0%)	82.8%[a]	18.0; 15.92-20.02 (64)[c]
Ruminant specialist	195 (44.6%)	53.9%[b]	14.2; 12.54-15.80 (170)[d]
Generalist	172 (39.4%)	64.3%[b]	16.7; 15.05-18.34 (143)
Total	437 (100%)	62.9%	15.8; 14.75-16.80 (377)

[ab] Sign differences between the groups; Pearson Chi Square $\chi2(2)$ = 16.679, p=0.000
[cd] Significant difference between the two groups (ANOVA; F=4.279, p=0.015)

The 3-dimensional CATPCA solution with 18 variables explained 42.4% of the variance of the scores provided by the respondents (7.63 as the sum of Eigenvalues from the three dimensions divided by 18 variables). The component loadings for the 3 dimensions solution are shown in Table 3. The plots of the component loadings with the centroid coordinates of the multiple supplementary categories are shown in Figures 1 and 2. Based on the grouping of different variables that have high value loadings on the different dimensions, three latent variables (dimensions) can be described:

- Dimension 1 is related to feelings of uncertainty to act independently from significant others' influences in antibiotic prescribing and improving animal health.

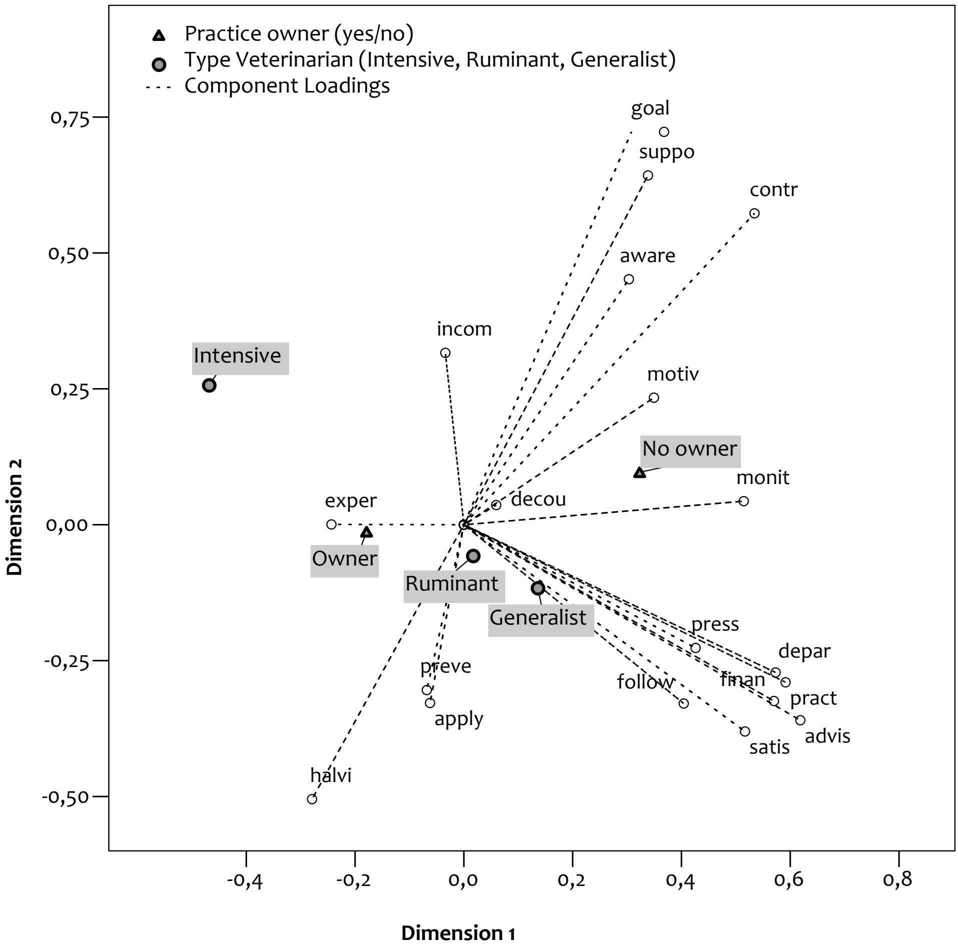


Figure 1. Biplot of component loadings for dimensions 1 and 2 for the active variables and multiple nominal category points.

Table 3. Component Loadings of 3 dimensional CATPCA analysis

Code	Variable	Dimension			
		1	2	3	Sum
contr	The possible contribution of veterinary antibiotic use to development of resistance in humans is worrisome	**,534**	**,573**		
suppo	I support the policy to halve veterinary antibiotic consumption by 2015 compared to 2013		**,643**		
motiv	An important motive for me to take up reduction of antibiotic use is to conserve the right to both prescribe and sell veterinary drugs			**,647**	
goal	It is my goal to reduce antibiotic use in my practice as far as possible		**,723**		
halvi	Halving veterinary antibiotic use will be at the cost of animal health and welfare		**-,505**		
aware	I have become more aware of the necessity to apply antibiotics restrictively last years		**,452**		
preve	Confronted with sick animals with a probable bacterial infection, I prefer to immediately apply antibiotics to prevent further exacerbation of the disease			**,445**	
apply	I don't have difficulties with applying antibiotics when I think I can prevent animal diseases			**,477**	
	I feel a need for clear criteria to help me decide whether I should continue or finish an antibiotic treatment				
	Farmers regularly fail to apply antibiotics correctly				
	Farmers regularly have difficulties in complying to their treatment protocols when treating animals				
	In our practice, we consciously take time to exchange knowledge and experience between colleagues				
	I feel a need for more knowledge exchange between my colleagues and myself				
	I would like my advising role for farmers to become more prominent in my daily activities				
advis	I consider it difficult to obtain a position as advisor amongst all other advisors that advice a farmer	**,619**			
pract	I consider it difficult to give practical advices to a farmer that contribute to improvements of animal health	**,591**			
	In my approach of farmers, I consciously adapt my communication style to the type of farmer I have to deal with				

Code	Variable	Dimension			
		1	2	3	Sum
follow	When I expect a farmer not to follow a certain advice, I will not give that advice	**,404**			
	I regularly am confronted with sick animals that likely could have been prevented when a farmer had complied to my advice				
	I often feel uncomfortable to charge the full amount of time that I spend on advising a farmer				
monit	When I could monitor animal health on a farm more frequently, antibiotic use on that farm can be lowered further	**,515**			
	I am in favour of compulsory post graduate education for veterinarians				
depar	I consider it difficult to depart from routines that farmers are accustomed to	**,573**			
press	I once in a while feel pressure from colleagues to perform activities which I in fact do not support, such as prescribing antibiotics	**,426**			
	Appreciation of farmers for my work is very important for me				
finan	Because of my financial dependency on a farmer, I do not always dare to be critical about the demeanour of the farmer	**,570**			
satis	I need to keep my clients satisfied, therefore I cannot refuse an explicit demand for antibiotics	**,517**			
	I regularly am confronted with situations in which non-veterinary advisors advice farmers about antibiotic treatments				
decou	The decoupling of prescribing and dispensing antibiotics by veterinarians should be effectuated			**-,570**	
incom	I am able to earn a decent income without incomes from the pharmacy in 5 years from now			**-,487**	
	Without pharmacy incomes, my hourly tariffs must substantially increase to guarantee a same level of income				
exper	Years of experience[a]				
	Total (Eigenvalue)	3,063	2,777	1,788	7,628
	Cronbach's α	,713	,678	,467	,920
	VAF (%)	17,0	15,4	9,9	42,4

a. Supplementary variable.
Variables in italics were not selected for final analysis because the VAF was <0.25
Component loadings <.40 are suppressed

- Dimension 2 is related to being supportive of reduction of veterinary antibiotic consumption to preserve public health and less obvious fear for detrimental effects on animal health.
- Dimension 3 is related to having a lower threshold to apply antibiotics to animals and a strong believe that the veterinary pharmacy should be preserved to remain a good income.

Only for dimension 1 there was a significant difference in mean object scores between veterinarians working with different animal species. Intensive specialist (mean score -0.455) scored significantly lower on dimension 1 (ANOVA; F=8.388; Bonferoni post hoc *p*=0.000) than ruminant specialists (0.017) and generalists (0.133). For dimension 2 and 3, no significant differences were found between veterinarians working with different animal species (F=2.687; *p*=0.69 and F=.398; *p*=0.672 respectively). Years of

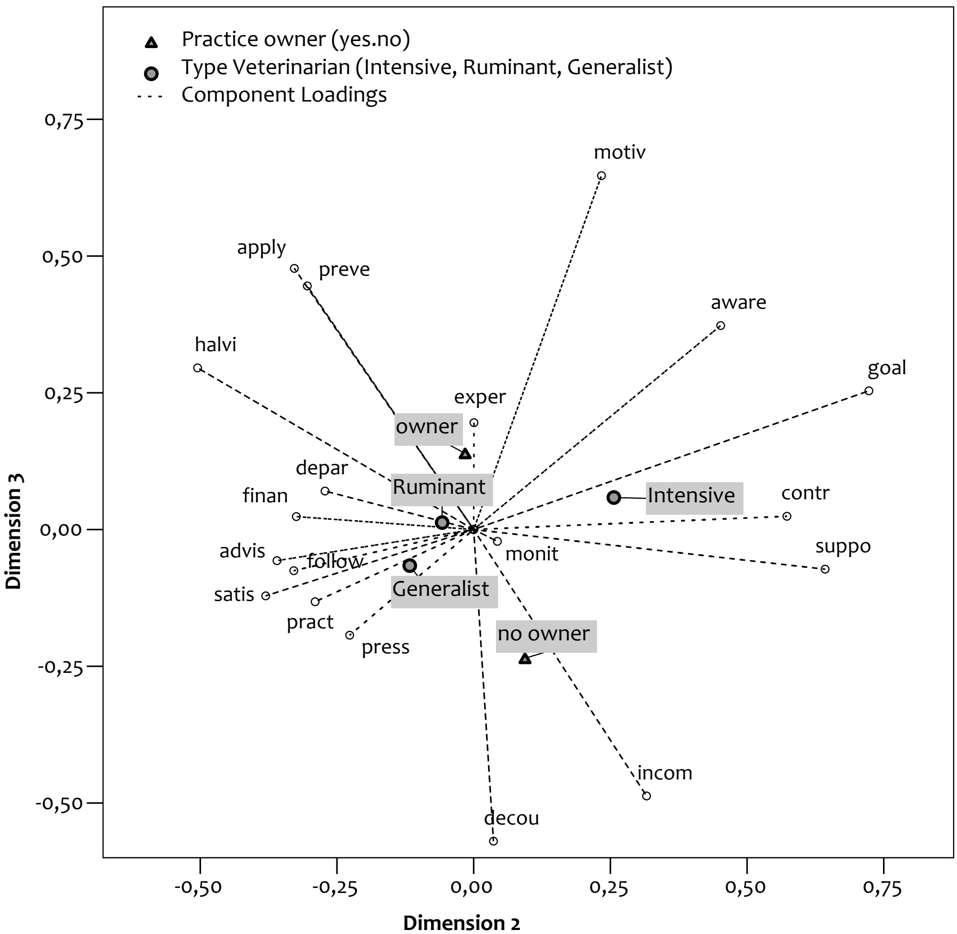


Figure 2. Biplot of component loadings for dimensions 2 and 3 for the active variables and multiple nominal category points

experience was negatively related to dimension 1 (Linear regression analysis β=-0.026; F=25.150, *p*=0.000), not related to dimension 2 (F=0.000; *p*=0.989) and positively related to dimension 3 (β=0.021; F=16.909, *p*=0.000). The CATPCA analysis also indicated that years of experience was negatively associated with the believe that the veterinary contribution to antimicrobial resistance was worrisome (Figure 1).

Perceived achievable reduction of antibiotic consumption

Over the major farm animal species (pigs, poultry, dairy and veal calves), the respondents estimated the highest reasonably achievable reduction (2015 compared to 2009) in pigs, 52.6% (95%CI 48.8-56.3%), followed by 39.3% (95%CI 33.8-44.7%) in veal calves, 35.0% (95%CI 25.8-44.2%) in poultry, and the lowest in cattle with 32.8% (95%CI 30.8-34.7%). Years of experience was not significantly related to the relative reasonably achievable reduction in veterinary antibiotic consumption, although a trend was visible that increasing years of experience was related with a less optimistic view on the relative achievable reduction (Linear regression analysis β=-.445; F=3.085, *p*=0.080).

Pressure to prescribe

The majority of respondents reported to feel pressure from clients to prescribe while they were not supporting this less than once every half a year (Table 5). However, a quarter of the intensive specialists reported to feel this pressure at least once every two months. Ordinal regression analysis with type veterinarian and years of experience revealed that an increase in experience (expressed in years) was associated with a decrease in frequency of felt pressure to prescribe (*p*=0.002) with an odds ratio of 0.97 (95%CI 0.95-0.99). Intensive specialist felt significantly more often forced to prescribe compared with generalist and a tendency was visible that they also more frequently felt this pressure compared with ruminant specialists (*p*=0.056).

Solutions for high veterinary antibiotic use

Respondents were asked in a single choice question which measure would in their opinion contribute the most to reduction of veterinary antibiotic consumption. Intensive specialists expected much from improving feed quality and benchmarking of antibiotic use and prescribing, while ruminant specialists and generalists expected much from improvements in housing and climate and benchmarking (Table 4).

Perceived reasons for farmers not to implement veterinary advices

Several reasons were ranked (5-point Likert scales) by respondents why farmers are thought to not comply with veterinary advices that would improve animal health (Table 6). They were mainly related to the financial and labour investments associated with complying with the veterinary advices and conflicting advices of other advisors. The latter was mentioned especially by intensive specialists to be important. Analysis of entered free texts indicated that several respondents believed that inveterate

Table 4. Ranking of perceived most important measure to reduce veterinary antibiotic consumption per veterinarian category and proportion of respondents within that category choosing this measure as most important measure

Proposed measure	Intensive		Ruminant		Generalist	
	%	Ranking	%	Ranking	%	Ranking
Uncoupling the prescribing and dispensing of antibiotics by veterinarians	0		0,6	**11**	1,9	**9**
Introduction of an antibiotic tax	15,2	**3**	10,1	**4**	12,1	**3**
Benchmarking of antibiotic use, including sanctioning of high users	16,7	**2**	18,4	**2**	25,5	**1**
Improving biosecurity on farms	6,1	**5**	4,5	**9**	7	**5**
Improving the quality of animal feed	37,9	**1**[a]	7,3	**6**[b]	7	**5**[b]
Improvements in housing and climate	4,5	**7**[a]	25,7	**1**[b]	22,9	**2**[b]
Increasing efforts to eradicate infectious diseases	6,1	**5**	10,6	**3**	5,7	**7**
Restricting treatments only for diseased animals	4,5	**7**	5	**8**	10,2	**4**
Increasing the use of supportive treatments (like NSAIDs)	0		2,2	**10**	0	
Increasing education for farmers on prevention of infectious diseases	0[a]		8,9[b]	**5**	4,5[a,b]	**8**
Increasing post graduate education for veterinarians on feed and climate	0		0,6	**11**	0	
Improving communicative skills of veterinarians	1,5	**8**	0,6	**11**	1,3	**11**
Others	7,6	**4**	5,6	**7**	1,9	**9**

Different subscript letters denotes a subset of veterinarian categories whose column proportions do differ significantly from each other at the ,05 level. Pearson Chi Square $\chi2(24) = 85.669$, p=0.000.

habits are not easy to change for farmers; especially when farmers do not see the need to change behaviour. Other respondents also mentioned the difficulties related to predicting the (cost) effectiveness of specific measures in the context of a specific farm. Then it was perceived as difficult to convince a farmer of the necessity of implementing specific measures.

Discussion

This study offers insights in different attitudes of different categories of farm animal veterinarians in the Netherlands towards antibiotic use and antimicrobial resistance in farm animals and their interaction with farmers herein.

Strengths and limitations of the study

The response rate of 34% based on completed questionnaires (40% returned) is relatively low, however reasonable when compared with others (Gunn, Heffernan et al. 2008, Dean, McIntosh et al. 2011, Cattaneo, Wilson et al. 2009). In this study there appeared no bias in respondents for distribution of veterinarians over the different farm animal species according to the species specific registers, indicating that a good sample of the whole population of farm animal veterinarians was taken. The mean experience in practice in this study was 15.8 years. Given the mean age of graduation of Dutch veterinarians at 28 years (Jaarsma, Dolmans et al. 2008), the mean age of the respondents in this study should be around 44 years of age which is comparable to the reported mean age of practicing veterinarians in the Netherlands of 45 years (KNMvD, personal communication).
This study was performed in the Dutch context where in the recent years policies and public opinion regarding veterinary antibiotic use have changed drastically (Speksnijder, Mevius et al. 2015). These developments might have already changed

Table 5. Proportion of answers given to the question “I feel forced to prescribe antibiotics while I do not really support this”

	Never	At least once a year	At least once every 6 months	At least once every 2 months	At least once every month
Intensive[a]	26,6%	21,9%	25,0%	10,9%	15,6%
Ruminants	32,4%	31,2%	26,5%	8,2%	1,8%
Generalists[b]	38,2%	24,3%	22,9%	12,5%	2,1%
Total	33,6%	27,0%	24,9%	10,3%	4,2%

[ab] Significant difference between a and b; Kruskal Wallis H-test $\chi 2(2) = 6.778$, $p=0.034$.

Table 6. Proportion of respondents scoring the following perceived reasons of farmers not to implement veterinary advices as "important" and "very important"

Perceived reasons	Intensive	Ruminant	Generalist	Total
Other advisors give conflicting advices	79,7%[a]	54,4%[b]	66,0%	63,1%
Farmers regard implementation of veterinary advices too expensive	56,3%[c]	65,9%	78,5%[d]	69,0%
Farmers regard implementation of veterinary advices too time consuming	75,0%	74,1%	81,9%	77,2%
Farmers do not believe that implementing veterinary advices will have better outcomes	20,3%	31,6%	33,3%	30,3%
Farmers regard implementation of veterinary advices in practice too difficult	49,2%	51,5%	52,4%	51,5%

[ab] Significant difference between groups; Kruskal Wallis H-test $\chi 2(2) = 15,529$, $p=0.000$.
[cd] Significant difference between groups; Kruskal Wallis H-test $\chi 2(2) = 8,987$, $p=0.011$.

some of the attitudes of farm animal veterinarians. Nevertheless, the gatekeeper role of veterinarians for antibiotic use and the encountered conflicts with demanding farmers is not restricted to the Dutch situation and these findings might therefore be relevant for comparable animal production systems where increasing attention exists to promote prudent use of antibiotics.

Comparison with existing literature

In our study we found that veterinarians with fewer years in practice experienced the most uncertainty to act as an independent advisor and the most frequent explicit pressure from their clients to prescribe antibiotics while they were not supporting this. It has to be said that in general the latter was not often felt in this study as more than half of the respondents reported to only feel this pressure twice a year or less. Coyne, Pinchbeck et al. (2014) in their study on pig veterinarians found that perceived pressure from clients can be a driver to prescribe antibiotics, but also mentioned the mutual relationship between veterinarian and farmer to be influential in prescribing behaviour. Studies on doctor-patient interactions show that seniority can be associated with being more ‘patient-centred’. This is characterized by a more flexible style of interaction in which physicians are better able to identify the extent to which patients want to be involved in decision making, to adapt to the needs of their patients and to refuse patients’ demands (Krupat, Rosenkranz et al. 2000, Walter, Chew-Graham et al. 2012). This might be also true for well-established long lasting veterinarian-farmer relationships in which more experienced veterinarians are better able to elicit farmers’ true demands and have a more flexible style of interaction to act as an independent and sometimes critical advisor and better able to resist pressure from clients. For younger veterinarians who like to build a long lasting mutual relationship with a farmer as a client, it might feel uncomfortable to be too paternalistic towards a farmer or to refuse strong demands. Another explanation for this finding might be that older veterinarians are less reluctant in antibiotic prescribing anyway and pressure from clients is not required or the pressure is perceived less by the older veterinarians (Akkerman, Kuyvenhoven et al. 2005). In our study we found that increasing experience is associated with being less concerned about a possible veterinary contribution to antimicrobial resistance and also being less concerned to prescribe antibiotics to prevent animal diseases. Cattaneo, Wilson et al. (2009) also found a negative relationship between years of practical experience and knowledge about consequences of antimicrobial resistance in bovine veterinarians. This might probably lower the barrier of older veterinarians to irrationally prescribe antibiotics when clients demand for it and probably also clients’ demand is less easily interpreted as pressure.

More experienced veterinarians in our study had a more pronounced opinion on the importance of keeping the right to prescribe and sell antimicrobials. One explanation for this observation might be that this group contains the highest proportion of practice owners who are personally responsible to run a profitable practice and see fewer opportunities for alternative incomes when the veterinary pharmacy would be removed from their practice. This might also explain the observation that younger vets have more optimistic views on the reasonably achievable reduction in antibiotic

consumption. Another explanation for this might be that younger veterinarians are during their training already more exposed to the success of preventive veterinary medicine and therefore have more optimistic views on the reduction possibilities.
Intensive veterinarians felt the least insecurity to act as an independent advisor. This might be related to the longer experience of intensive specialists, but also to the fact that advising instead of clinical work has become more and more a core business in the intensive farm animal sectors compared to other (farm) animal sectors.

Proposed measures to reduce veterinary antibiotic use

Where a large proportion of intensive specialists (the majority being pig veterinarians) believed most in improving quality of animal feed and benchmarking as important measures for reduction of antibiotic use, ruminant specialists and generalists preferred improvements in housing and climate next to benchmarking, indicating that probably different measures are needed in different animal sectors for reduction of antibiotic use. Coyne, Pinchbeck et al. (2014) found that pig veterinarians and pig farmers in the UK mentioned poor housing conditions as a very important hurdle in reducing antibiotic use, however this was not really confirmed by our findings in this study. Probably, Dutch farmers with intensively kept animals have already improved their housing conditions in the last years to such an extent that veterinarians see less need for improvement compared to other measures like improving feed quality. Postma, Stärk et al. (2015) confirmed the finding that improving feed quality in pig production was a highly ranked measure amongst important stakeholders in the pig industry. Improvements in housing and climate were regarded as important measures by ruminant specialists in our study which is in accordance with findings of other authors who stressed the importance of a balanced housing system for dairy cows to prevent diseases (LeBlanc, Lissemore et al. 2006, Vaarst, Bennedsgaard et al. 2006).
Interestingly, benchmarking was ranked highly amongst all respondents in our study as an important measure for reduction of antibiotic use, in contrast to for example the study of Postma, Stärk et al. (2015) were it was ranked quite low; Dutch stakeholders were not involved in that study. This might probably be explained by the fact that mandatory benchmarking of prescription and use of veterinary antibiotics was already introduced at the time of questionnaire distribution and veterinarians probably saw the first positive results from this in the field. Benchmarking in fact appeared to be effective in the Netherlands to reduce antibiotic use in farm animals (Speksnijder, Mevius et al. 2015).

Veterinary advices and farmers' compliance

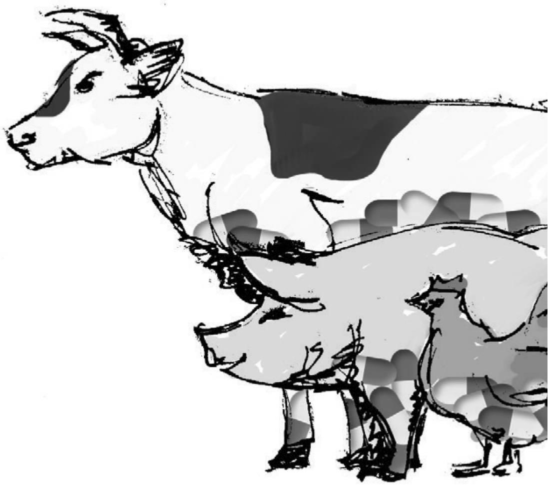
Several authors have stressed the importance of preventive strategies to reduce diseases and antibiotic use in farm animals, the important role of veterinarians as partners for farmers herein and the importance of a comprehensive animal health planning strategy with farmers' compliance on individual farms (Tremetsberger, Winckler 2015, Brennan, Christley 2013, Friedman, Kanwat et al. 2007, Cattaneo, Wilson et al. 2009, LeBlanc, Lissemore et al. 2006). Financial and practical (time) restrictions or the perceived insufficient return on investment as found in our study, are known important reasons for farmers not to implement preventive measures (Derks, van Werven et al. 2013, Friedman, Kanwat et al. 2007, Laanen, Maes et al. 2014, Wierup 2000, Leach KA 2008, Coyne, Pinchbeck et al. 2014), which is supported by our findings. However, several authors indicated that receiving more explanation about the importance of preventive measures by the herd veterinarian and showing the cost effectiveness of investments in animal health might help to increase interest of farmers to implement preventive measures (Brennan, Christley 2012, Lam, Jansen et al. 2011, Kristensen, Jakobsen 2011, Laanen, Maes et al. 2014). The training of veterinarians as confident and independent advisors might help in resisting demands for antibiotics by farmers or in dealing with conflicting advices of non-veterinary advisors. By eliciting the true expectations and worries of farmers by improved communication techniques, it might be possible to find alternative solutions for the problem than just meeting the demand for antibiotics. Similar techniques have successfully been used in human healthcare to help medical doctors deal with demands for antibiotics by patients (Cals, Butler et al. 2009, Little, Stuart et al. 2013). To counter conflicting advices of other advisors, it might be useful to include all involved parties (farmers, veterinarians, nutritionists and others) in the process of setting up and implementing animal health promoting activities (Tremetsberger, Winckler 2015).

Implications for future research and clinical practice

Younger veterinarians who have found to feel more uncertain to act independently might require additional support (training, guidelines) to act independently of farmers' and significant others' (other influential advisors for farmers, colleagues) wishes and demands. Younger professionals might be more receptive to new standards of care and these protocols might give them extra support in dealing with unwilling farmers (Choudhry, Fletcher et al. 2005, Walter, Chew-Graham et al. 2012). Additionally, efforts could be directed to more experienced veterinarians to educate them about possible risks related to overuse of veterinary antibiotics (Simpson, Wood et al. 2007) and feasible ways should be found and communicated to profitably change from reactive and curative veterinary practice which relies much on pharmacy incomes, towards proactive and preventive activities with less dependency on the veterinary pharmacy. The challenge for the future is that veterinarians, as independent and critical advisor, support farmers in developing a comprehensive animal health plan which is supported by all relevant advisors and subsequently support the farmer with the compliance to this plan (Speksnijder, Jaarsma et al. 2015a, Tremetsberger, Winckler 2015).
In conclusion: based on the questionnaire we were able to categorize the Dutch farm animal practitioners regarding antibiotic use and antimicrobial resistance, and their relation towards the farmers. Based on this categorization, interventions can be developed to target the different categories based on their profiles.

Acknowledgements

All respondents are kindly acknowledged for their participation in this study.



Chapter 4

Opinions of veterinarians on antimicrobial use in farm animals in Flanders and the Netherlands.

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Abstract

Veterinarians play an important role in the reduction of antimicrobial use in farm animals. This study aims to quantify opinions of veterinarians from the Netherlands and Flanders regarding antimicrobial use and resistance issues in farm animals.
An online survey was sent out to 678 and 1,100 farm animal veterinarians in Flanders and the Netherlands of which 174 and 437 were returned respectively. Suboptimal climate conditions were regarded as the most important cause for high antimicrobial use in farm animals. Flemish veterinarians also regarded insufficient biosecurity measures and farmers' mentality as important determinants, while the Dutch respondents ranked insufficient immunity of young animals and economic considerations of farmers as major causes. The majority of Dutch respondents (63.8%) supported the existing national policy, which aimed to halve veterinary antimicrobial use, while the Flemish (32.9%) were less supportive of such a policy. Improvements in housing and climate conditions, biosecurity measures and strict control of specific infectious diseases were seen as important and promising measures to reduce antimicrobial use.
To reduce antimicrobial use in farm animals, some shared approaches might be applicable in both countries. However, cultural, political and societal differences between Flanders and the Netherlands require differentiated approaches to reduce veterinary antimicrobial use.

Introduction

There is a strong global movement towards a reduction of antimicrobial use (AMU) in humans and animals to limit the increasing burden of antimicrobial resistance (AMR) (Aarestrup, Wegener et al. 2008, Angulo, Collignon et al. 2009, McEwen 2006, Prescott 2008). The majority of veterinary antimicrobials are used in food producing animals and as veterinarians are usually responsible for prescribing and overseeing these antimicrobials, addressing prescribing behaviour of farm animal veterinarians can be important to limit the evolving threat of AMR (Morley, Apley et al. 2005, Van Boeckel, Brower et al. 2015). However, little is known about determinants that drive antimicrobial prescribing behaviour of farm animal veterinarians and to which extent cultures and existing policies influence these attitudes.

More is known about prescribing decisions of physicians which are generally influenced by a wide range of factors related to personal attitudes, knowledge and patient influences, but also to more implicit influences like cultural dimensions and existing policies. Studies comparing antimicrobial prescribing behaviour and risk taking attitudes of general practitioners (GPs) in Flanders and the Netherlands have shown different levels of outpatient AMU which are partly related to cultural and policy differences (Coenen, Muller et al. 2009, Coenen, Welschen et al. 2004, Deschepper, Grigoryan et al. 2008, Grol, Whitfield et al. 1990).

Agricultural systems are quite comparable in Flanders (Dutch speaking northern part of Belgium comprising 60% of the inhabitants) and the Netherlands (EUROSTAT 2015). In 2009, veterinary AMU in Belgium and the Netherlands was at a similar level (EMA 2012). In 2010, the Dutch government introduced a strict compulsory policy to reduce veterinary AMU in farm animals by 50% in 2013 compared to 2009 and later formulated the ambition for a 70% reduction in 2015. Through several mandatory interventions, the Dutch livestock sectors accomplished a 56% reduction in 2013 with a levelling in 2014 (58%) compared to 2009 (Speksnijder, Mevius et al. 2015, MARAN 2015). In Belgium, the Center of Expertise on Antimicrobial Consumption and Resistance in Animals (AMCRA), was established in 2012, supported by both the government and the involved stakeholders (veterinary and agricultural organizations, feed and pharmaceutical companies, (veterinary) science). AMCRA attempts to reduce the AMU through advise and awareness raising of farmers, veterinarians and the public (AMCRA 2014, AMCRA 2017). A reduction in veterinary AMU of around 13% between 2011 and 2013 and a subsequent slight increase of 1.3% in 2014 was seen (BELVETSAC 2014, BELVETSAC 2015).

The aim of our study was 1) to describe the different opinions and behaviours regarding veterinary AMU in the Dutch and Flemish population of farm animal veterinarians during the first years of diverging veterinary antimicrobial policies between the two countries and 2) to assess the perceived effectiveness of several measures for reduction of AMU in the different countries. The outcomes of this study might improve the understanding of farm animal veterinarians in their antimicrobial prescribing behaviour in different countries and can guide different approaches aiming at improving judicious use of antimicrobials in different regions.

Materials and Methods

Questionnaire

Differences in beliefs of Dutch veterinarians related to veterinary AMU and antimicrobial reduction were previously identified using qualitative methods (Speksnijder, Jaarsma et al. 2015a). These results were used to generate a theoretical framework which in turn was used to develop a questionnaire which is described in detail in Speksnijder, Jaarsma et al. (2015b).
The questionnaire consisted of multiple choice questions and Likert type questions assessing attitudes, knowledge and self-reported behaviour of veterinarians regarding AMU in farm animals, their prescribing practices, their interactions with others and their perceived role in antimicrobial reduction.
Respondents were asked how strongly they agreed or disagreed with statements (5-point scale) and how they assessed the importance of several causes for high AMU and measures aiming at the reduction of veterinary AMU.
In the Netherlands, the questionnaire was distributed to virtually all practicing farm animal veterinarians working at least 1 day a week with farm animals (for further details, see Speksnijder, Jaarsma et al. 2015b). In Flanders, the original Dutch questionnaire had been slightly adjusted to fit the Flemish situation. Questions specifically designed based on the then existing Dutch policy were rephrased to questions asking whether Flemish veterinarians would support similar policy measures in Flanders.
In Flanders, all farm animal veterinarians that were registered in the email database of the institute for post academic veterinary education (IPV Diergeneeskunde) at Ghent University, received an invitation to participate in this online survey (n=678). The first request was sent in June 2012. A first reminder was sent 10 days later. A final reminder was sent four weeks later. The response was collected anonymously, unless contact details for future research were left voluntarily. Amongst responders that completed the questionnaire, ten €20,- vouchers were raffled as a reward. Both surveys were distributed online through Surveymonkey (SurveyMonkey.com, LLC, Palo Alto, California, USA).

Analysis

Analyses of all the data from both countries were performed using SPSS version 21 (IBM Corp. 2011). Descriptive distribution statistics of responses on the Likert scales were provided. Diverging stacked bar charts were created using Tableau 8.2 (Tableau Software, Seattle, WA). The non-parametric Mann-Whitney test was used for statistical analysis of the ordinal Likert type data to assess differences in frequency distribution between respondents from the two countries. P values <0.05 were considered significant. For binary outcomes (type of affiliation, working with several animal species; yes/no), Chi Square testing was used to compare respondents. To compare perceived achievable antimicrobial reduction estimates, the independent T-test was used.

Table 1. Respondents' characteristics, percentages of respondents devoting 0-20%, 21-40%, 41-60%, 61-80% or 81-100% of their working time to the different farm animal species

	Flanders (n=118)	The Netherlands (n=377)
Mean years in practice (95% CI)	16.4 (14.5-18.4)	15.8 (14.8-16.8)
Proportion practice owners	72.6%	62.9%
Devoted time to different animal species	Flanders (n=168)	The Netherlands (n=437)
>20% poultry	6.2%	9.8%
>20 swine *	51.9%	35.9%
>20% cattle *	93.0%	85.2%
>20% veal calves	26.3%	16.3%

* (*p*<0.01, Mann Whitney test)
Differences in numbers (n) due to incomplete questionnaires.

Results

Survey response and respondents' characteristics

After removal of respondents who did not fulfil the selection criterion of working at least one day a week with farm animals, we received 174 (of which 50 were incomplete) questionnaires from Flemish participants. In the Netherlands, we received 437 (60 incomplete) questionnaires, resulting in a response rate of 26% for Flanders and 40% for the Netherlands respectively, based on the number of questionnaires sent in Flanders (678) and the estimated population size of around 1.100 farm animal veterinarians in the Netherlands in 2012. Characteristics of the respondents are shown in Table 1. A (non-significant) tendency was visible that Flemish respondents were more frequently practice owners compared to their Dutch colleagues (p=0.06). Flemish respondents reported to devote more of their working time to pigs (p<0.01) and cattle (p<0.01) compared to the Dutch respondents. For the other farm animal species, there were no significant differences between the respondents from the two countries.

Perceived causes of high antimicrobial use in farm animals

The perceived importance of several possible causes for AMU in farm animals were tested in the questionnaire. Respondents from both countries equally believed that suboptimal climate conditions in the stables were one of the most important causes of high AMU (Figure 1). Flemish veterinarians had a strong opinion that insufficient biosecurity measures and the mentality of farmers to easily use antimicrobials were very important causes of high AMU in animals.
Dutch respondents considered the generally insufficient immunity of young farm animals and economic considerations of farmers as the most important causes of high veterinary AMU which significantly differed from their Flemish colleagues. Views differed markedly on feed quality as a cause for high AMU. Less than a quarter of the

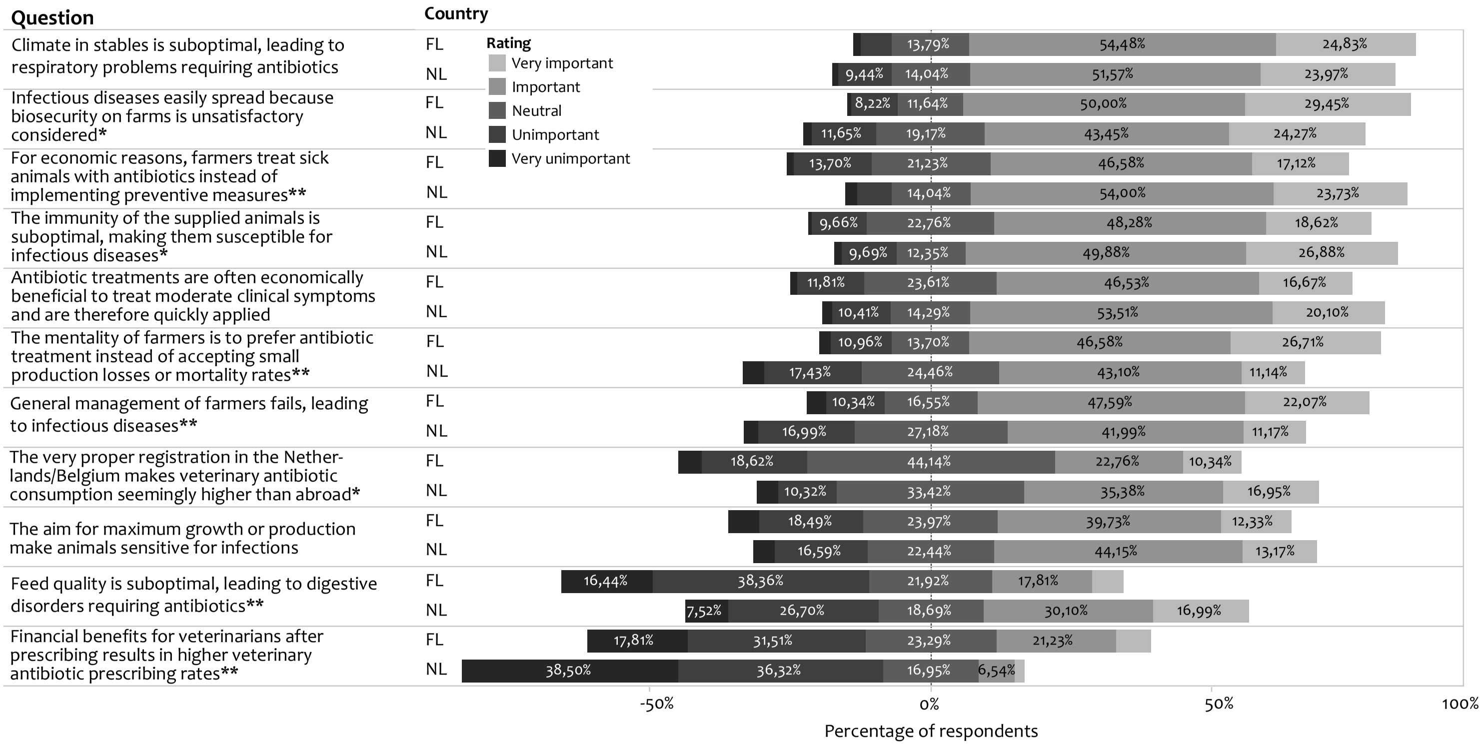

Figure 1. Perceived causes of high antimicrobial use in farm animals. The neutral responses are centred around the zero line and unimportant versus important ratings shown on the left and right, respectively. *$p<0.05$; **$p<0.01$

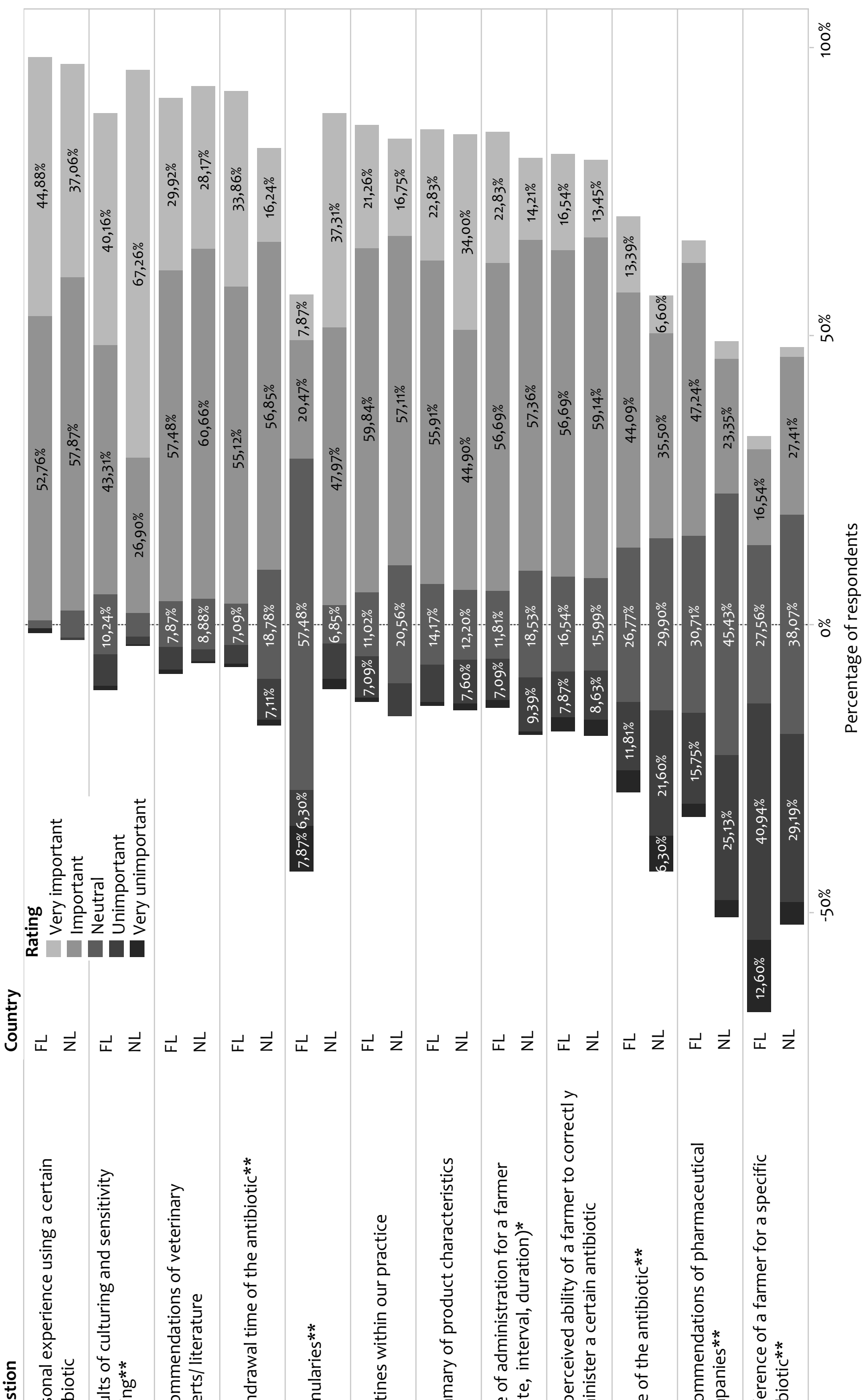

Figure 2. Relative importance of criteria for selection of antimicrobial treatment. The neutral responses are centred around the zero line and unimportant versus important ratings shown on the left and right, respectively. **p*<0.05; ***p*<0.01

Flemish respondents regarded this as somewhat or very important, while almost half of the Dutch respondents regarded it as somewhat or very important.
Possible financial gains for veterinarians after prescribing were not believed to play an important role in high veterinary AMU by the majority of respondents, although in Flanders this view was less pronounced compared to the Netherlands.

Criteria for selection of antimicrobial treatment

Both Flemish and Dutch respondents reported that personal experience, recommendations of veterinary experts/literature and the results of bacteriological culturing and sensitivity testing were the most important inputs to select a specific antimicrobial, although Dutch respondents had a significantly more pronounced view on the latter ($p<0.01$, Figure 2). Flemish respondents reported to rely the least on farmers' preferences in choosing an antimicrobial, while Dutch also cared little about pharmaceutical recommendations ($p<0.01$) and prices of antimicrobials ($p<0.01$). Formularies were reported to be considerably more important in the Netherlands compared to Flanders.

Attitude of veterinarians towards antimicrobial reduction and the role of the veterinary pharmacy

The majority of respondents from both countries believed that the possible veterinary contribution to AMR was worrisome; this belief was more pronounced amongst Dutch veterinarians (Figure 3). A great majority of respondents reported to have become more aware of the need to restrictively use antimicrobials and were aiming to reduce AMU in their practice as far as possible. Dutch respondents were on average in favour of the existing Dutch policy to halve veterinary AMU, while Flemish respondents were less supportive of the introduction of a similar policy in Flanders. The latter were significantly more afraid of negative consequences from halving veterinary AMU in terms of animal health and welfare issues compared to their Dutch counterparts. Flemish respondents reported to be significantly less reticent to prescribe antimicrobials to prevent or immediately treat a suspected bacterial infection compared to Dutch respondents. Respondents from both countries expressed almost comparable views on the current importance of the veterinary pharmacy for the viability of a veterinary practice (Figure 4). Flemish respondents were less optimistic about their ability to earn a decent income when pharmacy incomes would disappear compared to Dutch respondents. Conserving the veterinary pharmacy in the future was a stronger motivator for Flemish respondents to reduce AMU than for Dutch veterinarians ($p<0.01$).

Pressure to prescribe

About one-third of the Flemish and of the Dutch respondents reported to never have felt a pressure from a farmer to prescribe antimicrobials against their own opposing opinion. A comparable proportion (31.9%) of the Flemish respondents felt at least once in every two months forced to prescribe, while Dutch respondents (14.5%) felt this pressure less often ($p<0.01$).

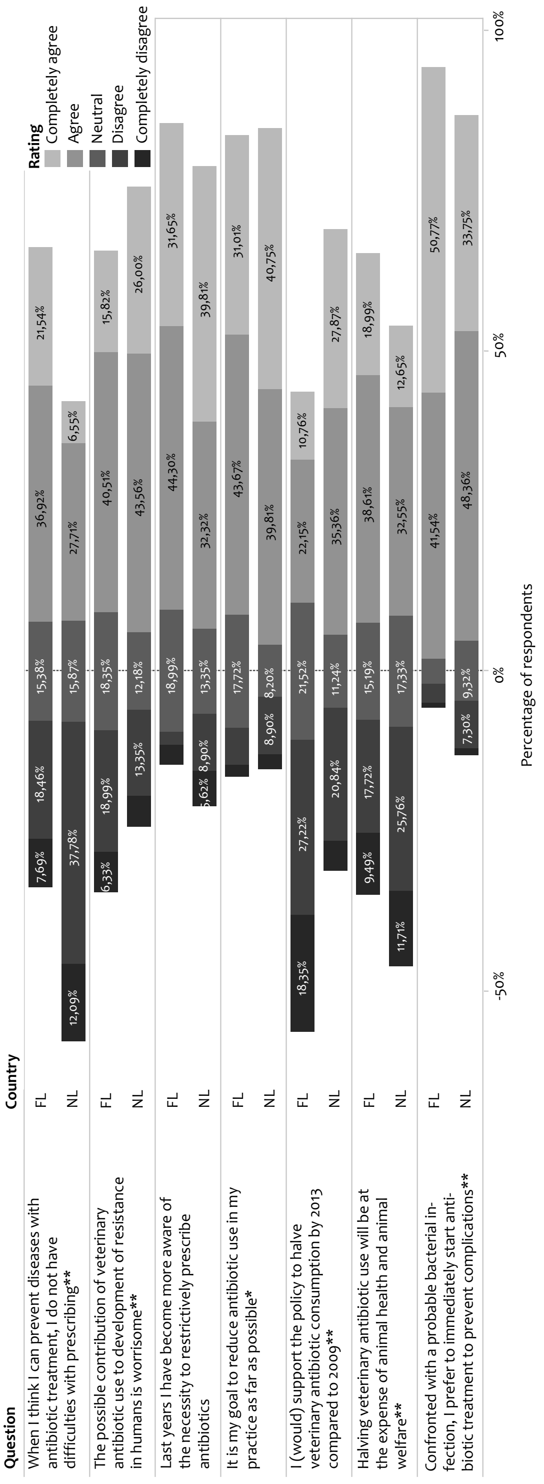

Figure 3. Attitudes of veterinary antimicrobial use. The neutral responses are centred around the zero line and unimportant versus important ratings shown on the left and right, respectively. *$p<0.05$; **$p<0.01$

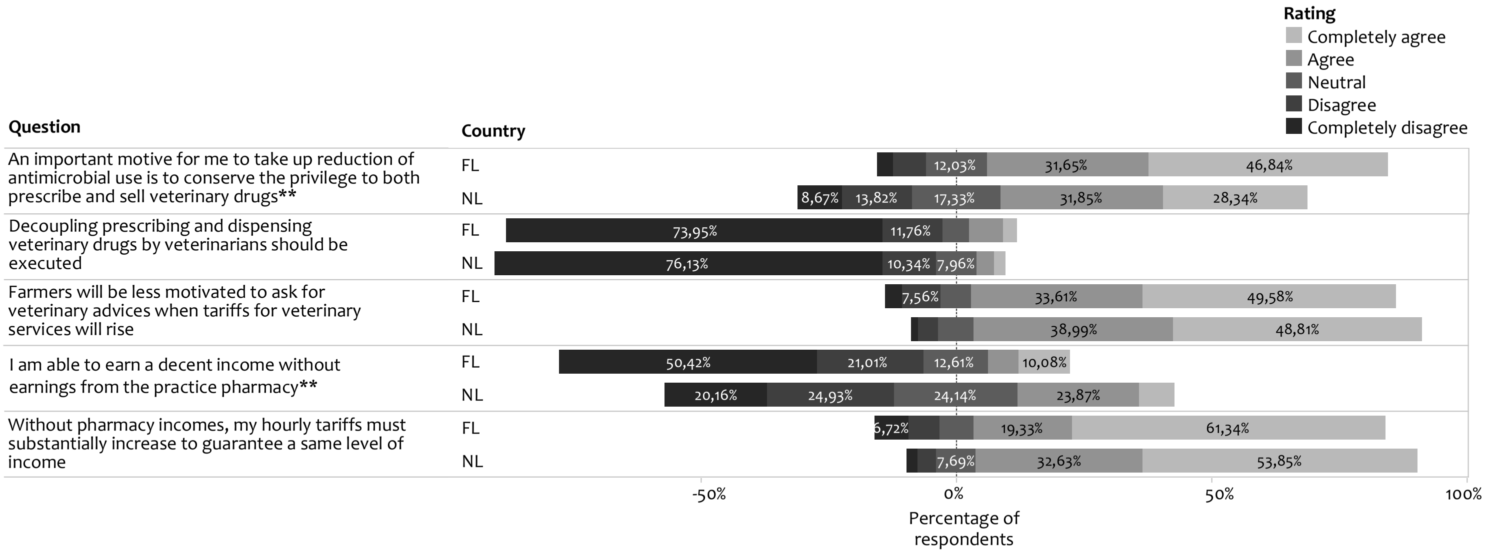

Figure 4. Attitudes of the veterinary pharmacy. The neutral responses are centred around the zero line and unimportant versus important ratings shown on the left and right, respectively. *$p<0.05$; **$p<0.01$

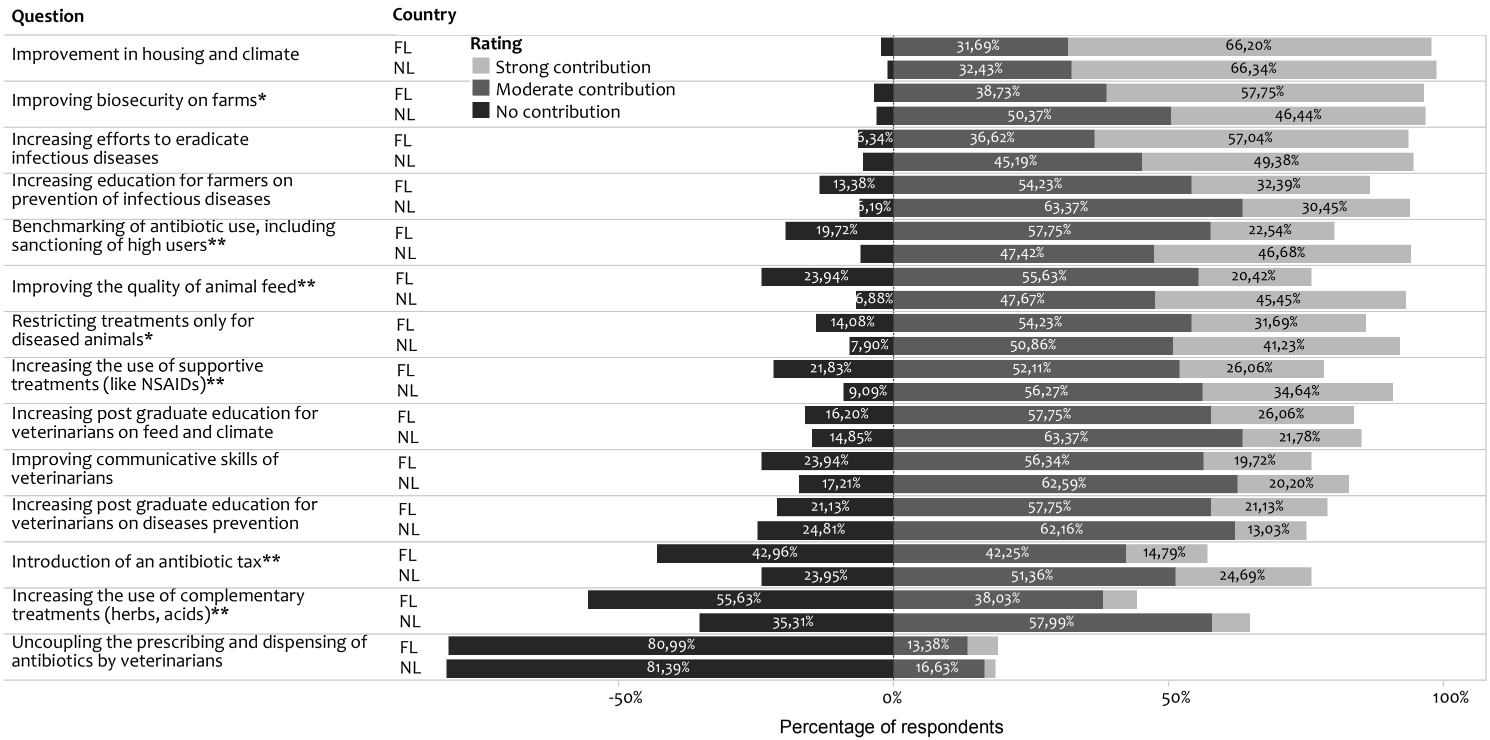

Figure 5. Perceived contribution of several measures to antimicrobial reduction. The 'no contribution' is shown on the left, 'moderate' and 'strong contribution' are shown on the right of the zero line. *$p<0.05$; **$p<0.01$

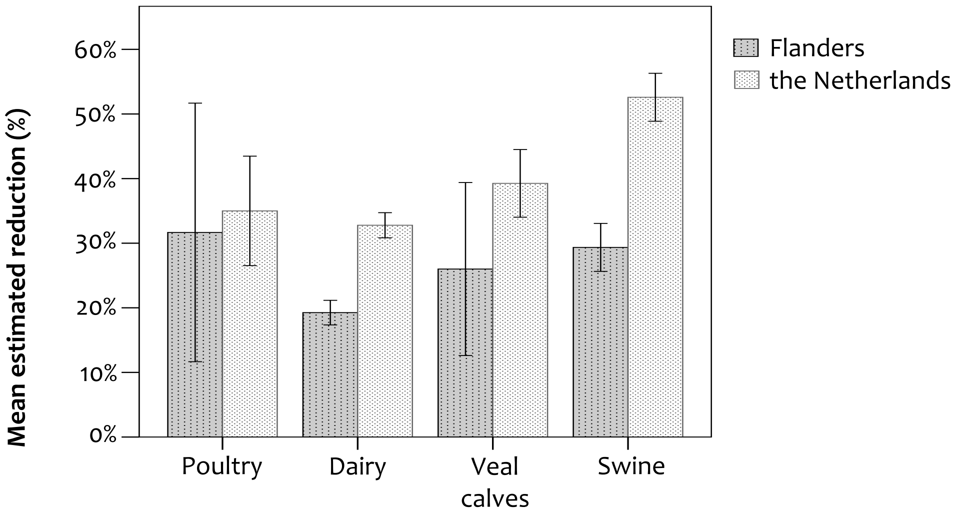

Figure 6. Perceived achievable veterinary reduction of antimicrobial use in 2015 compared with 2009 in percentages.

Expected achievable reduction of antimicrobial use

The by respondents estimated achievable antimicrobial reduction in farm animals in 2015 compared to 2009 is shown in Figure 6. Dutch respondents were more optimistic on the achievable reduction of AMU in all animal species and especially in cattle and swine where the expectation was almost double that of Flemish' respondents.

Perceived contribution of several measures to antimicrobial reduction

Respondents from both countries shared the opinion that strong reducing effects on AMU in farm animals could be expected from improvements in housing and climate conditions for farm animals as well as from the strict control of infectious animals (Figure 5). Respondents from both countries strongly believed in better implementation of biosecurity measures on farms as a means to reduce AMU, although Flemish respondents had the most marked opinion herein. Dutch respondents had a stronger believe in the positive effects of benchmarking of veterinary AMU ($p<0.01$) and improving the quality of animal feed ($p<0.01$). In both countries it was believed that uncoupling prescribing and dispensing of antimicrobials by veterinarians would hardly have any effect on the reduction of AMU.

Discussion

In this study we investigated the existing similarities and differences in opinions of farm animal veterinarians working in two neighbouring countries with comparable types of animal production systems, but with a diverging policy towards the issue of AMU in veterinary medicine at the time of the study. Respondents from both countries endorsed the problem of extensive veterinary AMU as a risk for AMR development in humans and the necessity to reduce veterinary AMU. Most Dutch respondents supported the existing national policy to halve veterinary AMU. However, Flemish veterinarians were less supportive of such a policy as they were more afraid of negative consequences on animal health and welfare. Opinions on the effectiveness of several measures on reduction of AMU were quite comparable between the two countries.

Limitations/reflections

Despite efforts to increase the response rate by offering vouchers and sending reminders, the response rate could not be increased beyond 26% and 40% in both countries which is comparable to other questionnaire studies of veterinarians in which response rates did not exceed 42% (De Briyne, Atkinson et al. 2013, Dean, McIntosh et al. 2011, Gunn, Heffernan et al. 2008). In Belgium, the post academic training is mandatory and assures a fairly complete email contact list of veterinarians (Nederlandstalige Gewestelijke Raad van de Orde der Dierenartsen 2015). Non-responder analysis was difficult as demographic data for farm animal veterinarians in Flanders was scarce. In the Netherlands, no response bias based on years of experience of the respondents or distribution of working time over animal species was found (Speksnijder, Jaarsma et al. 2015a).

At the moment of executing this study, 32% reduction in veterinary AMU was just reported in the Netherlands in the period 2009-2011, without major detrimental effects. This was obviously known to the Dutch respondents (Bondt, Puister et al. 2012). Both Dutch farmers and veterinarians have thus personally experienced the results of this remarkable reduction in AMU, which could explain their rather positive attitudes towards antimicrobial reduction. Flemish respondents have not yet experienced such a strong reduction themselves, which might explain their more sceptical opinion towards halving veterinary AMU. Interestingly, Flemish respondents reported to have acquired a stronger awareness in the last years to prescribe antimicrobials restrictively compared to their Dutch counterparts. This probably indicates that attitudes of Flemish respondents are currently changing under the influence of the increased attention for veterinary AMU while the Dutch respondents have changed their attitudes already at an earlier stage as the public debate in the Netherlands about veterinary AMU started earlier than in Belgium. In 2014, also the Belgian sector has announced through AMCRA their willingness to reduce AMU in farm animals with 50% by 2020 (AMCRA 2014, AMCRA 2017). Benchmarking of veterinary antimicrobial prescribing and use, as is implemented in the Netherlands, will also be part of this plan. It will be highly interesting to evaluate to what extend the setting of this strict quantitative goal influences the opinion of veterinarians in Flanders in the future.

Economic considerations are often mentioned as important barrier for specific disease preventing strategies and farmers appear more worried about financial issues than about AMR (McEwen, Fedorka-Cray 2002, Visschers, Backhans et al. 2015). Flemish veterinarians were sensitized in optimizing the level of biosecurity and taking overall preventive measures in several research projects (e.g. Ghent University 2010)

during the distribution of this questionnaire, which might have caused them to rank this as more important.
Respondents from both countries were relatively unanimous in their belief that decoupling the prescribing and selling of veterinary drugs, a measure that is often promoted by policy makers will not influence the level of AMU. As the majority of the respondents felt unable to earn a decent income without their pharmacy incomes, it is possible that their disbelief in the effect of decoupling was influenced by their fear of losing part of their income. However, an independent advisory body in the Netherlands concluded in 2010 that decoupling as a single measure was not expected to contribute much to the desired reduction (Speksnijder, Mevius et al. 2015). It would be interesting to ask a comparable question to veterinarians in countries (such as Denmark) where the decoupling has been realized in the past to see whether veterinarians there have a different opinion on the importance of the veterinary pharmacy.

Comparison with existing literature

The highly ranked possible causes of extensive AMU in farm animals in this study (suboptimal stable climate, lack of biosecurity, low immunity, economic considerations) are confirmed by many other authors (Brscic, Leruste et al. 2012, Laanen, Persoons et al. 2013, McEwen, Fedorka-Cray 2002). Flemish veterinarians in this study tend to link the reasons for high AMU more with farmers' mentality and lack of implementation of preventive measures, whereas Dutch respondents are more inclined towards specific animal problems such as insufficient immunity of young animals (which are supplied to raising farms) and economic considerations of farmers. In a recent study by Visschers, Backhans et al. (2015), Flemish pig farmers reported to perceive less contribution from their veterinarians regarding information on antimicrobials, their risks and alternatives compared to some other European countries, suggesting a correlation between farmers' and veterinarians' attitude and behaviour in Flanders.
Flemish respondents in this study reported a lower threshold to quickly apply antimicrobials to treat or prevent a suspected bacterial infection compared to Dutch veterinarians. Vandeweerd, Vandeweerd et al. (2012) in a study amongst French speaking Belgian veterinarians also found the tendency of Belgian veterinarians to treat immediately when confronted with a disease, especially when this treatment had solved a similar scenario in the past. Flemish veterinarians in this study also reported to be more afraid of animal health and welfare impairments when a fixed level of antimicrobial usage reduction would be proposed. Finally, they reported the risk-averse mentality of farmers to be an important factor in AMU in farm animals; the use of antimicrobials is preferred by Flemish farmers above the risks of small production losses due to outbreaks of infectious diseases. This finding is confirmed by Visschers, Backhans et al. (2015). All these observations lead to the impression that Flemish veterinarians are more risk averse compared to their Dutch colleagues when it comes to antimicrobial prescribing. Grol, Whitfield et al. (1990), and Deschepper, Grigoryan et al. (2008) concluded that compared to the Netherlands, Belgium is characterized by a higher level of uncertainty avoidance and power distance

(indicating a greater hierarchical distance between doctor and patient), leading to higher antimicrobial prescribing in medical healthcare. Quickly prescribing antimicrobials can be explained as a coping strategy for an uncertain diagnosis and to avoid a "doctor does not know" situation, which might be perceived as undermining the status of the doctor or veterinarian as an expert (Hulscher, van der Meer et al. 2010). The reported higher demand for antimicrobial prescribing by Flemish farmers compared to Dutch farmers might partly be explained by this higher risk averse culture in Flanders (Deschepper, Grigoryan et al. 2008, Hulscher, Grol et al. 2010, Visschers, Backhans et al. 2015). However, the perceived higher demand of farmers for antimicrobial prescribing might also be overestimated by the veterinarians as is often the case in human medicine (Deschepper, Grigoryan et al. 2008, Butler, Pill et al. 1998). In the Netherlands, due to the lower power distance, there probably is a higher tendency for deliberation between veterinarian and the farmer about the necessity for antimicrobial therapy, thereby lowering the chance for overestimating the demand of farmers for antimicrobial prescription. What also should be noted is the fact that attitudes of Dutch farmers regarding AMU recently have changed, probably resulting in a real lower demand for antimicrobials and a lower threshold for alternatives (Speksnijder, Jaarsma et al. 2015a).

Cultures cannot easily be changed. However, intensive international cooperation in the approach of the AMR issue and shared stewardship programs as well as specific educational programs might be helpful in slowly changing the culture of extensive AMU (Hulscher, van der Meer et al. 2010). Acquired knowledge about best practices to reduce antimicrobials should extensively be shared between countries, not only at policy level, but also at grassroots levels. Dutch policy makers, veterinarians and farmers took special interests in Danish accomplishments on reduction of AMU in the last decade. In the same way, Flemish veterinarians can learn from the Dutch experience and adopt the best practices.

The reported most important information sources for the selection of antimicrobial interventions in this study were personal experience, recommendations from experts and results of culturing/sensitivity testing. This highly substantiates the findings of De Briyne, Atkinson et al. (2013) who indicated that personal experience and results of sensitivity testing were major criteria for the selection of antimicrobials by veterinarians. They also found that formularies/prescription guidelines were less important for Belgian veterinarians in their selection of an antimicrobial. During the study period, formularies where not yet available in Flanders. They were only introduced from 2014 onwards by AMCRA. The fact that veterinarians were not yet too enthusiastic about formularies could be because of the fact that their benefits were still unknown to them. Another explanation can be the great emphasis veterinarians place on personal experience. Vandeweerd, Vandeweerd et al. (2012) describe the reported importance of personal experience in clinical decision making of veterinarians in Belgium in relation to evidence-based information sources and the need to incorporate scientific evidence into clinical practice through mandatory continuing education or other tools that can be applied to veterinarians' busy daily practice like guidelines.

Flemish respondents as well as Dutch respondents considered optimization of housing and climate conditions, control of infectious animals and improvement in the level of biosecurity important measures in the reduction of antimicrobials. A recent study among pig experts in six European countries, including Belgium, showed similar findings; improvement of the biosecurity level was scored as a high potential measure in the reduction of antimicrobial use, while improvement in the feed quality was less favoured in Belgium compared to some of the other countries (Postma, Stärk et al. 2015).

Conclusions

The assessed attitudes of veterinarians between the Netherlands and Flanders towards AMU and AMR showed some marked similarities and differences. The found differences in our study can at least partly be assigned to cultural differences (level of risk averseness, characteristics of the veterinarian-client relationship) which in turn can be caused by diverging policies towards veterinary AMU in Belgium and the Netherlands. The Dutch approach, with very strict policy measures, seems to be effective in reducing AMU and probably also in changing attitudes of veterinarians towards AMU; experiencing that good production results can be obtained with less AMU might have changed attitudes of Dutch farmers and veterinarians. These results can be important to convince Flemish counterparts of the feasibility of drastic reduction in veterinary antimicrobial use without clear detrimental effects.

Chapter 5

Impact of structural animal health planning on antimicrobial use and animal health variables in conventional dairy farming in the Netherlands.

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Abstract

Widespread veterinary use of antimicrobials might contribute to the increasing burden of antimicrobial resistance. Despite many successful efforts to reduce veterinary antimicrobial use in the Netherlands, the antimicrobial use on a substantial number of farms has remained relatively high over the past few years. Farm-specific solutions are required to further lower antimicrobial use on these farms. Reducing the burden of animal diseases at farm level by means of a structured approach to animal health planning could be a promising method. This intervention study aimed to evaluate the main effects of an animal health planning program developed by an advisory team consisting of a dairy farmer, his veterinarian and his feed adviser under guidance of a professional facilitator.

During an initial farm visit, the advisory team developed a farm-specific animal health planning program, supported by the facilitator. After one year, the effects of this program on animal health, production parameters and antimicrobial use were evaluated and compared to control farms without a facilitated animal health planning program.

Antimicrobial use on intervention farms was significantly reduced between the start and the end of the study period, however no significant differences in the rate of reduction between intervention and control group could be observed (-19% and -14% respectively). Reduced antimicrobial use did not result in negative effects on animal health and production parameters during the study period in both groups.

On intervention farms, a significant positive relationship was found between the percentage of completed action points at farm level and the percent reduction in antimicrobial use. The level of compliance to action points and the quality of collaboration between farmer and advisers were positively associated with the accomplishment of corresponding objectives. However, the total number of objectives was negatively associated with the level of compliance to action points and tended to be negatively associated with the percent reduction in antimicrobial use at farm level.

Gradually lowering antimicrobial use without adverse effects on animal health and productivity is possible by adjusting management practices in a team effort. A good collaboration between farmer, veterinarian and feed adviser and focusing on a limited number of objectives has positive effects on the outcomes of the animal health planning program and antimicrobial use.

Introduction

Over the last decades, it became apparent that extensive antimicrobial use (AMU) in food producing animals might contribute to the increasing burden of antimicrobial resistance (AMR) (Van Boeckel, Brower et al. 2015, World Health Organization 2012). Recent evidence shows that reducing AMU in livestock is associated with reducing AMR levels in farm animals (Dorado-Garcia et al., 2016). Lowering AMU in farm animals therefore can be an effective strategy to contain the increasing burden of AMR (Agerso, Aarestrup 2013, Dorado-Garcia, Mevius et al. 2016). Several countries have introduced successful policy measures over the last decades to reduce AMU in farm animals (Grave, Jensen et al. 2006, World Health Organization 2012, MARAN 2016). In the Netherlands, measures included setting strict mandatory reduction targets by the national government combined with private initiatives to accomplish this objective (Speksnijder, Mevius et al. 2015). However, there is great variation in AMU between farms in the Netherlands, indicating that there is room for further improvement on farms with higher than average antimicrobial use (Stichting Diergeneesmiddelen Autoriteit 2016).

Many animal health problems are still highly prevalent in modern farming systems. Thus focusing on the prevention of (infectious) diseases could be an effective approach in AMU reduction (Speksnijder, Jaarsma et al. 2015a, World Health Organization 2015, Tremetsberger, Winckler 2015). Extensive information exists to substantially reduce or prevent animal diseases (LeBlanc, Lissemore et al. 2006). The challenge, however, is to correctly identify risk factors for animal health, develop and consistently implement the required management practices, and thoroughly evaluate these in a structured animal health planning process (Speksnijder, Jaarsma et al. 2015a, Vaarst, Bennedsgaard et al. 2006, Postma, Stärk et al. 2015, Tremetsberger, Winckler 2015, Green, Leach et al. 2007, Ivemeyer, Smolders et al. 2012, LeBlanc, Lissemore et al. 2006). Crucial herein is that animal health planning is farm specific, warrants high involvement of the farmer during the development and implementation phase and includes clear action points which are unambiguous for those involved (Ivemeyer, Smolders et al. 2012, Kristensen, Jakobsen 2011).

Veterinarians are increasingly seen as animal health advisers and potentially play an important role in the animal health planning process and reduction of AMU. The success of veterinarians in this role relies on their abilities to elicit farmers' opinions and values and to clearly communicate information to farmers in a context of goal setting and regular evaluation, and in encouraging farmers in the implementation of agreed action points in a continuous cycle of improvement. This is challenging and often fails in practice (Main, Leach et al. 2012, Speksnijder, Jaarsma et al. 2015a, Derks, van de Ven et al. 2012, Whay, Barker et al. 2012, Tremetsberger, Winckler 2015, Jansen, Steuten et al. 2010, Clark, Timms et al. 2001, Kristensen, Jakobsen 2011).

Several recent studies have tried, with varying degrees of success, to improve animal health parameters through development and implementation of farm-specific animal health plans, especially in dairy farming. Most of these studies focused on only one health problem (i.e. udder health, claw health) and mostly did not include control farms. To a great extent, these studies involved external technical specialists (academic staff, disease specialists) to perform risk assessments and to formulate the animal health plans (Green, Leach et al. 2007, Tremetsberger, Leeb et al. 2015, Ivemeyer, Smolders et al. 2012, Whay, Barker et al. 2012, Tremetsberger, Winckler 2015, Bell, Bell et al. 2009). Although the outcomes of these studies are useful for assessing the effectiveness of specific interventions on certain animal health indicators, ultimately it should be the farm veterinarian in collaboration with the farmer and other farm advisers to take up a role in a structured approach to animal health planning. Therefore, we conducted a pragmatic randomized control trial over a one-year period to test the main effects of an animal health planning program by an advisory team consisting of a dairy farmer, his veterinarian and his feed adviser under guidance of a professional facilitator. Our aim was to evaluate this facilitated approach of animal health planning and its effects on animal health, production parameters and AMU compared to control farms.

Materials and Methods

More details of the study protocol are described in the Appendix.

Farm selection

The study named "Samen Beter Boeren" (Better Farming Together) was conducted between March 2014 and June 2015 in the Netherlands. Dairy farmers, including their veterinarian and feed adviser, were voluntarily recruited through advertisements on popular farmers' websites and through extension officers of the biggest dairy company in the Netherlands. Farmers were eligible for participation if they had an average yearly AMU within the signalling zone at that time (between 3-6 DDDA (Defined Daily Dose Animal, Stichting Diergeneesmiddelen Autoriteit 2016). Being in the signalling zone was a warning for farmers with a higher than average AMU, but did not require immediate additional measures. This AMU criteria was chosen because on these farms there was room for improvement in AMU and 2) it appeared that relatively few farms had moved to a lower benchmarking zone over the past few years. After randomization, 20 farms were assigned to the *intervention* group and 19 farmers to the *control* group. An introductory meeting was held prior to the start of the study to explain the background of the study to all participants (both intervention- and control group). The farms in the intervention group were enrolled in the intervention activities, while on the control farms only data were gathered during the study period. After ending the study, farms in the control group were enrolled to the intervention. During the study period, all participants received 2 newsletters describing general affairs related to the project (without details on the content of the intervention) and a summary of the introductory meeting. To minimize placebo effects, there were no other contacts with control farms during the study period. By the end of the study period, 4 dairy farmers from the control group decided not to continue with the study due to personal problems or loss of interest, resulting in a final control group of 15. There was no requirement for review of an ethical board for this study.

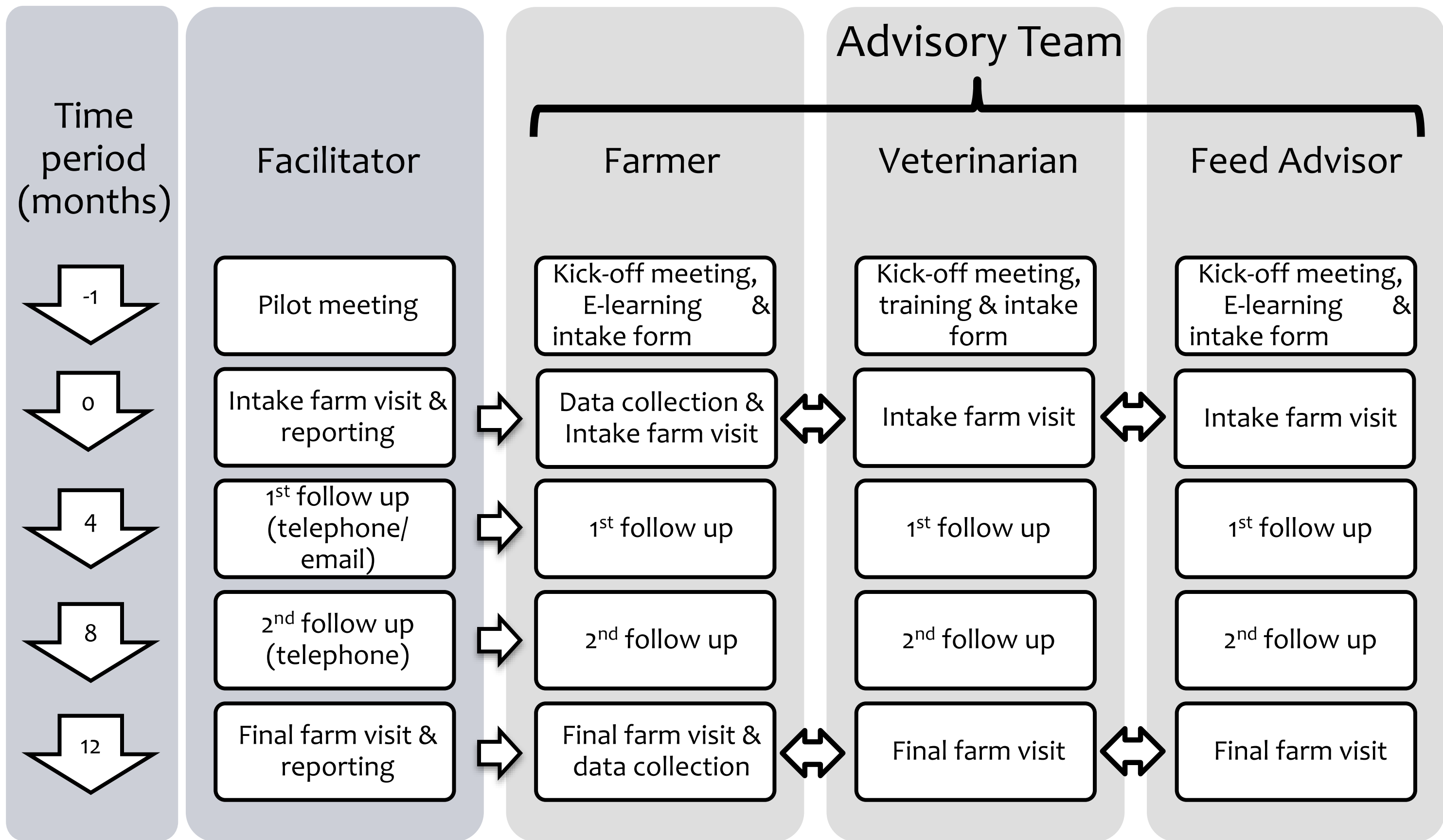

Figure 1. Study protocol describing the order of events in the study. During the initial and final farm visit, the farmer, veterinarian and feed advisor physically sat together with a facilitator to develop and evaluate their animal health plan.

Animal Health Planning Process

Preparation
Prior to the start of the study, participating veterinarians followed a course on communication and advisory skills (Figure 1). Farmers and feed advisers were invited to follow an e-learning course on structural animal health planning. Each member of the advisory team (farmer, veterinarian and feed adviser) submitted an intake form describing the participant's view on the current performance and points for improvements related to animal health.

Intake Farm Visits
Participating farms were randomly assigned to one of the 2 professional facilitators (IE and RS) who facilitated the animal health planning process during the study period. The explicit task of the facilitator was to create a culture of teamwork with fruitful discussion and to ensure that objectives and action points were supported by all participants. The facilitator's role was not to share technical knowledge and advice. The intake forms were used by the facilitators to prepare the initial farm visit. After a short farm walk, the advisory team started the development of their own animal health plan. SMART (specific, measurable, acceptable, realistic, and timely) objectives were set, priorities were chosen and action points planned.
The action points were summarized on a laminated A2 format activity plan which was returned to the farmer as a reminder. The facilitators also provided feedback for individual participants to improve their collaboration in animal health planning in the future.
After approximately 4 and 8 months, facilitators approached the participants by telephone and email to remind them on the activity plan, to monitor progress in the implementation of the action points according to the time table in the action plan and to support advisory teams who encountered difficulties in the implementation. After 1 year, a final farm visit with the facilitator was planned in which the collaboration as a team, the implementation of the activity plan and the objectives were evaluated. After this evaluation process, the advisory team was challenged to develop a new animal health plan for the upcoming year.

Data Collection

The facilitator assessed the quality of the animal health planning process per farm by assigning a score between 1 (poor) and 5 (good) on 10 variables grouped into 2 scales; 1) aspects concerning preparation for the consultation (5 variables) and 2) quality of the collaboration of the advisory team in the animal health planning process (5 variables). The collaboration of the advisory team was again assessed by the facilitator after the final farm visit. AMU data at farm level were derived from quarterly farm level AMU reports of the integral quality organization of the sector (MediRund). Farmers in the intervention and control group provided animal health and production data over the years preceding and during the study period. Most of these data were already available as part of the mandatory annual Farm Health Plan (Speksnijder, Mevius et al. 2015). Additional production and health parameters were derived from the herd improvement companies and dairy collaboration as far as these were available (official milk recordings, fertility reports, culling data) (Table 1). The objectives written in the activity plans were collected and grouped in the following categories: udder health, metabolic health/transition management, fertility, young stock rearing, housing/animal nursing, nutrition and production, collaboration within the advisory team, antimicrobial reduction and miscellaneous.

Statistical Analysis

Individual farms were the unit for the analysis. Data were analysed in SPSS vs22 (IBM SPSS Inc.,Chicago, IL). Data on AMU and animal health parameters were checked for normal distribution by creating Q-Q plots and performing the Kolmogorov-Smirnov test. Log10 transformation or square root transformation was performed on non-normally distributed data. The level of statistical significance was set at $\alpha=0.05$.

The level of compliance to the action points and accomplishment of the objectives were rated on a 0-2 scale (not at all performed/accomplished = score 0; partly performed/accomplished = score 1; fully performed/accomplished = score 2) to get an idea of the implementation and outcomes respectively of the animal health plans. The mean compliance score of the action points per single objective was calculated and ranged between 0 (none of the action points performed) and 2 (all the action points fully performed). An overall "objective score" was given to each farm by calculating the mean from all single objective scores per farm as an indication of the level of accomplishment of the proposed objectives.

Linear Mixed Models for repeated measures with first-order autoregressive covariance matrix were used with changes in repeated dependent variables as AMU and animal health parameters as outcome variables and assessment time (pre- and post-intervention) and group affiliation (intervention versus control) and their interaction as factors (Tremetsberger, Winckler 2015, Ivemeyer, Smolders et al. 2012). Regression analyses were used to find relationships between several variables on intervention farms.

Results

Farm Characteristics

All participating farmers had dairy farming as their primary occupation and kept their cows in free stall barns. Farmers were evenly distributed over the whole country. Participating intervention and control farms had an average milk quota of 912,111kg (± 587,582) and 793,731kg (± 277,436) respectively at the start of the project. Total arable land was 60.1ha (± 31.2) and 51.2ha (± 15.4) per farm respectively. Fifty percent of the intervention farms and 60% of the control farms grazed their cows on pastures during the summer period. Other characteristics are given in Table 2. Although intervention farms were on average larger in terms of numbers of animals, total annual milk production and arable land, farm sizes were not significantly different between the two groups.

Table 1. Description of antibiotic use and animal health parameters on the study farms

Parameter	Description	Data source*
DDDA	Yearly moving average total antimicrobial use (DDDA)**	MR
DDDA1	Yearly moving average use of 1st choice antibiotics (DDDA)***	MR
DDDA2	Yearly moving average use of 2nd choice antibiotics (DDDA)***	MR
DDDA3	Yearly moving average use of 3rd choice antibiotics (DDDA)***	MR
DDDAimm	Yearly moving average use of intramammary antibiotics (DDDA)	MR
DDDAdc	Yearly moving average use of dry cow therapy antibiotics (DDDA)	MR
DDDAinj	Yearly moving average use of injectable antibiotics (DDDA)	MR
DDDAiu	Yearly moving average use of intra uterine antibiotics (DDDA)	MR
BMSCC	Bulk Milk Somatic Cell Count (x1000)	MRD / SR
Mastitis	Yearly incidence of mastitis treated with antibiotics (per average adult dairy cow)	SR
HSCC	Average percentage of cows with a high somatic cell count on the MRD (>150.000cells/ml for heifers and >250.000cells/ml for adult cows)	MRD / SR
New HSCC	Average percentage of cows with a new high somatic cell count on the MRD (>150.000cells/ml for heifers and >250.000cells/ml for adult cows)	
MF	Yearly incidence of milk fever (per average adult dairy cow)	SR
Ketosis	Yearly incidence of ketosis (per average adult dairy cow)	SR
RFM	Yearly incidence of retained foetal membranes (per average adult dairy cow)	SR
Metritis	Yearly incidence of acute metritis (<14 days post-partum) (per average adult dairy cow)	SR
Endometritis	Yearly incidence of endometritis (>14 days post-partum) (per average adult dairy cow)	SR
Lame	Yearly incidence of treatments with antibiotics for lameness (per average adult dairy cow)	SR
Dead birth	Yearly incidence of calves being born dead or which have died <24 hrs post-partum (per average calve born/year)	SR / IR
Mortality	Yearly mortality rate of young animals >24hrs post-partum (per average calf born/year)	SR / IR
Respiratory	Yearly incidence of respiratory disorders in calves (per average calf born/year)	SR

Enteritis	Yearly incidence of enteritis in calves (per average calf born/year)	SR
Umbilical cord	Yearly incidence of umbilical cord infections in calves (per average calf born/year)	SR
Arthritis	Yearly incidence of arthritis in calves (per average calf born/year)	SR

* MR = MediRund, official antimicrobial use database for dairy farms; MRD = official Milk Recording Data; SR = Self-Recorded by farmer; IR = official Identification and Registration system (I&R) for food producing animals in the Netherlands
** Defined Daily Dose Animal
*** 1st, 2nd and 3rd choice antibiotics as defined by the Dutch Veterinary Antimicrobial Policy Working Group

AMU Characteristics

The average AMU at the start of the study (at the 2nd quarter (Q2) of 2014) was numerically but not significantly higher in the intervention group (DDDA = 3.74 ± 1.19) compared to the control group (DDDA = 3.41 ± 0.63; p=0.334; independent sample t-test; Table 3). AMU in the intervention and control group dropped significantly during the study period (p_{period}=0.001). In the intervention group we found a significant lower AMU at the end of the study period compared to the start of the study (-19%; p=0.026) while in the control group the AMU was not significantly different from the initial situation (-14%; p=0.091) (Table 3). The rate of reduction in AMU between the intervention and the control group however was not significant ($p_{group*period}$= 0.498). The average AMU in all dairy farms in the Netherlands in the same period dropped from 2.58 to 2.20 DDDA (-15%). Retrospective data from 7025 dairy farms with an AMU in the same percentile (between 3-6 DDDA) as the study farms in the first quarter (Q1) of 2014 showed a reduction in AMU of 23% (from 3.64 to 2.89 DDDA) between Q1 2014 and Q4 2014 (MediRund data) while the intervention and control farms had a reduction of 24% and 19% respectively in the same period (which partly overlapped the study period). Correcting for herd size or production level did not change the outcomes. The significant drop in total DDDA between the year before and after the start of the study in the whole study group (intervention and control group) was mainly attributed by a significant drop in the use of 2nd class antimicrobials (p_{period}=0.003), dry cow treatments (p_{period}=0.009) and antimicrobials applied per injection (p_{period}=0.014) during the pre- and post- intervention period.

Health Parameters

Animal health parameters were not significantly different between the intervention and control group at the start of the study (independent samples t-test). Most animal health parameters improved slightly over time on intervention farms, which was more pronounced than on control farms. However, no significant differences between the interventions and controls were observed for changes in the major health parameters over the study period, except for endometritis ($p_{group*period}$=0.006) (Table 4).

Table 2. Herd characteristics in the year before (pre) and after (post) the start of the intervention in spring 2014 on the study farms and national averages (calculated over 2013 and 2014 respectively)

	Number of adult dairy cows (> 2 years) per farm (mean ± SD)		Milk production annual rolling herd average per farm (kg milk/cow) (mean ± SD)		Average age lactating cows per farm (months) (mean ± SD)		Number of young stock (<2 years) per farm (mean ± SD)	
Period	*pre*	*post*	*pre*	*post*	*pre*	*post*	*pre*	*post*
Intervention (n=20)	111.2 ± 63.8	113.4 ± 61.2	9003 ± 778	8980 ± 791	54.1 ± 4.3	53.7 ± 4.1	86.0 ± 48.5	87.7 ± 49.1
Control (n=15)	96.6 ± 39.2	97.4 ± 36.1	8802 ± 1253	8984 ± 1203	54.4 ± 5.5	54.1 ± 5.4	65.8 ± 39.8	69.7 ± 31.9
National average	87.7	89.9	8376	8373	56	56	68.1	71.6

Compliance and its Effects on Intervention Farms

A total of 92 objectives were formulated on the 20 intervention farms (mean of 4.6; median of 4 objectives per farm) with 262 associated action points (mean of 13.1 action points per farm; median of 12.5). On the intervention farms (Table 5), 186 (71%), 29 (11%) and 47 (18%) action points were fully, partly and not implemented respectively and 34 (37%), 38 (41%) and 20 (22%) objectives were fully, partly and not accomplished respectively.

The number of formulated objectives per farm was negatively associated with the mean compliance score for the action points and percentage complete compliance of action points per farm in the intervention group (p= 0.029; R^2 = 0.238; ß = -0.112 and p=0.005; R^2 = 0.329; ß = -0.092 respectively, Linear Regression Analysis) and tended to be negatively related to the rate of reduction in average yearly DDDA (p=0.083; R2 = 0.158; ß = -0.068). The percentage of complete compliance to the action points per farm was positively correlated with the rate of reduction in DDDA (p=0.036; R^2 = 0.222, ß= 0.529). However, we found no association between the overall objective score and changes in DDDA (p=0.441) at farm level. An increase in the mean compliance score to action points was associated with an increase in the accompanying objective score (odds ratio of 2.066 (95% CI, 1.076-3.967), Wald χ^2 (1) = 4.752, p=0.029, Ordinal Regression Analysis) and tended to be positively associated with the reduction rate in average yearly DDDA (p= 0.114; R^2 = 0.133; ß = 0.271, Linear Regression Analysis.)

The facilitator's rated quality of collaboration in the first consultancy meeting was positively associated with the

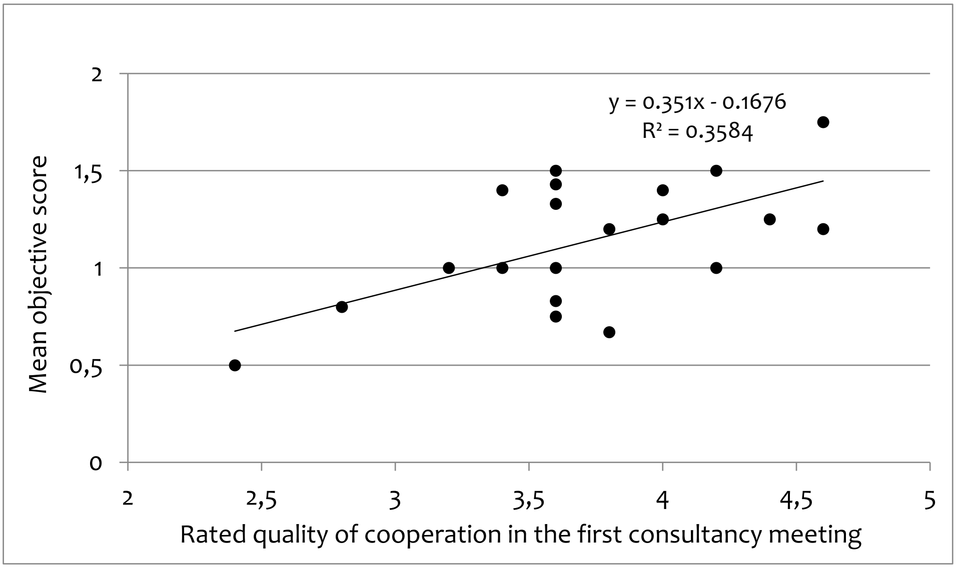

Figure 2. Relationship between rated quality of collaboration within the advisory team at the first consultancy meeting (five-point scale) and mean objective score (0-2 scale)

rated quality of collaboration during the evaluation consultancy meeting (p=0.012; R^2 = 0.300; ß = 0.734) and the mean objective score (p= 0.005; R^2 = 0.358; ß = 0.351) (Figure 2). A positive tendency was apparent between the quality of collaboration in the first consultancy meeting and mean compliance score per farmer (p=0.091; R^2 = 0.151; ß = 0.206).

Discussion

During the study period, total AMU over all study farms decreased significantly. Intervention farms had a significant reduction in total AMU between the start and end of the study, which was less pronounced and not significant on control farms. However, the rate of reduction was not significantly different between both groups. The results from our study indicate that through structured animal health planning, AMU can be reduced while sustaining high animal health. This approach can be useful when a reduction in AMU is dictated by external forces. In the intervention group, positive relationships were found between the quality of collaboration between farmer, veterinarian and feed adviser in the animal health planning process and the compliance to action plans and achievement of objectives, suggesting the added value of constructive collaboration between farmers and their advisers in animal health planning.

The facilitated animal health planning process in our study contained all the key features of a structured animal health planning strategy, including farm-specific targeted advice and the steps of a continuous improvement process, such as situation analysis, action planning, implementation, regular review and adaptation.

(Tremetsberger, Winckler 2015, Clark, Timms et al. 2001). Some possible limitations however were identified.

Animal health parameters were for a large part supplied by dairy farmers and they might be based on farmers' memory and not always on proper record keeping, leading to errors. Where possible, these self-reported data were checked using other reliable data sources. We have however no reason to assume that these errors will be different between both groups and over time and therefore will not influence the found differences between intervention and control farms (Ivemeyer, Smolders et al. 2012).

The MediRund quarterly AMU reports are based on the amount of prescribed antimicrobials at farm level and might deviate from the actual use in the study period due to stockpiling on a farm. However, taking the yearly average AMU will have negated the impact of stockpiling.

Table 3. Antimicrobial use parameters (expressed in Defined Daily Dosages Animal (DDDA)) for intervention and control farms in the year before the start of the study (pre) and the year after the start of the study (post) and the effects of time (period), being intervention or control (group) and the interaction of period x group on antimicrobial use.

					Model effects (*P* values)		
	Period	Intervention	Control	National mean	Group	Period	Group x Period
Total antibiotic use at farm level	Pre	**3.744 ± 1.186***	3.413 ± .630	2.58	0.399	**0.001***	0.498
	Post	**3.032 ± .704***	2.924 ± .877	2.20			
Use of 1st choice antibiotics	Pre	2.696 ± 1.048	2.067 ± .887	1.74	0.073	0.146	0.291
	Post	2.283 ± .579	2.000 ± .875	1.59			
Use of 2nd choice antibiotics	Pre	1.041 ± .501	1.346 ± .807	0.83	0.249	**0.003***	0.581
	Post	0.745 ± .286	0.917 ± .651	0.60			
Use of 3rd choice antibiotics	Pre	**0.008 ± .0167***	**0.000 ± .000***	0.00	0.401	0.872	0.064
	Post	0.004 ± .011	0.005 ± .016	0.00			
Intramam-mary treatment	Pre	0.758 ± .411	0.739 ± .352	0.55	0.929	0.119	0.852
	Post	0.649 ± .288	0.627 ± .280	0.52			
Dry cow therapy	Pre	1.531 ± .630	1.484 ± .501	1.20	0.758	**0.009***	0.816
	Post	1.245 ± .442	1.213 ± .592	0.91			
Injection	Pre	1.281 ± .667	1.082 ± .553	0.68	0.545	**0.014***	0.339
	Post	1.015 ± .554	0.963 ± .512	0.66			
Intra-uterine treatment	Pre	0.175 ± .194	0.101 ± .128	0.10	0.422	0.333	0.151
	Post	0.107 ± .128	0.100 ± 1.09	0.08			

* Significant differences between pre- and post-intervention period and significant model effects ($p<0.05$)

Table 4. Mean animal health parameters for intervention and control farms in the year before the start of the study (pre) and the year after the start of the study (post) and the effects of time (period), being intervention or control (group) and the interaction of period x group on animal health parameters

				Model effects (*P* values)		
Parameter	Period	Intervention	Control	Group	Period	Group x Period
Mean bulk milk somatic cell count (x1000)	Pre	174.6 ± 78.0	168.5 ± 29.2	0.988	0.919	0.190
	Post	178.4 ± 72.3	160.1 ± 34.7			
Mastitis incidence (%)	Pre	26.1 ± 15.2	26.3 ± 11.3	0.580	0.933	0.410
	Post	25.0 ± 17.3	27.9 ± 13.3			
Percentage of cows with high somatic cell counts	Pre	16.9 ± 8.2	14.9 ± 3.6	0.605	0.700	0.886
	Post	16.9 ± 7.9	15.3 ± 4.5			
Percentage of cows with new high somatic cell counts	Pre	8.1 ± 3.1	8.0 ± 2.3	0.959	0.688	0816
	Post	7.8 ± 3.0	7.9 ± 1.4			
Incidence of milk fever (%)	Pre	6.7 ± 5.0	10.4 ± 9.5	0.339	0.206	0.206
	Post	6.2 ± 4.8	8.1 ± 7.8			
Incidence of ketosis (%)	Pre	8.2 ± 8.4	7.4 ± 5.9	0.655	0.056	0.741
	Post	4.5 ± 4.8	5.6 ± 5.3			
Incidence of retained foetal membranes (%)	Pre	8.9 ± 6.5	8.7 ± 6.2	0.994	**0.000***	0.798
	Post	6.2 ± 4.9	6.5 ± 4.8			
Incidence of metritis (%)	Pre	5.3 ± 4.0	4.6 ± 3.3	0.908	**0.037***	0.937
	Post	3.1 ± 2.1	3.6 ± 4.1			
Incidence of endometritis (%)	Pre	8.4 ± 6.3	5.6 ± 4.1	0.929	0.578	**0.006***
	Post	6.1 ± 7.1	7.5 ± 5.5			
Incidence of lameness (%)	Pre	5.7 ± 4.9	4.6 ± 3.5	0.535	0.791	0.689
	Post	5.5 ± 3.6	5.1 ± 3.9			
Incidence of dead birth (%)	Pre	8.4 ± 4.6	9.2 ± 5.1	0.762	0.556	0.109
	Post	8.8 ± 3.1	7.4 ± 3.5			
Mortality rate (%)	Pre	4.1 ± 4.0	3.4 ± 3.0	0.942	0.947	0.401
	Post	3.0 ± 3.0	3.2 ± 2.35			
Incidence of respiratory infections (%)	Pre	5.6 ± 5.3	7.3 ± 7.1	0.061	0.771	0.147
	Post	**3.7 ± 3.3***	**10.6 ± 10.7***			
Incidence of calf diarrhoea (%)	Pre	14.1 ± 13.3	8.9 ± 8.7	0.459	0.869	0.086
	Post	10.5 ± 9.7	13.1 ± 7.9			
Incidence of umbilical cord infections (%)	Pre	2.4 ±1.9	2.5 ±2.1	0.931	0.430	0.716
	Post	2.7 ±2.4	1.6 ±2.4			
Incidence of arthritis (%)	Pre	0.8 ±1.3	1.3 ±2.3	0.591	0.626	0.945
	Post	0.7 ±1.2	0.9 ±1.5			

* Significant differences between pre- and post-intervention period and significant model effects (*P* <0.05)

The absence of significant differences in AMU reduction rates and animal health parameters between intervention and control farms during the study period might partly be explained by a lack of power. Despite many efforts to incorporate 50 farmers, only 39 farmers subscribed to participate and during the study period 4 control farms decided to withdraw. A period of one year might be too short to find significant differences in animal health parameters and antimicrobial reduction rates (Ivemeyer, Smolders et al. 2012, Tremetsberger, Winckler 2015, Bell, Bell et al. 2009). Implementing management changes costs time and it takes even more time until results become visible. We found a tendency for intervention farms to reduce faster than control farms over the period of 1 year. In a recent study of Tisdall, Reyher et al. (2015), it took some years before a real decline in AMU became visible.
In anticipation to the abolishment of the milk quota system in spring 2015, many dairy farmers increased their herd sizes. This may have resulted in farmers conservatively treating animals with antimicrobials to avoid any risk of losing an animal and being less inclined to cull animals with dormant diseases (Santman-Berends, Swinkels et al.

Table 5. Number of formulated objectives per focus area (including percentage of intervention farms having objectives within this focus area), average objective scores (0= objective not accomplished; 1= objective partly accomplished; 2= objective fully accomplished), total number of action points per focus area, mean compliance score of the action points per focus area (0= non-compliant; 1= partly compliant; 2= fully compliant) and percentage of action points per focus area with full compliance

Focus area	# Formulated objectives (% of farms)	objective score (0-2)	# Action points per focus area	Mean compliance score (0-2)	% Action points with full compliance
Udder health	18 (80%)	0.94	68	1.63	78%
Claw health	13 (60%)	1.08	29	1.24	55%
Metabolic health/ transition management	9 (35%)	1.33	23	1.43	61%
Fertility	11 (50%)	1.00	35	1.50	71%
Young stock rearing	12 (50%)	1.33	33	1.69	88%
Housing/ animal nursing	6 (30%)	1.50	22	1.22	45%
Collaboration	6 (30%)	1.33	7	1.10	43%
Nutrition and production	7 (35%)	1.29	19	1.80	84%
Antibiotic reduction	5 (25%)	1.20	13	2.00	100%
Miscellaneous	5 (25%)	0.80	13	1.22	54%
Total / average	92	1.16	262	1.50	72%

2016). This probably explains to some extent the relatively moderate reduction in AMU compared to the national reduction.
In our study, the focus was to improve multiple animal health parameters at the same time. From literature it appears that it is easier to improve one single health parameter at a time where all efforts are directed to (for example udder health) (Tremetsberger, Winckler 2015). This is substantiated by our findings that the number of objectives per action plan was inversely associated with the compliance to action points. It might therefore be advisable to focus on a limited number of objectives and action points when developing an animal health planning program.

Determinants for Antimicrobial Use

The reduction in AMU was mainly attributed to a drop in antimicrobials used in dry cow therapy and 2nd choice antimicrobials. This can be explained by the introduction early 2014 of a new guideline to set restrictions on the application of blanket dry cow therapy to shape the compulsory ban on prophylactic AMU and the routine use of 2nd choice antimicrobials in veterinary medicine in the Netherlands (RW.ERROR - Unable to find reference:558, Stichting Diergeneesmiddelen Autoriteit 2016). This resulted in a reduction of 30% in antimicrobial dry cow treatments in 2014 in the Netherlands (source MediRund) of which a substantial part were 2nd choice antimicrobials (Stichting Diergeneesmiddelen Autoriteit 2016).
In terms of animal health, available data indicated that herds in our study did not seem to perform differently from the average Dutch dairy herd when udder health and calf mortality were compared (Santman-Berends, Swinkels et al. 2016, Santman-Berends, Buddiger et al. 2014). The other animal health parameters were also comparable to the Dutch average. However, AMU remained higher than average on our study farms, indicating that other determinants than herd health level per se might also influence total AMU. In human medicine, the influence of attitudes, risk perception and risk aversion of medical doctors is widely acknowledged to influence antimicrobial prescribing practices, apart from rational clinical considerations (Hulscher, van der Meer et al. 2010). Probably the same phenomenon is at play in dairy farming where attitudes and risk perceptions of farmers and veterinarians probably influence the level of unnecessary (extended) antimicrobial treatments with subsequent effects on total AMU. Differences in mind-set and risk perception as a determinant for total AMU in dairy farming has also been suggested by other authors and needs further investigation (Swinkels, Hilkens et al. 2015, Stevens, Piepers et al. 2016).

Control farms

After finishing the study on the intervention farms, it appeared that several control farms had also started consultancy meetings with their veterinarian and feed adviser on their own initiative. Although limited to a minimum, some contact with control farms by means of a newsletter was regarded essential to keep them motivated to provide data. This could unintentionally have triggered them to initiate some measures together with their advisers. Being in the “signalling zone” for AMU per se did not require additional measures (Stichting Diergeneesmiddelen Autoriteit 2016).

The combination of being in a high benchmarking zone for AMU and being part of a study aiming to reduce AMU might already have created a sense of urgency to work at a reduction of AMU and affected daily management. This phenomenon is known as the "Hawthorn Effect" and is known to influence outcomes in randomized control studies in dairy farming as well as in studies aiming at altering antimicrobial prescribing behaviour of general practitioners (Tremetsberger, Winckler 2015, Main, Leach et al. 2012, Mangione-Smith, Elliott et al. 2002). This influence probably led to an underestimation of the real effects of our intervention. Recruiting farmers on a voluntary basis might have introduced a selection bias for farmers with a higher motivation to reduce AMU compared to fellow farmers. The approach as described in this study therefore may not necessarily work for dairy farmers with less motivation to reduce AMU (Tremetsberger, Winckler 2015).

Facilitated Animal Health Planning

Feedback from participating advisory teams indicated that a facilitator contributed to a more structured approach of their animal health planning. In our study, the advisory teams could generate realistic objectives and implementable action points with positive effects on AMU reduction. The need for implementable action points that are supported by the farmer is substantiated by our findings that higher compliance led to better outcomes. A 71% complete compliance to the action plan is relatively high compared to other studies, probably indicating the importance of heavy involvement of the farmer and daily advisers in the planning process (Green, Leach et al. 2007, Tremetsberger, Winckler 2015, Barker, Wright et al. 2012, Whay, Barker et al. 2012). Ownership of a farmer is known to be a key element in animal health planning as it improves compliance (Tremetsberger, Winckler 2015, Green, Leach et al. 2007, Vaarst, Gratzer et al. 2010, Kristensen, Jakobsen 2011). Bell, Bell et al. (2009) for example found a poor compliance and no effects of an action plan to improve lameness in dairy cows, probably because farmers and veterinarians were not fully involved in the assessment and planning process (Tremetsberger, Winckler 2015). Another explanation for success could be the frequent follow up of the action points by the facilitator which improved compliance (Tremetsberger, Winckler 2015). The downside of ownership and involvement of farmers could be that without specific assessment protocols, important health issues or risk factors could potentially be missed. Considering the high compliance to action points and high level of accomplishment of objectives, it might be possible that the advisers in our study had reservations to really challenge their farmer to formulate objectives that would have had a great impact on antibiotic use in order to conserve a good relationship (Speksnijder, Jaarsma et al. 2015b). Independent external experts could possibly stimulate farmers to formulate more ambitious action points (Kristensen, Jakobsen 2011). However, these ambitious goals should not compromise "ownership" by the farmer in order to safeguard compliance.

Conclusions

In this paper, we presented the results of an animal health planning intervention study with a control group on animal health parameters and antimicrobial use on conventional dairy farms in the Netherlands over the period of 1 year. A significant reduction in AMU was observed on study farms without obvious adverse effects on animal health parameters and productivity, indicating the value of structured animal health planning in reducing AMU while sustaining good animal health. Good collaboration between farmer, veterinarian and feed adviser and ownership in animal health planning on dairy farms has a positive influence on the compliance to action plans and achievement of objectives.

Acknowledgements

All participating farmers, veterinarians and feed advisers are gratefully acknowledged. We also like to thank Friesland Campina for helping recruiting dairy farmers; St. Anna Advies for providing trainings for veterinarians on communication and advisory skills; Digiredo for their collaboration in the development of the E-learning course and Wietske Dohmen and Henry Voogd for providing and analysing national MediRund AMU data for farms in the signalling zone.

Appendix Study Protocol

Farm Selection

Power analysis on available AMU data over 2012 in dairy farms (SDA Rapport 2012) indicated that 2x10 farms would be necessary to find a 20% difference between intervention and control farms when AMU would be stable in control farms. To correct for possible drop outs (20%) and a not stable AMU at control farms, it was chosen to incorporate 50 farms in the study, 25 farms per group.

Animal Health Planning Process

Preparation
Approximately 3 weeks before the start of the project in April 2014, veterinarians followed a course on communication and advisory skills, organized by professional trainers (St. Anna Advies) (figure 1). For farmers and feed advisers, a specially e-learning course was developed that covered aspects related to SWOT analysis, structural animal health planning and SMART goal setting (accessible via www.digiredo.nl/samenbeterboeren, in Dutch). Before the first visit of a facilitator, each member of the advisory team (farmer, veterinarian and feed adviser) submitted an intake form in which the participant's view on the current performance of the farm (strengths, weaknesses), possible points for improvements and possible barriers for improvements, with an emphasis on animal health was expressed. This intake form was used by the facilitators to prepare the first visit. By comparing the intake forms of the farmer, veterinarian and feed adviser, the facilitator could assess whether advisers and their farmer had comparable or opposing views on the current situation and points for improvements.
Two professional facilitators (IE and RS) facilitated the animal health planning process on the participating farms. Both facilitators had years of experience in the farm animal industry and as facilitator. A joint pilot farm visit was undertaken together with the researchers and a protocol was subsequently developed for the facilitators to be used during the farm visits to ensure a harmonized facilitator approach across all farms

Intake Farm Visits
Participating farms were randomly assigned to one of the 2 professional facilitators. Intake farm visits on *intervention* farms took place between April and June 2014. To create a relaxed atmosphere and to get to know each other (many veterinarians and feed advisers had never met before at the farm), the visit started with a small round on the farm of about 30 minutes wherein advisers and farmers could already point out some points of attention regarding animal health. After this farm walk, the facilitator and participants started a structured consultation in which the facilitator facilitated the group in the process of structural animal health planning. At the start, every participant was invited to frankly share his/her view on the current performance of the farm and possible points of concern related to animal health. The intake forms could sometimes help the facilitator to motivate advisers to speak frankly.

Subsequently, all the mentioned points of concern were written down and a deliberation was started to prioritize these in urgent versus non-urgent and important versus not important and write them down in a priority quadrant according to the Covey's Time Management Grid (http://www.usgs.gov/humancapital/documents/TimeManagementGrid.pdf). The next step was selecting a handful of these points of concern and trying to formulate SMART (specific, measurable, acceptable, realistic, and timely) objectives for these points of concern. When agreement was reached about the formulation of the objectives, specific points of action were formulated that were believed to contribute to achieving the described objectives. For every action point, it was noted who was responsible for implementing it, when it should be done and when it should be evaluated. In this whole process, the facilitator explicitly took the role of facilitating the process and did not interfere with the (technical) content. The task of the facilitator was to create a culture of teamwork with fruitful discussion and to make sure that objectives and action points were mutually supported by all participants.
After the session, the facilitator wrote a report about the consultancy process and summarized the points of concern; SMART formulated objectives and points of action on a plasticised A2 format activity plan which could be hang on a visible place on the farm as a reminder for the farmer. In the report, the facilitator shared some remarkable findings of the consultancy process and some recommendations for individual participants to better perform consultancy sessions in the future (recommendations regarding communication skills, advisory skills, advice asking skills etc.).

Follow Up

After 4 and 8 months, facilitators approached the participants by telephone and email to get insight in the implementation of the activity plan on each individual farm. These interim evaluations had 2 purposes; a) to remind participants of the activities written down in their activity plan and b) to support advisory teams without any progress by giving recommendations how to get back on track or by organizing a new consultancy meeting.
After 1 year (between April and June 2015), a final farm visit was planned in which the advisory team under guidance of the facilitator evaluated the collaboration in the last year, the implementation of the points of action and to which extend they resulted in achieving the objectives. After this evaluation process, the advisory team was challenged to develop a new activity plan for the next year, but now with limited guidance of the facilitator.

Data Collection

The facilitator assessed the quality of the animal health planning process per farm by assigning a score between 1 (poor) and 5 (good) on 10 variables measuring aspects around preparation for the consultation (mean of 5 variables) and quality of the collaboration of the advisory team in the consultancy process (mean of 5 variables) (see Table A1). The collaboration of the advisory team was again assessed by the facilitator after the final farm visit on a 5-point scale for 5 different variables.

Table A1: rated quality of preparation of the participants and quality of collaboration in the advisory team by the facilitator

Scale	Rated variable	Rating criteria (1 = poor; 5 = good)
Preparation for intake farm visit	Preparation farmer	Intake form filled and shows efforts for thorough reflection on the current farm situation
	Preparation veterinarian	Intake form filled and shows efforts for thorough reflection on the current farm situation
	Preparation feed adviser	Intake form filled and shows efforts for thorough reflection on the current farm situation
	Similarities intakes farmer and veterinarian	The extent to which intake forms of farmer and veterinarian show resemblances (high rating) in their analysis on points for improvement, indicating prior discussions between farmer and veterinarian
	Similarities intakes farmer and feed adviser	The extent to which intake forms of farmer and feed adviser show resemblances (high rating) in their analysis on points for improvement, indicating prior discussions between farmer and veterinarian
Quality of collaboration during the intake farm visit	Atmosphere	Atmosphere during the intake visit: there is a relaxed atmosphere, constructive to work towards commonly agreed objectives
	Openness	Presence of mutual trust to express all kinds of thoughts and ideas, participants are curious for thoughts of others, questions are easily expressed
	Communication	Participants actively participate in the discussions, actively listen to each other, try to understand the views of others, high level of interaction
	Role play	Level to which the participants behave according to their role: farmer with a leading role in the discussions as entrepreneur; veterinarian and feed adviser as consultant with expert knowledge with the capacity to connect their advices to the demands and needs of a farmer
	Synergy	There is a high level of synergy (1+1+1=4): participants actively elaborate on topics that are brought in by other participants so that meeting in the advisory team leads to better recommendations than would have been the case in bilateral meetings (farmer and veterinarian versus farmer and feed adviser)

Chapter 6

Structural animal health planning in dairy farming in the Netherlands; short- and long-term effects on animal health and antibiotic use.

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In preparation

Abstract

Farm-specific solutions are required to lower antimicrobial use on dairy farms with a relatively high use of antibiotics. Structural animal health planning in a collaborative effort between a farmer and daily advisers might be a promising approach to improve animal health and lower antibiotic use. In this study, the long term effects of a facilitated animal health planning program were evaluated.
In this cross-over design study, advisory teams consisting of a dairy farmer, his veterinarian and feed adviser, developed and implemented a farm specific animal health plan supported by a professional facilitator (group A). Results were evaluated after one year and a new animal health plan was developed without support of the facilitator. The effects on antibiotic use and animal health parameters were evaluated and compared to a control group (group B). After this first year, group B followed the program. At the end of the second study year, the results of group B and the long term effects in group A were evaluated.
The majority of group A farms continued structural animal health planning meetings in advisory teams and were able to continue to achieve high compliance to their activity plan without the support of a facilitator in the follow-up period. Antibiotic use and most animal health parameters tended to continue to improve.
During their intervention period, group B farms achieved similar compliance rates to their activity plan as group A farms in the first year. Most animal health parameters tended to improve; antibiotic use however tended to increase in this period, probably due to a rebound effect to correct for a too fast reduction in antibiotic use in the previous year.
The major predictors for reduction in antibiotic use on all study farms over the 2-year study period was the baseline antibiotic use followed by the decrease in mastitis incidence in this period. We did not find clear relationships between disease incidences and antibiotic use, indicating that non-clinical factors as risk aversive behaviours might substantially influence antibiotic use in dairy farming.
Constructive collaboration between farmers, veterinarians and feed advisers in animal health planning results in a high compliance to activity plans to improve animal health and seems to allow for a gradual decrease in antibiotic use whilst maintaining or even improving animal health parameters over a longer period of time. However, the influence of mindset, risk perceptions and risk aversive behaviours on antibiotic use needs further research.

Introduction

The Netherlands has a recent history of an impressive reduction in antibiotic use in food production animals, including the dairy sector, paralleled with a decreasing level of antimicrobial resistance (AMR). Many farmers were able to produce with considerably less antimicrobials. However, there are farms where antibiotic use remains higher compared to peers ad on these farms additional efforts are needed to reduce antibiotic use. Structural animal health planning in a collaborative effort between a farmer, veterinarian and other daily advisers might be a promising approach to improve animal health and lower antibiotic use on these farms (Laanen, Maes et al. 2014, Ellis-Iversen, Cook et al. 2010, Gunn, Heffernan et al. 2008, Speksnijder, Jaarsma et al. 2015a, Speksnijder, Jaarsma et al. 2015b). Earlier studies have demonstrated various effects of structural animal health planning programs with the aim to improve (certain) animal health parameters, mostly in dairy farming (Green, Leach et al. 2007, Tremetsberger, Leeb et al. 2015, Ivemeyer, Smolders et al. 2012, Whay, Barker et al. 2012, Bell, Bell et al. 2009). Key aspects of successful animal health planning are believed to be a close involvement of the farmer and his daily advisers, and a structured approach to animal health including unambiguous objectives and a clear activity plan (Tremetsberger, Winckler 2015).
In an earlier paper, we described the results of a prospective randomized control trial to evaluate the main effects of an animal health planning program by an advisory team consisting of a dairy farmer, his veterinarian, and his feed adviser under guidance of a professional facilitator (Speksnijder, Graveland et al. 2017). We described the positive effects of a constructive collaboration in the advisory team on the accomplishment of objectives and a gradual decline in antibiotic us without adverse effects on animal health and productivity. However, the real impact of structural animal health planning can only be evaluated after a certain period as it takes time to implement measures and to determine effects. The main objective of this study was therefore to evaluate the effects of this facilitated approach of structural animal health planning on animal health, production parameters and antibiotic use for an extended period of one year following a one-year intervention. Secondly, the effects of this intervention in a former control group of farmers were evaluated and observational data on antibiotic use and animal health parameters on all study farms will be presented to find possible relationship between antibiotic use and animal health parameters on conventional dairy farms.

Materials and Methods

The study named "Samen Beter Boeren" (Better Farming Together) was conducted between March 2014 and May 2016 on conventional dairy farms in the Netherlands. Dairy farmers within a higher benchmarking zone for antibiotic use than average, between 3-6 DDDA (Defined Daily Dose Animal), together with their veterinarian and feed adviser voluntarily participated in the study and were randomized in an intervention (group A; n = 20) and a control group (group B; n = 19). At the start of the first year of the study (spring 2014), the advisory team consisting of the farmer,

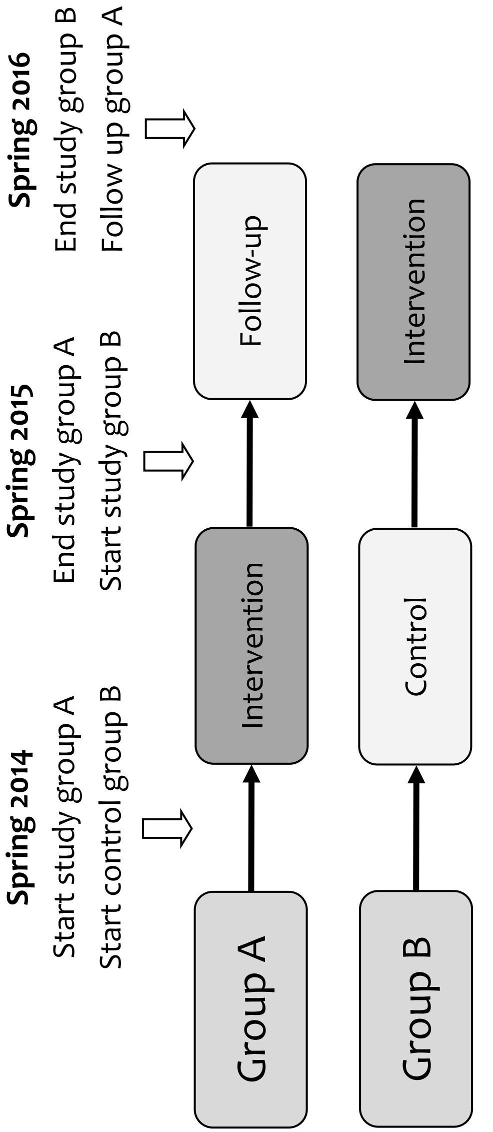

Figure 1. Study protocol

veterinarian, and feed adviser in group A followed an initial training. During a first farm visit they developed their own tailor made one-year animal health planning program under guidance of one of the two professional facilitators who were assigned to the project. This was written down in an activity plan with priorities and clear action points. In the following year, the facilitator contacted the advisory team several times to stimulate implementation of the activity plan and to monitor progress made in the implementation. At the end of the first year (spring 2015), the advisory team in group A evaluated the achievements of their animal health planning program under guidance of the facilitator. They were challenged to develop a new animal health planning program for the subsequent year as an advisory team, but without support from the facilitator. In the first year of the study, group B farms acted as controls, with data collection only. By the end of the first year (2014-2015), 4 farmers from group B had decided to withdraw from the study. In year 2 (spring 2015 – spring 2016), group B farmers (n = 15) with their advisers were enrolled in the same intervention program as was conducted in group A the year before. The study ended in group B farms in spring 2016. In spring/summer 2016, group A farmers were approached by telephone to evaluate their animal health planning program in the year after they ended the facilitated animal health planning program in the study (Figure 1). Full study details can be found in Speksnijder, Graveland et al. (2017).

Data collection and statistical analysis

The quality of the animal health planning process per farm was semi-quantitatively assessed by the facilitator by assigning a score between 1 (bad) and 5 (good)on 10 variables grouped into 2 scales; aspects concerning preparation for the consultation (5 variables) and quality of the collaboration of all participants of the advisory team in the animal health planning process (5 variables).
Antibiotic use data at farm level were obtained from quarterly farm level reports of the integral quality organization of the sector (MediRund). Farmers in the study provided animal health and production data over the years preceding and during the study period. Additional production and health parameters were derived from official milk recording data, fertility reports, reports from quality schemes and culling data (Chapter 5, Table 1). Differences in disease incidences were calculated by distracting the disease incidence in the pre-intervention periods (one year per period) from the disease incidence during the intervention periods (one year per period). Differences in antibiotic use were calculated as percentages reduction compared to the previous year.
The objectives and action points from the activity plans were collected and grouped in the following focus areas: udder health, metabolic health/transition management, fertility, young stock rearing, housing/animal nursing, nutrition and production, collaboration within the advisory team, antibiotic reduction and miscellaneous. The level of compliance to each single action point and accomplishment of each objective was rated to get an impression of the level of implementation and outcomes of the activity plans (not performed/accomplished = score 0; partly performed/accomplished = score 1; fully performed/accomplished = score 2). The mean compliance score of the action points belonging to one single objective or per farm was calculated and ranged between 0 (none of the action points performed) and 2 (all action points fully performed). An overall "objective score" was calculated per farm as an indication of the level of accomplishment of the proposed objectives (Speksnijder, Graveland et al. 2017).
Individual farms were the unit for the analysis and level of significance was set at $\alpha=0.05$. Data were analyzed in SPSS vs24 (IBM SPSS Inc. Chicago, IL). Data were checked for normal distribution by creating Q-Q plots and performing the Kolmogorov-Smirov test. Log10 transformation and square root transformation was performed on non-normally distributed data. Independent samples T-tests, Analysis Of Variance (ANOVA) and Multivariate Regression Analyses were used to find differences and relationships between several variables on intervention farms.

Results

Farm Characteristics

Dairy farming was the primary occupation of all participating farmers who were dispersed over the whole country. In terms of housing system and grazing, there were no differences between farms in group A and group B. Farms in the study were slightly

Table 1. Herd sizes, annual milk production and average age of lactating cows (mean, standard deviation) during the study period in intervention and control farms.

	Number of adult dairy cows (> 2 years) per farm (mean ± SD)			Milk production annual rolling herd average per farm (kg milk/cow) (mean ± SD)			Average age lactating cows per farm (months) (mean ± SD)		
*Period**	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*	*2014*	*2015*	*2016*
Group A (n=20)	111.2 ± 63.8	113.4 ± 61.2	124.5 ± 71.4	9003 ± 778	8980 ± 791	9215 ± 805	54.1 ± 4.3	53.7 ± 4.1	53.4 ± 4.0
Group B (n=15)	96.6 ± 39.2	97.4 ± 36.1	105.3 ± 39.2	8802 ± 1253	8984 ± 1203	9131 ± 1024	54.4 ± 5.5	54.1 ± 5.4	54.3 ± 4.7
National mean**	90	93	101	8376	8373	8663	56	55	55

*Actual data in spring of the respective years
**Calculated as average in the respective years; source CRV Jaarstatistieken

larger than the Dutch average but no significant differences between the two groups were found (Table 1).

Follow up of Group A farms after 1 year

Sixteen out of the original 20 farms from group A decided to formulate a new activity plan with new objectives during the final farm meeting at the end of their intervention period. A total of 62 new objectives were formulated on these farms (mean of 3.9 objectives per farm; median of 4) with 188 associated action points (mean of 11.8 action points per farm; median of 12.5). Evaluation one year after ending the intervention period learned that of the action points on these farms, 125 (66%), 35 (19%) and 28 (15%) action points were fully, partly, and not implemented respectively and 23 (37%), 28 (45%) and 11 (18%) objectives were fully, partly and not accomplished respectively.
A total of 12 farmers continued meetings with their advisory teams on a frequent basis (varying from 1 time a year to 1 time a month; average of 3.1 times a year, median of 2.5). Eight farmers discontinued meeting on a frequent basis. Some because they did not believe it added value, others indicated there were no urgent problems to be solved and they considered the advisory team mainly as a problem-solving instrument and a last group expressed the intention to continue but just did not do it for time or organizational reasons. There was a tendency for farms that continued advisory meeting to have a higher percentage of full compliance to the activity plan (70%) compared to farms that discontinued advisory meetings periodically but who did formulate a new activity plan at the final farm meeting (58% full compliance) (p=0.054; Independent samples T-test).
On group A farms, a significant reduction in total antibiotic use in their intervention period (-19%; p=0.026) had been observed. This decline in antibiotic use continued in the post-intervention year (-6%) but this was not statistically significant (p=0.353) (Figure 2). The total decline between the start of the intervention and the end of the

follow-up period however was significant (-24%; p=0.004). This decline mainly was attributed by a reduction in antibiotics used for mastitis treatments (-29%; p=0.081), antibiotic dry cow treatments (-23%; p=0.081; Independent Samples T-test) and antibiotics used for injection (-22%; p=0.130; Independent Samples T-test) (Table 2). Most animal health indicators continued to improve in the follow-up period, although no significant changes in disease incidences could be observed in the follow-up period (Table 3).

Antibiotic use and animal health characteristics in group B farms

In group B farms, a (non-significant) increase in antibiotic use (+9%; p=0.471) was visible in their intervention period after a (non-significant) decline in their pre-intervention period (-14%; p=0.091) (Table 2 and Figure 2). The antibiotic use dynamics in group B were however not significantly different from group A in both periods. A borderline negative relationship between antibiotic use reduction in the pre-intervention period and antibiotic use reduction in the intervention period on group B farms was visible (p=0.084; R^2 = 0.212; ß = -0.551; Linear Regression Analysis). In depth analysis indicated that 3 farms in group B had an increase of >50% in total antibiotic use in their intervention period (+2.09 DDDA; average of 97%) after a 36% decrease in AMU in their pre-intervention period. These dynamics were mainly caused by antibiotic dry cow treatments which decreased from 1.36 to 0.72 DDDAdc (-47%) in the pre-intervention period of these 3 farms and subsequently increased to 2.10 DDDAdc (+192%) in their intervention period. The other 12 farms had an average decrease in antibiotic use of 0.21 DDDA (-6%) in their intervention period after a 9% decrease in their pre-intervention period caused by a gradual decrease in dry cow treatments from 1.52 to 1.34 (-12%) to 1.07 DDDAdc (-20%) in these periods respectively. Another striking difference was that these 3 farms had an increase in mastitis incidence where the other farms in group B had an average decrease in mastitis incidence during their intervention period (+6.5 cases/100 cows versus -6.4 cases/100 cows respectively; p=0.091).

Action points and objectives in the intervention period

During the respective intervention periods in group A and B, a total of 161 objectives were formulated on 35 farms (Table 4). Of the objectives, 37% and 32%, 41% and 57%, and 22% and 12% were fully, partly, and not accomplished respectively in group A and B. Mean objective score per farm (indicator of accomplishment of objectives) was positively influenced by the compliance to the action points and the quality of collaboration during the intake farm visit (p =0.002; R^2 = 0.360; $ß_{compliance}$ = 0.372; $ß_{collaboration}$ = 0.157).

Observational relationships between antibiotic use and animal health parameters in the total study period

When total antibiotic use on all study farms (group A and B) is analysed, a significant reduction of 17% between spring 2014 and spring 2016 could be observed; from 3.60 DDDA to 2.98 DDDA (p=0.006). This reduction is comparable to the national average reduction in the same period (-16%). At baseline (spring 2014) total AMU (DDDA) at farm level could not be explained by differences in farm size, milk production and disease incidences for the different parameters tested, except for the Square root of Endometritis incidence (p=0.038; R^2 = 0.141; $ß_{SQREndometritis}$ = 0.404).

Table 2. Mean AMU indicators ± SD for intervention and control farms in the study period (Italic indicates the intervention period)

Antibiotic class	Period	Group A	Group B	National mean
DDDA	Spring 2014	*3.74 ± 1.19*[ab]	3.41 ± 0.63	2.58
	Spring 2015	*3.03 ± 0.70*[a]	*2.92 ± 0.88*	2.20
	Spring 2016	2.84 ± 0.61[b]	*3.17 ± 1.09*	2.16
DDDA1	Spring 2014	*2.70 ± 1.05*	2.07 ± 0.89	1.74
	Spring 2015	*2.28 ± 0.58*	*2.00 ± 0.88*	1.59
	Spring 2016	2.22 ± 0.52	*2.31 ± 0.96*	1.56
DDDA2	Spring 2014	*1.04 ± 0.50*[a]	1.35 ± 0.81	0.83
	Spring 2015	*0.75 ± 0.29*	*0.92 ± 0.65*	0.60
	Spring 2016	0.61 ± 0.35[a]	*0.86 ± 0.40*	0.59
DDDA3	Spring 2014	*0.01 ± 0.02*	0.00 ± 0.00	0.00
	Spring 2015	*0.00 ± 0.01*	*0.01 ± 0.02*	0.00
	Spring 2016	0.02 ± 0.05	*0.01 ± 0.02*	.00
DDDAimm	Spring 2014	*0.76 ± 0.41*	0.74 ± 0.35	0.55
	Spring 2015	*0.65 ± 0.29*	*0.63 ± 0.28*	0.52
	Spring 2016	0.54 ± 0.31	*0.71 ± 0.36*	0.51
DDDAdc	Spring 2014	*1.53 ± 0.63*	1.48 ± 0.50	1.20
	Spring 2015	*1.25 ± 0.44*	*1.21 ± 0.59*	0.91
	Spring 2016	1.18 ± 0.46	*1.28 ± 0.78*	0.88
DDDAinj	Spring 2014	*1.28 ± 0.67*	1.08 ± 0.55	0.68
	Spring 2015	*1.02 ± 0.55*	*0.96 ± 0.51*	0.66
	Spring 2016	1.00 ± 0.53	*1.05 ± 0.49*	0.68
DDDAiu	Spring 2014	*0.18 ± 0.19*	0.10 ± 0.13	0.10
	Spring 2015	*0.11 ± 0.13*	*0.10 ± 1.09*	0.08
	Spring 2016	0.11 ± 0.15	*0.07 ± 0.07*	0.07

Superscript: Significant differences between years (ANOVA)

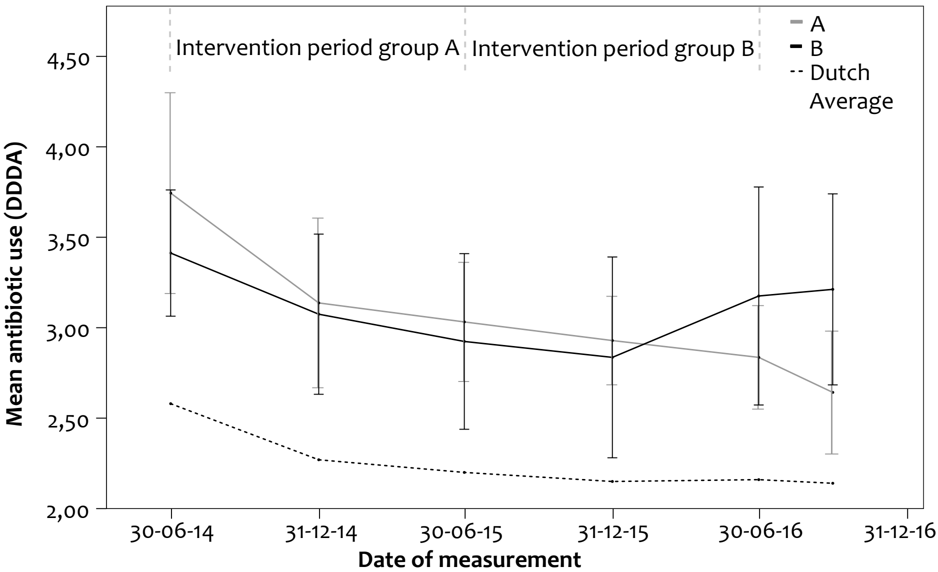

Figure 2: Total antimicrobial use dynamics over the study period in group A (black) and group B (grey) farms, including the Dutch average (dotted line).

The major predictor for total reduction in antibiotic use (DDDA) at farm level over the 2-year study period was the height of the initial antibiotic use (DDDA) followed by the decrease in mastitis incidence (cases/100 cows/year) at farm level during this period ($P < 0.001$; $R^2 = 0.687$; $ß_{DDDA} = -0.723$; $ß_{mastitis} = 0.038$). These relationships did not change when the reduction in AMU was expressed as percent reduction in DDDA in this period ($P < 0.001$; $R^2 = 0.548$; $ß_{DDDA} = -0.134$; $ß_{mastitis} = 0.013$). The other variations in disease incidences did not significantly affect changes in AMU in this 2-year period.

Discussion

In this study we saw that a facilitated approach had also long term effects on structured animal health management in dairy farms. A continuation of moderate improvement of most animal health parameters and further reduction of antibiotic use was observed. The major predictor for the percent reduction in antibiotic use in the whole 2-year study period over all farms was the initial height of AMU and the decrease of mastitis incidence during this period.

Some study limitations should be considered. Major effects of our structured animal health planning approach on animal health parameters and antibiotic use have not been found in our study although the trends in antibiotic use and animal health parameters were positive. A power issue can be assumed as only 35 farmers participated in the study where 50 farmers were proposed (Speksnijder, Graveland et al. 2017). In the 20 farms within group A for example, we found a 26% reduction in mastitis incidence after 2 years and a 29% reduction in the amount of antibiotics used

Table 3. Mean animal health parameters ± SD for intervention and control farms in the study period (Italic indicates the intervention period) and available national averages

Parameter	Period	Group A	Group B	National mean
BMSCC (x1000)	Spring 2014	*175 ± 78*	*169 ± 29*	~200*
	Spring 2015	*178 ± 72*	*160 ± 35*	~200*
	Spring 2016	163 ± 70	*143 ± 38*	~190*
Mastitis (%)	Spring 2014	*26.1 ± 15.2*	26.3 ± 11.3	
	Spring 2015	*25.0 ± 17.3*	*27.9 ± 13.3*	32.2 (2013)**
	Spring 2016	19.3 ± 10.7	*24.1 ± 9.1*	
HSCC (%)	Spring 2014	*16.9 ± 8.2*	14.9 ± 3.6	
	Spring 2015	*16.9 ± 7.9*	*15.3 ± 4.5*	
	Spring 2016	15.3 ± 7.5	*13.2 ± 4.1*	
NewHSCC (%)	Spring 2014	*8.1 ± 3.1*	8.0 ± 2.3	~8*
	Spring 2015	*7.8 ± 3.0*	*7.9 ± 1.4*	~8*
	Spring 2016	7.8 ± 3.2	*7.5 ± 1.6*	~9*
MF (%)	Spring 2014	*6.7 ± 5.0*	10.4 ± 9.5	
	Spring 2015	*6.2 ± 4.8*	*8.1 ± 7.8*	
	Spring 2016	5.9 ± 4.0	*7.4 ± 6.8*	
Ketosis (%)	Spring 2014	*8.2 ± 8.4*	7.4 ± 5.9	
	Spring 2015	*4.5 ± 4.8*	*5.6 ± 5.3*	
	Spring 2016	4.5 ± 4.2	*6.9 ± 6.1*	
RFM (%)	Spring 2014	*8.9 ± 6.5*	8.7 ± 6.2	
	Spring 2015	*6.2 ± 4.9*	*6.5 ± 4.8*	
	Spring 2016	6.3 ± 3.7	*4.4 ± 3.6*	
Metritis (%)	Spring 2014	*5.3 ± 4.0*	4.6 ± 3.3	
	Spring 2015	*3.1 ± 2.1*	*3.6 ± 4.1*	
	Spring 2016	4.3 ± 3.2	*3.5 ± 3.7*	
Endometritis (%)	Spring 2014	*8.4 ± 6.3*	5.6 ± 4.1	
	Spring 2015	*6.1 ± 7.1*	*7.5 ± 5.5*	
	Spring 2016	6.5 ± 7.4	*5.6 ± 5.1*	
Lame (%)	Spring 2014	*5.7 ± 4.9*	4.6 ± 3.5	
	Spring 2015	*5.5 ± 3.6*	*5.1 ± 3.9*	
	Spring 2016	4.1 ± 3.5	*6.3 ± 7.6*	

Parameter	Period	Group A	Group B	National mean
Dead birth (%)	Spring 2014	8.4 ± 4.6	9.2 ± 5.1	
	Spring 2015	8.8 ± 3.1	7.4 ± 3.5	
	Spring 2016	7.5 ± 3.9	7.1 ± 4.1	
Mortality (%)	Spring 2014	4.1 ± 4.0	3.4 ± 3.0	
	Spring 2015	3.0 ± 3.0	3.2 ± 2.4	4.8 (2011)**
	Spring 2016	3.8 ± 3.8	6.1 ± 5.7	
Respiratory (%)	Spring 2014	5.6 ± 5.3	7.3 ± 7.1	
	Spring 2015	3.7 ± 3.3[a]	10.6 ± 10.7[a]	
	Spring 2016	4.6 ± 4.8	6.1 ± 7.8	
Enteritis (%)	Spring 2014	14.1 ± 13.3	8.9 ± 8.7	
	Spring 2015	10.5 ± 9.7	13.1 ± 7.9	
	Spring 2016	8.4 ± 7.6	11.6 ± 7.4	
Umbilical cord (%)	Spring 2014	2.4 ± 1.9	2.5 ± 2.1	
	Spring 2015	2.4 ± 2.3	2.6 ± 3.7	
	Spring 2016	1.5 ± 1.7	1.8 ± 2.6	

Superscript: significant differences between groups (Independent samples T-test)
*Source CDM (Q2-Q1)
** Source (Santman-Berends, Swinkels et al. 2016, Santman-Berends, Buddiger et al. 2014, Santman-Berends, Buddiger et al. 2014)

for mastitis treatment (DDDAimm). Similar reductions have been found in a study of Ivemeyer, Maeschli et al., (2008) who found a significant 32% reduction in mastitis treatments on 65 organic farms in an intervention study of 2 years. Although we assumed to be able to find more robust effects after a longer monitoring period as described in our former paper, we should conclude that even a period of 2 years probably is too short to draw radical conclusions on the effect of structural animal health planning on animal health and AMU (Speksnijder, Graveland et al. 2017). Most probably, several years should be devoted to monitoring the effects of structural animal health planning in dairy farming (Ivemeyer, Smolders et al. 2012, Tremetsberger, Winckler 2015).

Implementation of the activity plan

It is believed that farmers in general have positive attitudes towards preventive measures to improve animal health and reduce antibiotic use. However, these positive attitudes are not always translated into action and compliance to veterinary advice generally appears to be low (Laanen, Maes et al. 2014, Gunn, Heffernan et al. 2008, Ellis-Iversen, Cook et al. 2010). In our study, we found a relatively high degree of implementation of action points in both groups compared to other studies where the

Table 4. Objectives and Action Points in all study farms in their respective intervention period

	# Formulated objectives (% of farms)	Mean objective score (0-2)	# Action points per focus area	Mean compliance score (0-2)	% Action points with full compliance
Udder health	26 (63%)	1.08	90	1.64	77.8%
Claw health	20 (46%)	1.15	55	1.34	61.8%
Metabolic health / transition management	16 (43%)	1.31	44	1.50	68.2%
Fertility	23 (60%)	0.96	72	1.65	80.6%
Young stock rearing	19 (46%)	1.37	66	1.74	87.9%
Housing / animal nursing	12 (34%)	1.25	33	1.31	48.5%
Collaboration	15 (40%)	1.33	29	1.32	58.6%
Nutrition and production	15 (40%)	1.27	42	1.84	88.1%
Antibiotic reduction	7 (17%)	1.14	16	1.71	93.8%
Miscellaneous	8 (20%)	0.88	20	1.35	55.0%
Total / average	161	1.17	467	1.56	72.2%

advisory team was not (fully) involved in drawing the activity plan (Green, Leach et al. 2007, Tremetsberger, Winckler 2015, Barker, Wright et al. 2012, Whay, Barker et al. 2012, Postma, Vanderhaeghen et al. 2016). Together with the finding that the majority of group A farmers continued the advisory team meetings and had a higher compliance to the activity plan compared to farmers who discontinued the advisory tem meetings, this substantiates the added value of regular and structured meetings with the advisory team. It also supports the idea that advisory teams can work autonomously after an initial start under supervision of a facilitator. Our study results indicate that ownership of the farmer and involvement of daily advisers in designing and implementing the animal health program are critical success factors for effective animal health planning (Speksnijder, Graveland et al. 2017, Tremetsberger, Winckler 2015, Kristensen, Jakobsen 2011).

Seen the great variation in animal health parameters, it is difficult to calculate a cost-benefit ratio of adding a facilitator to an advisory team. Considering that the facilitator is only needed to start up an advisory team, which costs about 10 hours in total, and the success rate in implementing advices with subsequent improvements in animal health, it can be argued that hiring a facilitator can be a good investment to accelerate improvements in animal health and productivity.

Antibiotic use and animal health

Several relationships have been found between antibiotic use dynamics an animal health parameters in our study. A higher baseline antibiotic use was significantly associated with a higher reduction in antibiotic use (percentage and absolute) during the intervention period and over the total study period. Other studies also found that higher users can reduce faster when they are subjected to an intervention study or mandatory reduction targets (Postma, Vanderhaeghen et al. 2016, Stichting Diergeneesmiddelen Autoriteit 2016).

In group B farms there appeared to be a rebound effect in antibiotic use in the second study year. Farms that educed the most in their control period (first year of the study) appeared to reduce the least or even increased in their antibiotic use in the subsequent year which was their intervention period. Some farms in group B already started activities to improve animal health on their farms at their own initiative when they were the controls in the first study year. Probably some group B farmers had reduced their AMU in the previous year a little too forced in the light of the recent Dutch reduction policy, being in the signalling zone for AMU and being a control farm in a study aiming at a reduction in AMU and therefore being at risk of being influenced by the "Hawthorn Effect" (Speksnijder, Graveland et al. 2017). It is possible that the reduction on these farms was not backed by proper measures discussed in their advisory team to allow for a sustainable reduction in antibiotic use which led to a rebound phenomenon. The 3 farms in group B with the highest increase in AMU in the intervention period almost halved the amount of antibiotics used for dry cow therapy in their pre-intervention period. This seemed however to be followed by a considerable rise in mastitis cases in the subsequent year (being the intervention period) which may have caused these farmers to increase the use of antibiotic dry cow treatments again as a rebound effect.

An interesting finding in or study is the significant positive association found between udder health and reduction of antibiotic use. Ivemeyer et al. (2012) also reported an improvement in udder health together with a lower AMU in an intervention study on organic dairy farms in several European countries (Ivemeyer, Smolders et al. 2012). Scherpenzeel, den Uijl et al. (2014) concluded that a reduction in antibiotic use through the implementation of mandatory selective dry cow therapy would lead to a higher mastitis incidence. In our study, we have shown that in structural animal health planning udder health and other health parameters can be improved with accompanying reductions in antibiotic use.

Although we have seen a reduction in antibiotic use in our study farms, it remained still higher than the national average over the study period. When compared to available data, it is remarkable that our study farms performed similar or even better in terms of animal health parameters compared to their peers. One explanation could be that the farmers in our study used more antibiotics to prevent diseases (e.g. antibiotic dry cow treatments). However, we did not find a deterioration in udder health after a substantial decrease in antibiotics used for dry cow therapy in the study period. Secondly, antibiotic use for curative treatments (mainly mastitis treatments and injection) was higher on our study farms despite disease incidences appeared to be lower compared to national means. Possibly farmers in our study use longer treatment durations and/or are quicker to apply antibiotics to treat a disease. It feeds the idea that not only clinical parameters determine total antibiotic use at farm level but that also non-clinical influences as mindset, risk perceptions and risk aversive behaviours might determine the level of AMU (Speksnijder, Graveland et al. 2017). These aspects were not specifically targeted in our study but following our findings must be considered in tailoring new interventions aiming at a reduction of AMU in dairy farming.

Conclusions

In this paper, we presented the long-term results of an animal health planning intervention study with a control group on animal health parameters and antibiotic use on conventional dairy farms with a higher than average antibiotic use in the Netherlands over the period of 2 years. Our results have shown that constructive collaboration of farmers, veterinarians and feed advisers in animal health planning results in a high compliance to activity plans to improve animal health and seems to allow for a gradual decrease in antibiotic use whilst maintaining or even improving animal health parameters over a longer period of time. However, a substantial influence of mindset, risk perception and risk aversive behaviour of farmers on total antibiotic use cannot be ruled out and urgently warrants further research.

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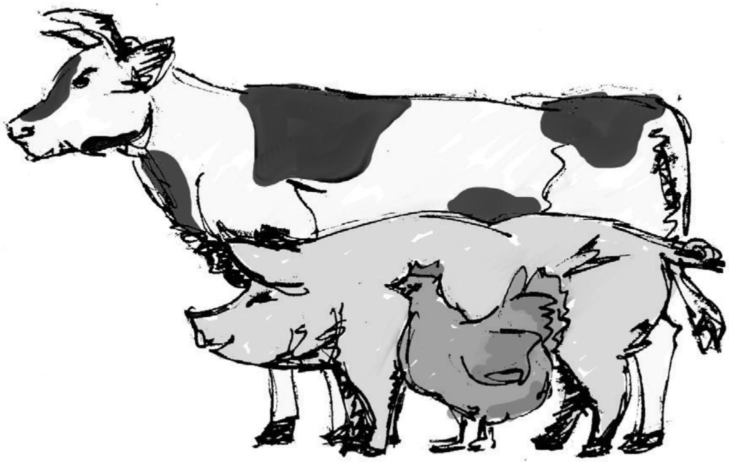

Chapter 7

General discussion

Introduction

A general principle of prudent antibiotic use in veterinary medicine is that animals receive antibiotics appropriate to their clinical needs, while the efficacy of these antibiotics is sustained (OIE World Organization for Animal Health 2016, World Health Organization 1987, Scott Weese, Page et al. 2013). Unnecessary antibiotic use practices should be limited, the need for antibiotic use in farm animals should be diminished by minimizing the incidence of infectious diseases and antibiotic treatments should be carefully selected and administered, based on available evidence (Laxminarayan, Duse et al. 2013, Aarestrup 2015, Rushton, Pinto Ferreira et al. 2014, Page, Gautier 2012).

Over the last decade, total antibiotic use in Dutch the animal production sector has been reduced with almost 65% with the greatest reduction visible between 2009 and 2013 (Chapter 1). Since then however, the reduction in antibiotic use has levelled off and despite the continuing efforts delivered by the livestock sectors, they have not been able to achieve the 70% reduction target by 2015 compared to 2009 as set by the government (Chapter 1). It is assumed that the low hanging fruit has been harvested and new, more specific and tailor made, measures are needed to responsibly continue reducing antibiotic use in the Dutch livestock sectors since it is believed that a further reduction is both necessary and feasible (Letter to the Parliament 2016).

The studies described in this thesis were designed to identify prescribing determinants of farm animal veterinarians, options for reductions in antibiotic use and to assess the impacts of a multi-faceted intervention study aimed at improving animal health and reducing antibiotic use.

In our qualitative and quantitative studies (Chapters 2-4), we have found that veterinarians have various opinions on the necessity, the possibilities and risks related to a reduction in antibiotic use in production animals. A major theme that emerged was the importance of prevention of animal diseases to reduce antibiotic use in production animals and the obstacles faced in practice in the uptake of these preventive measures by farmers. The role of veterinarians is restricted to advise farmers on specific management practices and an often heard complaint is that farmers do follow advices of veterinarians only to a limited degree (Chapters 2-4) (Kristensen, Jakobsen 2011, Kluivers, Binnendrijk et al. 2015, Derks, van Werven et al. 2012, Sayers, Good et al. 2014, Ruston, Shortall et al. 2016).

In our intervention study described in Chapters 5 & 6, we have studied the possibilities to increase the uptake of veterinary advices by farmers through a structured and facilitated animal health improvement program with the aim to improve animal health and lower antibiotic use. The relatively high degree of implementation, the tendency for improved animal health and substantially lowered antibiotic use and the maintained advisory team meetings on most intervention farms indicate the potential value of such facilitated animal health improvement programs in the future.

It is clear that reducing antibiotic use in production animals requires behaviour changes of farmers and veterinarians (Visschers, Backhans et al. 2016, Coyne, Latham et al. 2016, Laanen, Maes et al. 2014, Kristensen, Jakobsen 2011, Sheehan 2013, Ruston, Shortall et al. 2016). The role of veterinarians should change from reactive, curative

antibiotic prescribers towards proactive animal health management consultants, and the role of farmers should change from operational farm labourers to proactive production managers who manage risks to avoid animal diseases (Chapters 2 & 3). It is therefore necessary to understand which factors influence current behaviour and which factors drive or inhibit an individual to change his/her behaviour (Garforth 2015, Kristensen, Jakobsen 2011, Brennan, Christley 2013). A number of sociological models exist to understand the complexities related to human behaviour. In this general discussion, the Social Ecology Model (SEM) will be used to frame the different factors and beliefs that influence behaviours of farmers and veterinarians related to antibiotic use practices and the uptake of preventive measures (Box 1). This model assumes that an intention to change is based on intrinsic beliefs about outcomes, social norms and abilities. The subsequent actual implementation of change is more dependent on knowledge and skills and extrinsic enabling factors in the environment.
In the following paragraphs, the decision-making process in relation to uptake of preventive measures and prudent antibiotic use practices by farmers and veterinarians in the Netherlands will be further discussed and framed based on the steps described in the Social Ecology Model (Figure 2).

Box 1

Changing behaviour of people has been a major subject of research over the last decades. Much of our behaviour is believed to be without much conscious rational reflection upon the consequences of the actions, but rather automatic, influenced by all kinds of stimuli and quite difficult to change (Marteau, Hollands et al. 2012). Many social psychological theories have been used to understand what drives current behaviour of people and what could drive or limit certain behaviour change (Michie, Johnston et al. 2008). In human medicine, these theories are extensively used to understand reasons for inappropriate medical care and to design tailored interventions aiming at improving appropriate care (Finch, Low 2002, Godin, Bélanger-Gravel et al. 2008, Eccles, Grimshaw et al. 2007, Butler, Rollnick et al. 1998, Hulscher, Grol et al. 2010). The use of these theories for example has shown how antibiotic prescribing for urinary tract infections is largely driven by habituation, or the role of perceived patient pressure to prescribe antibiotics (Eccles, Grimshaw et al. 2007, Walker, Grimshaw et al. 2001). These theories are also increasingly being used to explain behaviours of farmers and veterinarians related to the uptake of preventive measures, antibiotic use practices, and other farmer related activities (Jones, Marier et al. 2015, Garforth 2015, Swinkels, Hilkens et al. 2015, Coyne, Latham et al. 2016, Jan, McIntosh et al. 2012, Edwards-Jones 2006, Visschers, Backhans et al. 2016, Brennan, Christley 2013).
Most psychological models try to explain actual behaviour by a set of motivational and enabling/inhibiting stimuli. The sum of all these stimuli eventually drives or suppresses behaviour. Detailed knowledge of stimuli that are drivers or suppressors for a certain behaviour can be used in developing interventions to stimulate behaviour changes in the desired direction. A widely-used model to study human behaviour,

including prescribing behaviour of physicians, is the Theory of Planned Behaviour (TPB) (Ajzen 1991). It assumes that the strength of an intention, the intrinsic motivation, to engage in a certain behaviour is a predictor of actual behaviour. Three different beliefs variables influence the strength of the intention: 1) behavioural beliefs, 2) normative beliefs and, 3) perceived control beliefs or self-efficacy. Behavioural beliefs are determined by beliefs about the outcome of a certain behaviour and the evaluation of this behaviour. In other words, it describes whether a person believes a certain behaviour results in a certain outcome and if that outcome is desirable. It can be influenced by perceptions of risks, past experiences, personal characteristics, knowledge etcetera. Normative beliefs are determined by the perception of views of others towards the behaviour and the motivation to comply to these views. In other words, what do I think others want me to do and do I care what they want me to do? It is a form of perceived social proof regarding what is appropriate or inappropriate behaviour in certain circumstances. Perceived behavioural control refers to the perceived ease or difficulty of performing a certain behaviour and the extent to which performing the behaviour is up to the actor. It is influenced by past experiences, external factors in the environment, seeing others doing it and anticipates on

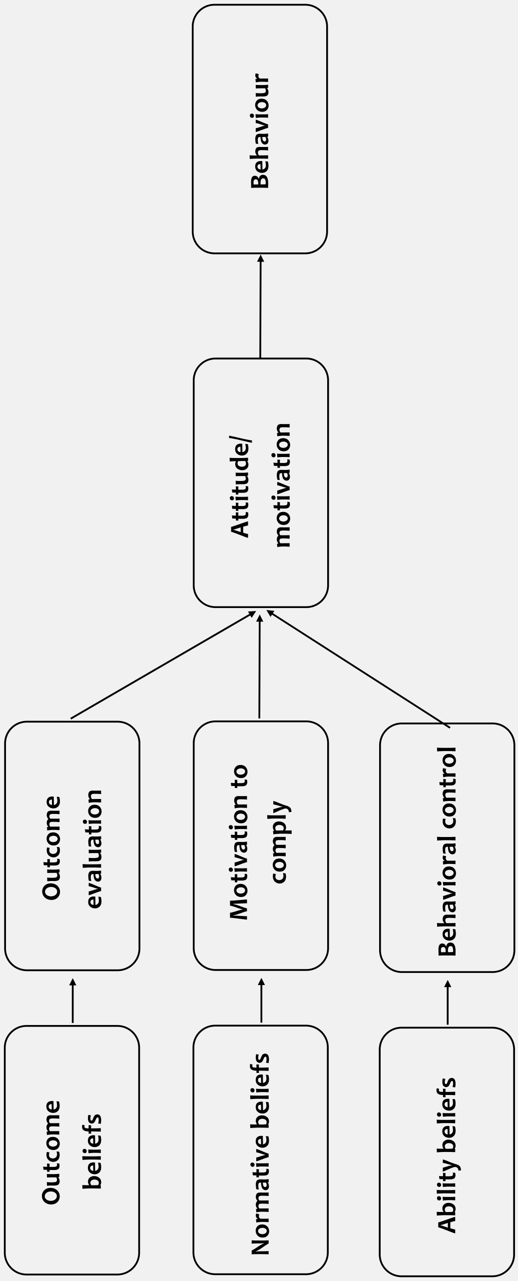

Figure 1. Building blocks of the Theory of Planned Behaviour

perceived impediments and obstacles for performing the behaviour. It is the fundamental belief in one's own ability to "make it happen" (Figure 1) (Ajzen 2002, Jansen, Van den Borne et al. 2009).

Once an intention for a certain behaviour has been established, it needs to progress into action and should be sustained to have a lasting impact. However, here other factors come into play over which an individual mostly has often limited control. The hardware (skills and knowledge) and environment of a person can facilitate or restrict the performance of an actual behaviour through providing enabling and reinforcing factors as resources, tools, knowledge, subsidies or barriers as regulations, organizational constraints, fines etcetera (van Bokhoven, Kok et al. 2003, Ellis-Iversen, Cook et al. 2010).

These intrinsic motivating and enabling factors are combined in the Social Ecology Model (SEM) which focusses on the social and physical settings contextualising human behaviour and includes the interplay between intrinsic motivating and enabling factors (Panter-Brick, Clarke et al. 2006). This model was later adapted by Ellis-Iversen, Cook et al. (2010), to explain the decision making process of dairy farmers related to biosecurity measures.

Enabling factors in this SEM are grouped into 3 groups. The first is the influence of the agricultural community and industry which comprises norms, values, traditions, financial pressures, and regulations within this community. The second is the influence of the outside world, the society, which encompasses laws and regulations, moral values and demands of consumers and the public. The last one is (access to) knowledge, skills, tools and abilities. This may include access to financial resources, specialist knowledge, tools, skills, time, physical abilities, characteristics of the organisation. All these factors can be enabling or restrictive factors for behaviour, but may also influence behavioural beliefs themselves.

Once behaviour change has been established, the person will evaluate the outcomes. These evaluations will in turn feed internal beliefs that drives future behaviour.

Motivations for behaviour

There is extensive knowledge available to substantially prevent or reduce the burden of animal diseases and to lower antibiotic use in production animals; the battle ground is in consistently and effectively implementing the necessary management changes (LeBlanc, Lissemore et al. 2006, Ruston, Shortall et al. 2016). Implementing preventive measures on farms first of all depends on the veterinarians' and producers' understanding of the principles underlying such measures and their motivation for implementing them (Brennan, Christley 2013). Farmers and veterinarians will not change inveterate practices when they see no need for change or when they fear negative outcomes of a behaviour change (Chapters 2 & 3). Only when an intention to change has been established, the process of implementation will start (as explained in the SEM).

Intrinsic motivating factors

Attitudes

Veterinarians

-Decisive link veterinary AMU <=> AMR?

-Reduce AMU => fear of complications

-Believe in efficacy disease prevention on AMU

-Positive beliefs veterinary herd health advisory services; but sometimes demotivating past experiences

-Personal experience great influence on prescribing

Farmers

-Decisive link veterinary AMU <=> AMR?

-Risk and uncertainty avoidance => AMU

-Positive beliefs efficacy veterinary advice

-Wrong frame of reference animal diseases

-(Cost-) effectiveness alternative practices?

-Conflicting advices => uncertainty

-Past experiences effectiveness, costs and revenues influence attitudes preventive measures and AMU

Referents and normative beliefs

Veterinarians

-Professional obligation to secure animal health

-Farmer main customer => service provider => client satisfaction and sympathize with farmers

-Public health interest => prudent and restrictive AMU

-Norm setting bodies => veterinary privileges

-Not always "practice ethos" on prevention?

Farmers

-Veterinarian major referent on prevention and AMU, but do not perceive much "pressure" from veterinarian

-Peer farmers => pressure to be a "good" farmer => some AMU practices as social norm

-Lack peer pressure for disease prevention?

Ability beliefs

Veterinarians

-Sometimes no alternative for AMU; feel not confident to waive antibiotic therapy

-Confidence in own knowledge disease prevention

-Lack belief in capabilities to act as entrepreneurial advisor; independent of farmers' demands/wishes

-Competition other advisers

Farmers

-Sometimes no alternative for AMU; feel not confident to waive antibiotic therapy

-Knowledge => over– or underestimated

-Time and financial constraints to implement preventive measures

-Physical environment does not facilitate changes

-Efforts in AMU useless from global perspective

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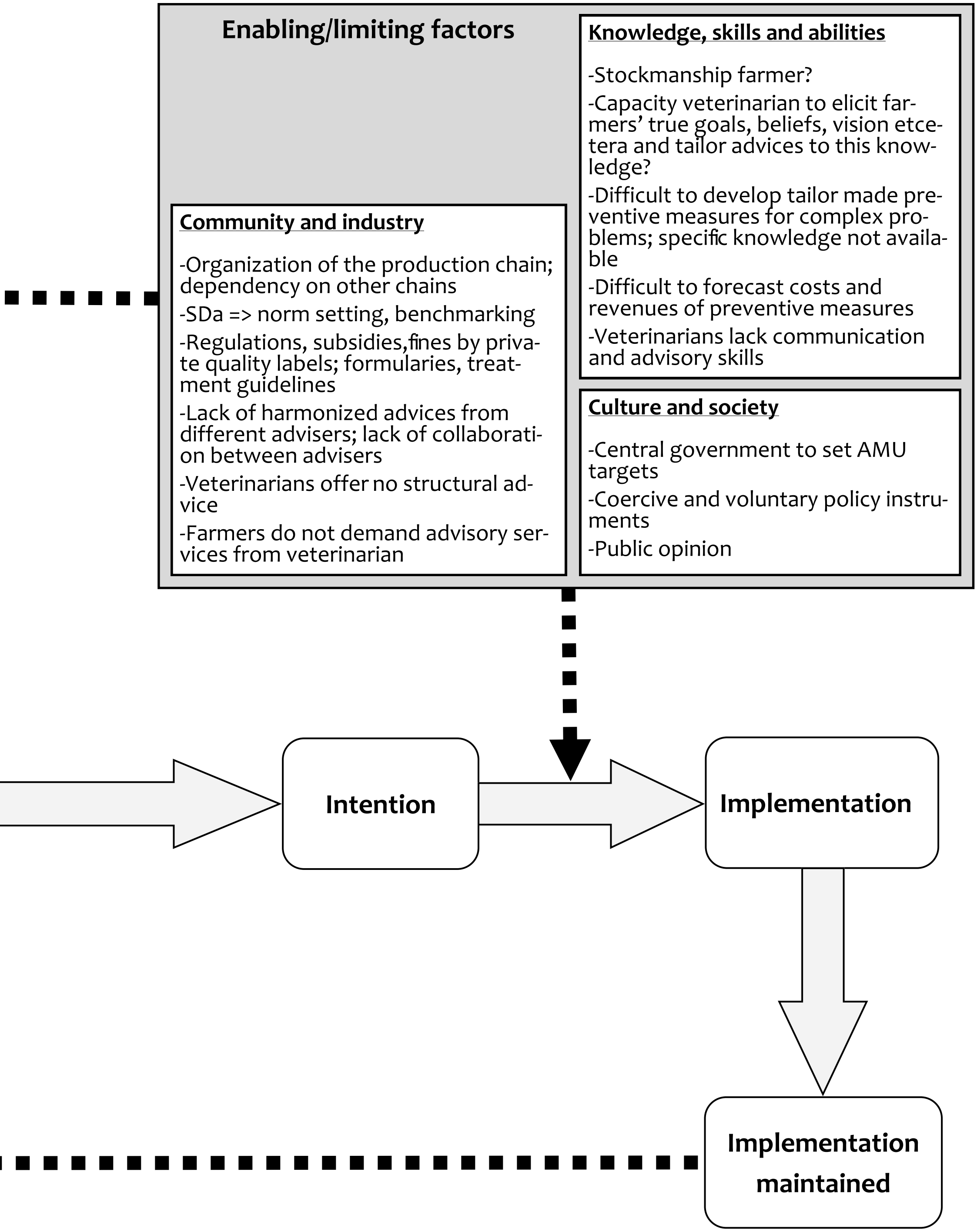

Figure 2. SEM related to the uptake of preventive measures and antibiotic reducing practices by farmers and veterinarians (adapted from Panter-Brick, Clarke et al. 2006).

The role of attitudes

Beliefs of risks related to AMR

The more veterinarians and farmers are aware of potential repercussions of irresponsible antibiotic use in animals, the more likely they will act upon breaking the chain of development of resistance (Sheehan 2013, Kluivers, Binnendrijk et al. 2015, Visschers, Postma et al. 2016). However, when antibiotic use in animals is not perceived as a risk, they will probably be less motivated to reduce antibiotic use. Although AMR is generally believed by veterinarians to be a risk for human health, studies in different European countries indicated that veterinarians do often not consider veterinary antibiotic use to be a large contributor to the global burden of resistance (Coyne, Latham et al. 2016, Coyne, Pinchbeck et al. 2014, Visschers, Backhans et al. 2016). We have found that attitudes of veterinarians in the Netherlands can vary remarkably towards the risks related to antibiotic use. A number of veterinarians might not be aware of, or believe in, the dangers related to antibiotic use in animals (Chapters 2-4). Veterinarians often do not experience serious resistance issues in their own daily practice, which can be a reason to question the link between veterinary antibiotic use and AMR (Chapter 2) (Coyne, Latham et al. 2016). The perceived risks related to antibiotic use in production animals can partly be influenced by culture in a country (Chapter 3) but also can be situational. For example, the higher the perceived necessity or moral obligation for antibiotic treatment in a specific situation, the less the possible risks related to AMR development plays a role in the treatment decision (Simpson, Wood et al. 2007, McNulty, Francis 2010, Jan, McIntosh et al. 2012).

Also farmers may question the connection between antibiotic use in their animals and the development of AMR as a public health issue. Reducing antibiotic use might therefore not be highly ranked on their priority list (Coyne, Pinchbeck et al. 2014, Visschers, Backhans et al. 2016, Visschers, Postma et al. 2016, Friedman, Kanwat et al. 2007, Jones, Marier et al. 2015). It is possible that a number of farmers and veterinarians consider reduction in antibiotic use in production animals as an externally imposed solution for a problem that is not caused by them (Heffernan, Nielsen et al. 2008).

At the same time, other farmers and their family members in the Netherlands indeed became problem owners after they were confronted with the potential personal health risks of antibiotic use in their animals as they were subjected to strict isolation measures at hospital admission to prevent possible Livestock Associated-methicillin-resistant *Staphylococcus aureus* (LA-MRSA) transmission (van Rijen, Van Keulen et al. 2008) (Chapter 1). This made some farmers and veterinarians very critical about antibiotic overuse in animals and becoming front runners in the reduction of antibiotic use.

Antibiotic use as a risk avoiding strategy

A fear of complications can be a major driver for antibiotic use in food producing animals (Chapters 2-4). Quite some veterinarians in our studies were afraid of negative effects on animal health and animal welfare after strongly reducing antibiotic use in

farm animals. Most veterinarians indicated that confronted with a probable but not (yet) confirmed bacterial disease, they prefer to initiate an antibiotic therapy as soon as possible to prevent potential complications (Chapters 2 & 4). Veterinarians might be quite hesitant to take the risk of not prescribing as a 'better safe than sorry' approach, which also plays its part in human medicine (Gibbons, Boland et al. 2013, Hulscher, van der Meer et al. 2010).
Farmers are believed to be risk and uncertainty aversive and there appears to be a widespread fear of negative effects on animal health and welfare after abandoning structural antibiotic use practices during high risk periods (Scherpenzeel, Tijs et al. 2016, Swinkels, Hilkens et al. 2015, Coyne, Pinchbeck et al. 2014, Valeeva, van Asseldonk et al. 2011). In Chapters 5 and 6, we have also found an indication for risk aversive behaviour of farmers to be a possible explanation for a relatively high antibiotic use on dairy farms, as clinical factors could not really explain the higher antibiotic use compared to peer farmers.

Preventive measures and compliance to veterinary advice
Veterinarians in general appear to believe in the efficacy of preventive measures to maintain or improve animal health and reduce antibiotic use (Chapters 2 & 4) (Cattaneo, Wilson et al. 2009). However, the attitudes of veterinarians towards shifting from a curative towards a more advisory role has never really been studied. In our study, 64% of the veterinarians (partly) agreed on the statement "I would like my advising role for farmers to become more prominent in my daily activities" (unpublished). A finding that is confirmed by a study of Hall and Wapenaar (2012).
Farmers also seem to have positive beliefs about the benefits of preventive measures on animal health and antibiotic use (Laanen, Maes et al. 2014, Gunn, Heffernan et al. 2008, Coyne, Pinchbeck et al. 2014). However, in practice the compliance of farmers to these advices appears to be low for several reasons. Farmers may not have a realistic frame of reference on typical animal health parameters, probably influenced by their own experiences or perceived inability (behavioural control) to influence them (Lam, Jansen et al. 2011, Kluivers, Binnendrijk et al. 2015). If they do not perceive a relatively high disease burden, the presence of risk factors for disease or AMR as an issue, they may take it for granted and will not be highly motivated to consider action (Kluivers, Binnendrijk et al. 2015, Sok, Hogeveen et al. 2016, Garforth 2015, Santman-Berends, Buddiger et al. 2014). A re-emerging theme in many studies is the by farmers perceived uncertainty over, or disbelief in, the (cost-) effectiveness of preventive measures compared to current (antibiotic use) practices (Chapters 2 & 3) (Laanen, Maes et al. 2014, Scherpenzeel, Tijs et al. 2016, Garforth 2015, Gunn, Heffernan et al. 2008, Sayers, Good et al. 2014, Alarcon, Wieland et al. 2014, Valeeva, van Asseldonk et al. 2011). The use of antibiotics is regularly believed to be an easier, faster and less expensive solution for a disease problem than upgrading the farm environment, improving feed quality or engaging in expensive vaccination schemes (Chapter 2) (Coyne, Latham et al. 2016).
Another often-mentioned obstacle for farmers to comply to veterinary advices are conflicting and fragmented advices from different (non-veterinary) advisers (Chapters 2 & 3) (Sayers, Good et al. 2014, Ruston, Shortall et al. 2016, Kluivers,

Binnendrijk et al. 2015). Farmers may be tempted to filter veterinary advice with their own beliefs and advices from different advisers and adopt only the ones that fit them (McDougall, Compton et al. 2016, Ruston, Shortall et al. 2016). This may undermine their motivation to adopt the changes suggested by their veterinarian.

Role of inveterate habits and personal experience

Personal experience and habituation largely feed the outcome beliefs of farmers and veterinarians on reducing antibiotic use and the uptake of preventive measures (Chapter 2) (Swinkels, Hilkens et al. 2015, Friedman, Kanwat et al. 2007, Kristensen, Jakobsen 2011, Alarcon, Wieland et al. 2014). If certain measures appear, or are perceived, to sort limited effects on the farm, farmers might discontinue to apply those measures and the motivation to undertake similar interventions in the future might be reduced (Kluivers, Binnendrijk et al. 2015, Brennan, Christley 2012, Garforth 2015, Ellis-Iversen, Cook et al. 2010). At the other hand, positive experiences will probably increase the likelihood that they engage in new measures to prevent animal diseases and reduce antibiotic use (Visschers, Backhans et al. 2016, Alarcon, Wieland et al. 2014).

It is known that engaging in changing (imposed) policies can positively influence attitudes and a tendency is visible that Dutch farmers and veterinarians are changing towards more positive attitudes to restrict antibiotic use in production animals (Chapters 2 & 3) (Edwards-Jones 2006, Visschers, Backhans et al. 2016). This relatively positive attitude of many Dutch veterinarians towards the antibiotic use reducing policy and their optimistic view on antibiotic use reduction targets compared to their peers in other countries might be fed by positive personal experiences with feasible practices to reduce antibiotic use without jeopardizing animal health and productivity (Chapters 2 & 4).

Personal experiences of veterinarians may greatly influence decisions in antibiotic prescribing and engaging in an advisory role. Antibiotic prescribing by veterinarians is largely driven by personal experience as shown in Chapters 2 & 4. Several authors have found that personal experience of veterinarians mostly prevails above evidence based resources, especially when they are conflicting (McDougall, Compton et al. 2016, De Briyne, Atkinson et al. 2013, Vandeweerd, Vandeweerd et al. 2012, Sheehan 2013).

Negative experiences with farmers (perceived to be) not motivated to change or not willing to pay for advice can adversely influence the motivation of veterinarians to (again) adopt this role (Mee 2007, Sayers, Good et al. 2014). It can be very demotivating for veterinarians to advice the same measures over and over again when they are not perceived to be feasible or being followed by farmers (Chapter 2) (Kluivers, Binnendrijk et al. 2015).

Referents and normative believes

Veterinarians are widely seen as the major referent by farmers concerning animal health and can be in the front line for knowledge transfer on prudent antibiotic use practices and feasible preventive measures (Swinkels, Hilkens et al. 2015, Laanen, Maes et al. 2014, Brennan, Christley 2013, Coyne, Pinchbeck et al. 2014, Friedman, Kanwat et al. 2007, Visschers, Postma et al. 2016, Gunn, Heffernan et al. 2008, Jones, Marier et al. 2015, Hall, Wapenaar 2012, Alarcon, Wieland et al. 2014). The approval of the social and advisory network of farmers can be a great driver for the intention to reduce antibiotic use and a positive influence of support from a veterinarian on the intention of farmers to reduce antibiotic use has been observed (Jones, Marier et al. 2015, Visschers, Backhans et al. 2016). Veterinarians are thus important to feed the normative beliefs of farmers and can act as coaches to support farmers in implementing changes. Many studies however concluded that veterinarians largely fall short in adopting this role as pro-active and motivating animal health consultant, and farmers often indicate to only get (technical) advice from their veterinarians on demand (Laanen, Maes et al. 2014, Jones, Marier et al. 2015, Friedman, Kanwat et al. 2007, Hall, Wapenaar 2012, Kristensen, Enevoldsen 2008, Lam, Jansen et al. 2011, Mee 2007, Gunn, Heffernan et al. 2008, Ruston, Shortall et al. 2016, Alarcon, Wieland et al. 2014).

Peer farmers may also greatly influence antibiotic use practices and the uptake of preventive measures by farmers. Specific antibiotic use practices can be considered by the farmers' community as being appropriate (the social norm) to secure animal health and welfare (Coyne, Pinchbeck et al. 2014, Swinkels, Hilkens et al. 2015, Jones, Marier et al. 2015, Alarcon, Wieland et al. 2014). The often reported sub-optimal uptake of biosecurity measures by farmers might partly be explained by a lack of (perceived) social pressure within the farmers' community to adopt them (Ellis-Iversen, Cook et al. 2010, Gunn, Heffernan et al. 2008, Brennan, Christley 2013). At the other hand, farmers' organisations can certainly be influential in promoting disease control measures. For example, the Dutch dairy sector currently promotes eradication of Bovine Virus Diarrhoea and Infectious Bovine Rhinotracheïtis which has led to an increased uptake of control programs. Other important referents can be purchasers of animals and animal products who can impose or stimulate additional measures to be taken by the farmer, but also other advisers from feed and breeding companies (Alarcon, Wieland et al. 2014, Ruston, Shortall et al. 2016).

Veterinarians face many conflicting interests from different sides when prescribing antibiotics and advising on preventive measures. An important factor influencing decision making is the perceived professional, normative obligation to ensure animal health and alleviate animal suffering, if necessary with antibiotics (Chapter 2) (Jan, McIntosh et al. 2012, Coyne, Latham et al. 2016, Dean, McIntosh et al. 2011, Ruston, Shortall et al. 2016). Farmers are undoubtedly the main referents for veterinarians as they work with farmers on a personal and daily basis and farmers are their main source of income. Because the main role of veterinarians is to provide services to farmers, veterinarians are highly motivated to satisfy their clients who are often perceived to demand fast and cheap solutions (Coyne, Latham et al. 2016). A fear of losing a client after a wrong therapy decision might greatly influence decision making by veterinarians (Chapter 2) (Coyne, Latham et al. 2016).

Studies have shown that veterinarians can strongly sympathize with the perceived negative attitudes and financial constraints of their farmers to implement preventive measures and often lack a sense of demand from their clients for advice (Gunn, Heffernan et al. 2008, Sayers, Good et al. 2014, Mee 2007, Kluivers, Binnendrijk et al. 2015, Coyne, Latham et al. 2016). Therefore, veterinarians can be hesitant to act as a

'policeman' denying requests from farmers, or as a 'preacher' preaching unasked advices repeatedly (Chapters 2 & 3). To sustain a good relationship with the farmer, veterinarians might choose to play a more passive advisory role on demand rather than pro-actively stimulating farmers to change (Ruston, Shortall et al. 2016).
Veterinarians are also affected by the interests from the side of the society which demands optimal animal welfare and limited antibiotic use; from regulatory norm-setting institutions who impose regulations on antibiotic use; and other colleagues from whom pressure may be perceived to act in a certain way (Chapters 2-4) (De Briyne, Atkinson et al. 2013, Gibbons, Boland et al. 2013, Vandeweerd, Vandeweerd et al. 2012, Coyne, Latham et al. 2016, Dean, McIntosh et al. 2011, Sheehan 2013). Just over half of the farm animal veterinarians interviewed in a recent study in the UK indicated their practice had a 'preventative ethos', implying that almost half of the veterinary practices did not. Also most practices did not actively promote their preventative skills (Ruston, Shortall et al. 2016). Not much peer-pressure was experienced by veterinarians to promote preventive measures; it was rather based on the motivation of individual veterinarians. We found that younger generation veterinarians seem to be more aware of the necessity of restrictive antibiotic use and have more positive attitudes towards reduction (Chapter 3). This probably reflects increasing attention for the topic in veterinary education and in the society and thus might indicate that the social norm of the veterinary profession is changing.
Norm-setting organisations as the government and private bodies can be important referents as they provide veterinarians with several professional privileges (i.e. prescribing and selling veterinary drugs, inspection tasks etcetera) (Ruston, Shortall et al. 2016). The fear of losing the privilege to prescribe and sell antibiotics for Dutch veterinarians for example appeared to be an important driver to engage in the Dutch policy to reduce antibiotic use in farm animals (Chapters 2-4).

Beliefs in abilities

Veterinarians in our survey generally felt quite confident that they own the technical knowledge to support farmers to considerably reduce the burden of animal diseases and antibiotic use. Of the respondents, 60% (partly) agreed with the statement "I am regularly confronted with sick animals which likely could have been prevented when a farmer had complied to my advice" and 69% (partly) agreed with the statement "If I could monitor animal health on a farm more frequently, antibiotic use on that farm could be lowered further" (unpublished results). Also Visschers et al. (2016), found that veterinarians felt confident that they could support farmers to reduce antibiotic use (Visschers, Backhans et al. 2016).
Although they may believe in their own technical knowledge to advice on animal health improvements on a farm, many veterinarians perceive difficulties to really put this knowledge into practice as animal health management consultant and being paid for accordingly (Chapter 3) (Lam, Jansen et al. 2011, Mee 2007, Ruston, Shortall et al. 2016). This can be related to competition with other veterinarians and non-veterinary advisers, perceived lack of advisory and communication skills and a perceived lack of time or vision within the organisation to invest in advisory skills (Chapters 2 & 3) (Mee 2007, Sayers, Good et al. 2014, Gunn, Heffernan et al. 2008, Hall, Wapenaar 2012,

Ruston, Shortall et al. 2016). For example, in our survey, 38% of the respondents (partly) agreed with the statement “I consider it difficult to obtain a position as adviser amongst all other advisers that advice a farmer” (unpublished).
Veterinarians perceive it beyond their control to impose changes in farmers’ behaviours and may acquiesce in the status quo when they feel their farmers are not motivated or cannot be motivated to change their management (Chapters 2 & 3). A real challenge for veterinarians often is how to convince farmers of a risk or a disease problem (see the frame of reference of farmers described above) and forecasting the (cost-) effectiveness of these measures within a specific farming context (finances, labour) (Kluivers, Binnendrijk et al. 2015, Alarcon, Wieland et al. 2014). Veterinarians might also acquiesce in the status quo when they feel certain complex disease problems are intangible and technical know-how is lacking to specifically control them without the input of antibiotics (Chapter 2) (Kluivers, Binnendrijk et al. 2015).
In Chapter 3, we have shown that the perceived ability of veterinarians to act as an independent animal health adviser is partly dependent on the experience of a veterinarian. Older veterinarians reported to experience less uncertainty to act as independent professional without being influenced by wishes and demands of farmers and other advisers. It is possible that older vets tend to sympathize more with their clients (as described above) as they are more client centred (Chapter 3) and therefore their frame of reference on feasible antibiotic use and disease preventive measures is closer to that of farmers. Younger veterinarians in our studies showed a slightly different frame of reference on feasible antibiotic use reduction goals and acceptance of the Dutch policy compared to their older colleagues (Chapter 3). Where farmers being the major referent for older veterinarians, it could be that younger veterinarians care more about the social acceptance and implications of their acting on society and therefore experience more internal conflicts in decision making. It is easier to act as an independent professional when there is not a huge dissonance between the actual and desired situation (older veterinarians) than where there is a wider gap. On the other hand, it is without doubt that increasing experience makes it easier to deal with different situations and older veterinarians with long lasting veterinarian-client relationships obviously have more authority to act independently.
The more farmers and veterinarians believe in, or have experience with, their abilities to control animal diseases with less or no use of antibiotics, the higher their intention to actively engage in practices to reduce antibiotic use (Visschers, Backhans et al. 2016, Coyne, Pinchbeck et al. 2014, Jones, Marier et al. 2015, Lam, Jansen et al. 2011). However, substantial proportions of farmers and veterinarians see few feasible alternatives for the use of antibiotics to control animal diseases in the current husbandry systems and do not feel confident to operate with less use of antibiotics (Chapters 2 & 4) (Coyne, Pinchbeck et al. 2014, Visschers, Backhans et al. 2016, Scherpenzeel, Tijs et al. 2016, Swinkels, Hilkens et al. 2015, Kristensen, Jakobsen 2011). This will obviously negatively influence the motivation of both farmers and veterinarians to reduce antibiotic use.
When farmers lack belief in their peers to successfully engage in preventive measures, they might lose confidence in their own behaviour being effective as infectious diseases will continue to spread to their farm (Ellis-Iversen, Cook et al. 2010, Gunn,

Heffernan et al. 2008, Brennan, Christley 2013, Heffernan, Nielsen et al. 2008). Likewise, farmers and veterinarians with an already relatively low antibiotic use might tend to believe that their efforts for a further reduction is useless as long as some peers use much more or as long as other countries use much more antibiotics in animal production or they blame human medicine for the AMR problem (Chapter 2).
Time and financial constraints (Chapters 2 & 3) can feed the attitudes of farmers not to implement certain measures as a cost-benefit calculation (cost-effectiveness). However, they can also feed the perceived abilities of farmers to implement certain measures. For example when they have positive beliefs on the benefit of the advised measure but when they do not see how they should afford or organize the implementation of the measure (Hall, Wapenaar 2012, Kluivers, Binnendrijk et al. 2015, Gunn, Heffernan et al. 2008, Coyne, Latham et al. 2016, Alarcon, Wieland et al. 2014).
The physical environment of the farm can be a perceived hurdle to implement certain measures. Farmers may for example believe that implementing these changes is not practically feasible in their current buildings (Coyne, Pinchbeck et al. 2014, Garforth 2015, Kluivers, Binnendrijk et al. 2015, Alarcon, Wieland et al. 2014). Sometimes farmers may also believe that there are no feasible technical possibilities to solve a complex multifactorial disease and acquiesce in the situation (Alarcon, Wieland et al. 2014, Brennan, Christley 2013). This may result in a status of 'cognitive dissonance' where farmers (and obviously also veterinarians) change their beliefs to fit the current situation. Even though they are aware that the current situation might be sub-optimal, they tend to tell themselves that this situation is inevitable or beyond one's control and there is no reason to act (Jansen, Van den Borne et al. 2009, Kristensen, Jakobsen 2011).

From motivation to actual behaviour

Once intention to change is present, personal abilities and external factors should enable the implementation of disease preventive measures and changes in antibiotic use practices. Several factors from our studies and in literature can be obtained that appear to drive or limit a proper implementation of these measures (Chapters 2-4).

Culture and Society

Role of the government
As AMR is a multisectoral problem which touches upon different parts of the society, the containment of AMR needs a comprehensive One Health approach of all involved actors. Commitment and regulation of a central government herein is crucial, but also close involvement of the livestock sectors is crucial (Chapter 1) (Dar, Hasan et al. 2016). Several policy options are available to influence antibiotic use practices in production animals . Behaviour change can be enforced by coercive instruments as regulations and fines. They can also be facilitated by non-coercive instruments which address intrinsic beliefs of prescribers and users of antibiotics via social pressure (social norms), provisions, subsidies and education (Chapters 1 & 2) (Ellis-Iversen, Cook et al. 2010, Visschers, Backhans et al. 2015, Kluivers, Binnendrijk et al. 2015, Van Woerkum, Kuiper et al. 1999). Coercive instruments can be fast in inducing changes in antibiotic

use practices in medical healthcare (Davey, Brown et al. 2013). The Dutch approach has shown that it can also be quite fast in inducing changes in antibiotic use practices in animal production (Chapter 1). The introduction of strict mandatory usage targets by the Dutch government was clearly required as there was hardly any reduction of total veterinary antibiotic use after signing a voluntary Memorandum of Understanding. However, enforced behaviour changes may only last in the presence of enforcement which requires high inputs and can result in illegal antibiotic use practices (Cleveland- Nielsen, Aarestrup et al. 2007). Only when farmers and veterinarians have adopted an internal drive to change, it will be more likely that the changed behaviour will be maintained in the absence of regulations and strict enforcement. The example of the ban on the use of antimicrobial growth promoters (AGPs) (Chapter 1), where the AGPs were simply replaced by therapeutic doses of antibiotics, makes clear that a unilateral restrictive policy without touching on intrinsic beliefs of farmers and veterinarians did not sort much effects. In the current Dutch strategy there has been a more comprehensive approach and a mix of compulsory and voluntary instruments whereby the Dutch government adopted a more facilitating role. There was a high involvement of farmers and veterinarians via their organizations in choosing the policy mix to accomplish the targets set by the government which may have positively influenced their motivation to comply (Chapter 1).

Role of the public opinion

Public opinion can be very influential in political agenda setting which might induce policy changes (Freimuth, Linnan et al. 2000, Baumgartner F.R., Jones B.D. and True J.L. 2007). Experiences in Sweden, Denmark and Germany showed that consumer concerns initiated restrictions in antibiotic use (Bager, Aarestrup et al. 2000, Ungemach, Müller-Bahrdt et al. 2006, Hayes, Jensen et al. 2002). Also, the Dutch experience clearly showed that not much changed in veterinary antibiotic use until societal concerns put this issue prominent on the political agenda. Another possible influential factor was the increase of socio-ethical concerns about the contemporary large-scale livestock industry perceived to be associated with impaired animal welfare, misuse of antibiotics, risks of animal to human transmission of pathogens and environmental pollution which put pressure on the livestock sectors to evolve towards more sustainable husbandry systems (Croney, Apley et al. 2012).

Need for global action

Although debate exists about the quantitative attribution of antibiotic use in food animals to antibiotic resistance in human pathogens, there are strong indications that there is animal-human transmission of antibiotic resistance which justifies the application of the precautionary principle to reduce veterinary antibiotic use (Swann, Baxter et al. 1969, Bager, Aarestrup et al. 2000, Smith, Dushoff et al. 2005, Aarestrup, Wegener et al. 2008, European Commission 1999, 2000). The livestock sector is internationally oriented and has large economic impacts. Unilateral policy measures of one country might introduce a competitive disadvantage for its own livestock sector, promote illegal imports of antibiotics and at the end of the day sort only moderate effects because antibiotic resistant pathogens will simply enter the country from abroad (Chapter 2).

An increased global awareness of the possible adverse effects of extensive antibiotic use in animals is now visible, especially in the highly-industrialized countries and at supra-governmental level (i.e. the World Health Organization (WHO), Food and Agricultural Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE)) (World Health Organization 2015, Orand, Moulin et al. 2016, Food and Agricultural Organization 2015). These developments could well be used by governments and other interest parties to expand and exploit the evolving window of opportunity to change antibiotic policies and practices (Speksnijder, Mevius et al. 2015).

An extensive amount of evidence is available to guide (government led) antimicrobial stewardship programs in production animals, especially in developed countries (Scott Weese, Page et al. 2013, Page, Gautier 2012, Aarestrup, Wegener et al. 2008, Dar, Hasan et al. 2016, O'Neill 2016, Laxminarayan, Van Boeckel et al. 2015, World Health Organization 2016). Seen some large reductions in antibiotic use in production animals in several countries, a reduction of antibiotic use should be very feasible in a number of other countries (Grave, Torren-Edo et al. 2010, Grave, Jensen et al. 2006, Speksnijder Mevius et al. 2015, Dar, Hasan et al. 2016, Gelband 2015). It however requires political will and commitment of all relevant stakeholders to combat AMR (Dar, Hasan et al. 2016). In all circumstances, policy makers should be aware that antibiotic use is a result of human behaviour and the specific drivers and barriers for behaviour change of the involved actors should be considered in the development of effective policies. In other words, policies should be tailor made to the local context and the use of sociological models to understand behaviour and behaviour changes could assist in tailoring these interventions.

Community and Industry

Some factors influencing disease dynamics and antibiotic use are completely beyond the control of the individual farmer and veterinarian which thus limits their operating framework. In several animal sectors (e.g. veal calves and broilers), farmers are dependent on the resilience of the supplied animals to cope with stress factors and high loads of pathogens (Chapters 2 & 4). Some herds/flocks seem to be very susceptible for disease which can greatly be traced back to management circumstances earlier in the production chain (Kluivers, Binnendrijk et al. 2015). Also, feed quality is mentioned to be an important factor in the susceptibility for diseases and related antibiotic use (Chapters 2-4), but sometimes is beyond the control of the farmer as this can be specified by the integration which supplies the animals (Kluivers, Binnendrijk et al. 2015).

Interaction between farmers, veterinarians and non-veterinary advisers

It is found that veterinarians do give a lot of advice to farmers; however, it is questionable if these advices are always in accordance with the farmer's needs, beliefs, and risk perception. A farmer should be receptive for the message/advice of an adviser in order for an advice to land (Kristensen, Jakobsen 2011).

What became clear from our studies (Chapters 2 & 3) is that advices of different advisers are often not harmonized. This potentially leads to confusion at the level of the farmer. A lack of collaboration between farmer's advisers can be a major cause for this lack of harmonization. Most of the advisory teams in our intervention study (Chapters 5 & 6) had never sat together in this configuration prior to the study. Almost three quarters of the dairy veterinarians in the UK indicated not to liaise with other advisers (Hall, Wapenaar 2012). In the study of Sayers, Good et al. (2014), over 60% of the farm animal veterinarians indicated not to communicate with other advisers on a regular basis, indicating this is a widespread phenomenon in modern animal production systems.

Professional standards and regulations

The tightened status of the veterinary formularies and the introduction of veterinary treatment guidelines in the Netherlands (Chapter 1) have further narrowed the operating framework of veterinarians and farmers regarding antibiotic use. However, as the formularies and guidelines have been developed by veterinarians themselves, they can assist practitioners in evidence based decision making and convincing farmers to adopt this decision. A remarkable observation was the relatively high priority given to formularies in treatment decisions of Dutch veterinarians compared to their Flemish counterparts, although personal experience still surpassed formularies in these decisions (Chapter 4). This probably can be explained by the legal status of the formularies in the Netherlands to direct antimicrobial treatment decisions in production animals and the long history of these formularies in Dutch veterinary practice (Chapter 1). The veterinary treatment guidelines on selectively drying off dairy cows and on prevention and treatment of *Streptococcus suis* infections in weaned piglets have really given direction to prudent antibiotic use practices in both sectors and showed to be effective in reducing antibiotic use whilst maintaining animal health (Chapters 5 & 6) (Navis 2016). It indicates that formularies and guidelines can be quite important in guiding prescribing decisions when they are perceived as trustworthy by veterinarians.

The introduction of benchmarking of antibiotic use and prescribing by the Dutch Veterinary Medicines Authority (SDa) has certainly had a great impact on Dutch veterinarians and farmers (Chapter 1). It was not only a tool to enforce compliance, as high users and prescribers could be sanctioned, but it also influenced the social norm as farmers were able to compare their antibiotic use with that of peers. Veterinarians ranked this as a very effective measure to reduce antibiotic use at farm level (Chapters 3 & 4).

Knowledge, skills, and abilities

"If you can get decent buildings, a decent level of stockmanship, decent health status and a reasonable vaccination program, then a lot of farms would manage with very little antibiotics", a pig veterinarian stated in a recent study of Coyne, Latham et al. (2016), which more or less echoes our findings in Chapter 2. Proper "stockmanship" skills of farmers are essential for an early recognition of risk factors for disease and taking prompt risk management actions (Raad voor Dieraangelegenheden 2016,

Coyne, Latham et al. 2016, Ellis-Iversen, Cook et al. 2010). When a farmer lacks these skills, it will be difficult to change the management on that farm. Veterinarians and other advisers may to some degree supervise and coach such farmers to increase his stockmanship (Chapter 2). However it is ultimately the farmer who should do the job and it is questionable if every farmer can successfully adopt these skills.
Financial and time constraints can be perceived as constraints by veterinarians and farmers to implement certain measures, but they can also be real when financial reserves or human resources are lacking to invest in decent buildings or for changing management practices (Chapter 2) (Kluivers, Binnendrijk et al. 2015).
In some instances, farmers might overestimate their knowledge and skills to successfully implement preventive measures and can be 'unconsciously incompetent' (Hall, Wapenaar 2012). This can potentially be dangerous as ill-thought measures can result in negative experiences which in turn will feed future motivations to engage in disease preventive measures as mentioned earlier in this general discussion and discussed in Chapter 6 (Brennan, Christley 2012). Other farmers might however be aware of their lack of knowledge (Alarcon, Wieland et al. 2014). This can either result in farmers actively seeking for this knowledge or it could lower the belief of a farmer in his/her abilities to control a disease without the use of antibiotics.
As stated earlier, there is extensive knowledge available to substantially prevent or reduce the burden of animal diseases and to lower antibiotic use on most farms. Although the technical knowledge of veterinarians on some specific topics is sometimes questioned (nutrition, climate), veterinarians in general own a lot of technical knowledge or have access to this (Chapter 2) (Kristensen, Enevoldsen 2008, Gunn, Heffernan et al. 2008, Kristensen, Jakobsen 2011). The challenge for veterinarians is to translate this expert knowledge to a specific farm situation. An often described observation is that veterinarians are more preachers than psychologists; the farmer's true goals, needs, beliefs, values, knowledge etcetera are often not elicited through asking questions and active listening (Derks, van Werven et al. 2012, Hall, Wapenaar 2012, Ruston, Shortall et al. 2016, Kristensen, Jakobsen 2011, Jansen, Steuten et al. 2010, Sayers, Good et al. 2014). Technical knowledge is simply provided with the assumption that this will lead to behaviour change of a farmer (Lam, Jansen et al. 2011). Several authors have stated that veterinarians should invest in their communication and advisory skills. Just being a skilled practitioner ("fire brigade") for emergency work is thought to be insufficient to remain in business in the future. They should obviously invest more in knowledge of herd health dynamics, data management and communication and coaching skills (Chapter 2) (Kristensen, Enevoldsen 2008, Gunn, Heffernan et al. 2008, Lam, Jansen et al. 2011, Mee 2007).

Intervention study

Improving animal health can be an important approach to reduce the need for antibiotic use (Chapter 2). From our intervention study, it can be concluded that working in a structural animal health planning approach can overcome the frequent mismatch between farmers and veterinarians in goal and priority setting and the selection of proper measures; overcome the issue of conflicting and fragmented advices from different advisers; and result in a high compliance to action points (Chapters 5 & 6). The finding that the majority of the farmers continued advisory team meetings after finalizing the study, where most of them did not have such a form of consultation prior to the study, indicates that this approach of initially facilitated animal health planning can result in sustainable animal health planning in an advisory team configuration. The heavy involvement of the farmer and his daily advisers leading to ownership, eliciting true goals, beliefs and values leading to tailored advices and frequent follow up can greatly improve structural animal health planning in the future (Green, Leach et al. 2007, Tremetsberger, Winckler 2015, Kristensen, Jakobsen 2011).

Another conclusion that can be drawn is that lowering antibiotic use does not have to jeopardize animal health and productivity when approached in a structural way, a finding that has been confirmed by others (Postma, Vanderhaeghen et al. 2016, Ivemeyer, Smolders et al. 2012, Vaarst, Bennedsgaard et al. 2006).

At the start of the intervention study, the assumption was that a relatively high antibiotic use could be explained by a higher disease incidence. Following this paradigm, our hypothesis was that improving animal health would lower (the need for) antibiotic use. Although many animal health parameters improved and antibiotic use has significantly been reduced in our study, clear relationships between disease incidences and antibiotic use could not be found. This leads to the impression that antibiotics on these farms were (partly) used to mask uncertainty about the diagnose or course of an infection/disease. It has recently also been found by other authors that non-clinical reasons of farmers (and probably veterinarians) can highly influence antibiotic use at farm level (Stevens, Piepers et al. 2016, Swinkels, Hilkens et al. 2015, Scherpenzeel, Tijs et al. 2016). The attitudes towards antibiotic use and AMR, perceived social norms and perceived control of farmers and veterinarians regarding managing certain infections/diseases with less or no use of antimicrobials were however not specifically addressed in our study. With hindsight, this proved to be an omission in our intervention study and should be incorporated in future on-farm studies trying to improve antibiotic use practices.

Implications for future research, policy and practice

Communicate need for restrictive use of antimicrobials

Although the contribution should not be exaggerated, it is of utmost importance that veterinarians and farmers are aware of the necessity to reduce antibiotic use as far as reasonably possible. As veterinarians are the main and trustworthy information source for farmers, it is important to use this information channel to inform farmers. Also peer farmers can act as opinion leaders, for example farmers that were personally confronted with AMR issues. Veterinarians can best be informed via their veterinary organisations, peer meetings and veterinary journals as they are highly trusted.

Sharing and stimulating best practices
Farmers and veterinarians largely navigate on their own experience and experiences of trustworthy peers in their daily decisions. Best practices and experiences of peers should be exchanged to encourage others. Veterinary and farmers associations and veterinary colleges can play a huge role herein and influence social norms and collective experience. A very important finding from literature is that farmers' confidence in implementing change is reinforced by influential referents such as their veterinarians and peer farmers so that they can proceed from an intention to change to a maintained control measure (Ellis-Iversen, Cook et al. 2010, Lam, Jansen et al. 2011).

Veterinary herd health advisory services
The challenge for veterinarians is in effectively guiding the farmer with advices that address the farmers' values, beliefs, risk perceptions and needs. When giving advice, veterinarians should start to match the beliefs, and risk perceptions of a farmer and identify areas of cognitive dissonance that should be addressed. Veterinarians should acquire the skills to show the (cost-) effectiveness of proposed measures. Subsequently, veterinarians should continuously stimulate and encourage farmers to develop and implement their own risk management practices to ensure ownership. This requires coaching skills as trust, empathy, listening skills, tact and diplomacy, competency, dedication, honesty, and openness of a veterinarian (Kristensen, Jakobsen 2011, Lam, Jansen et al. 2011).

Harmonization of advices and collaboration in the production chain
There is an urgent need for advices of different advisers to be harmonized when it comes to implementing disease prevention measures. Important advisers in a farmer's environment should try to articulate the same message (Ruston, Shortall et al. 2016, Lam, Jansen et al. 2011, McDougall, Compton et al. 2016). Improvement in communication and standardization of advice across service providers would likely lead to greater trust amongst clients in the provided information (Sayers, Good et al. 2014). As several actors in the production chain are often interdependent, it requires a collaborative chain approach to reduce antibiotic use in production animals. Several promising initiatives have been conducted and successful ones should be further rolled out.

Research
The role of risk perception and uncertainty avoidance in antibiotic use practices of both veterinarians and farmers has until now hardly been studied but can be more important than previously assumed. Studies trying to elucidate differences in attitudes, risk perceptions and management decisions between high and low antibiotic users and prescribers to identify best practices are therefore urgently needed to tailor specific interventions aiming at further reducing antibiotic use in production animals.

To assist the uptake of preventive measures by farmers, it is necessary to show them how proposed measures will impact key performance indicators. Several on-farm decision tools to show the costs related to certain animal diseases are widely available, but how they relate to costs associated with preventive measures is often hard to calculate. Proper calculation tools showing the (cost-) effectiveness of many recommended biosecurity practices obviously needs further research (Brennan, Christley 2012).

Policy making

Where possible, governments should try to stimulate and enable front running initiatives that aim at producing with a minimum input of antibiotics by means of provisions or altered regulations. The recently implemented new UDD measure for example has more flexible regulations for farmers using low amounts of antibiotics and can be a promising way to motivate farmers to continue to reduce or stay at a low usage level (Ministry of Economic Affairs, The Netherlands 2016).

At the other hand, notoriously high users and prescribers of antibiotics need sanctioning and probably an ultimate sanction could be to withdraw a license to produce/operate. As shown by our studies, a policy mix of a government setting strict targets but leaving it to the stakeholders on the ground to develop and implement specific approaches to accomplish these targets has proved to be working well. Additional policies in the future should try to address the specific intrinsic drivers for change as well as enabling factors to make a change possible.

There is an urgent need for an international One-Health approach and a level playing field in legislation and regulation of antibiotic use practices. Joint efforts, coordinated by organisations like the EU, WHO, OIE and FAO are currently being conducted. It is now up to individual countries to join these efforts and start developing and subsequently implementing National Action Plans to combat antimicrobial resistance (World Health Organization 2015). Political will and global collaboration will be the only way to deal with the global threat (O'Neill 2016).

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Summary

From the 2nd World War onwards, antibiotics were increasingly applied in animal husbandry. Despite growing concerns that widespread use of antibiotics in animals could select for antibiotic resistance with possible transmission to humans, the Netherlands in 2007 was one of the most consuming countries in Europe. Together with the discovery of large reservoirs of methicillin resistant *Staphylococcus aureus* (MRSA) and Extended Spectrum Beta Lactamase (ESBL) producing bacteria in Dutch livestock, this resulted in political and social pressure to curb the use of antibiotics. In 2010, the Dutch government formulated strict reduction targets: the antibiotic use in animals must be reduced by 50% in 2013. The Minister of Agriculture left it up to the livestock sectors to develop and implement measures.
Part of these measures were transparency in and benchmarking of antibiotic use at individual farm level. Preventive use of antibiotics became prohibited by law and the use of certain antibiotics (highest prioritised critically important antimicrobials for human use) in farm animals became restricted. Farmers could only obtain veterinary services and veterinary medicines from one single veterinary practice with which a farmer had to develop a farm health plan and animal treatment plan and update these plans annually. This would give the farm veterinarian more insight in the animal health status and antibiotic use at farm level. For veterinarians, a quality system was established. This included the development of specific veterinary guidelines to support treatment choices, and to encourage responsible use of antibiotics.
These initiatives have led to a reduction in antibiotic use by 58.4% between 2009 and 2015. Following this reduction, a slow decline in resistance levels in commensal *Escherichia coli* from animals have been noticed in the national surveillance for antimicrobial resistance. Over the last two years, the decline in antibiotic use levels off. Still, there remains much variation between farms and between veterinarians in the level of antibiotic use. For a further reduction in antibiotic use, new and tailored interventions at farm level are warranted. Because veterinarians are gatekeepers with regards to antibiotic use in animal husbandry, a good understanding of factors influencing their prescribing behaviour is essential for targeted policies.

In **Chapter 2** a qualitative study has been described with veterinarians participating from the various livestock sectors. Veterinarians saw themselves primarily as a doctor for sick animals and as animal health consultant for farmers. They believed it was their moral and professional duty to treat sick animals in the best possible way and wanted to be able to use antibiotics to avoid any animal suffering. Respondents stressed the importance to regularly check (possible risk factors for) animal health together with a farmer and to subsequently specifically advice these farmers based on their findings. A frustration was that advices to prevent animal diseases are often not accepted by farmers. This regularly led to a situation in which antibiotic treatment became unavoidable. According to the respondents, an important motive for farmers not to implement their advices was because of economic considerations, workload and

conflicting advice from other advisors. In addition, veterinarians not always manage to convince farmers of the effectiveness of certain specific measures.
Veterinarians are often in a complex tension between the social pressure to carefully prescribe and use antibiotics versus the competitive environment in the animal husbandry sector in which much revolves around the economy. Veterinarians are greatly dependent on their farmers for their income and an explicit demand for antibiotics felt difficult to refuse.
Veterinarians differed in their attitudes on the consequences of antibiotic use in animals. Some were very concerned about the possible contribution of veterinary antibiotics to the problem of antimicrobial resistance and were very motivated to reduce antibiotic use as much as possible whereas others had their doubts. Some shared their fear that the sharp reduction targets would be detrimental to animal health and animal welfare.

The results of this qualitative work have been used to develop a questionnaire which has been sent to all farm animal veterinarians working in the Netherlands in 2012 (**Chapter 3**). The respondents could be divided into three groups: veterinarians who were particularly engaged with intensive husbandry sectors, particularly dairy veterinarians and generalists who dealt with all kinds of animals.
Young veterinarians, veterinarians particularly working in dairy and the generalists seemed to feel more insecure to take treatment decisions independently from the wishes and demands of farmers compared to older veterinarians and veterinarians working in intensive husbandry sectors.
Compared to younger vets, older veterinarians seemed to be less concerned about a possible contribution of veterinary antibiotic use to the issue of antimicrobial resistance; they appeared to feel less hesitation to administer antibiotics in case of an uncertain diagnosis or even to use antibiotics preventively in order to avoid animal diseases. They are also more often worried about the possible decoupling of prescribing and dispensing veterinary drugs and thus losing the veterinary pharmacy.
Veterinarians working in the intensive husbandry sectors regarded improvements in feed quality and benchmarking of antibiotic use as promising measures to reduce the use of antibiotics. Veterinarians working in dairy and generalists also rated improvements in housing and climate in stables as an important measure.
In the intensive husbandry sectors, conflicting advice of other, non-veterinary, advisors are seen as a very important reason farmers do not follow up veterinary advice. Also, respondents indicated that implementing these advices can be perceived by farmers as too time consuming. Veterinarians working in dairy and generalists indicated that major hurdles for accepting veterinary advice are in the perception of farmers regarding the costs and time investments that implementing those advices would bring along.
Future interventions could focus on supporting young veterinarians to make well-balanced decisions as an independent professional without being directed by wishes and opinions of farmers and other advisors. Older veterinarians would probably benefit from education on the risks related to antibiotic use in animal husbandry and ways to become less dependent on the veterinary pharmacy.

The same survey has also been sent out in Flanders (Belgium) in the same period (**Chapter 4**). Where Dutch veterinarians saw inadequate climatic conditions, economic considerations of farmers, and insufficient immunity of young animals as main causes for high antibiotic use, Flemish colleagues especially regarded poor biosecurity and the risk averse mentality of farmers as main cause for antibiotic use, together with poor climate conditions. Nearly two-thirds of the Dutch respondents expressed their support for the policy to halve the use of antibiotics in livestock farming, compared to only one-third of the Flemish veterinarians who expressed to support a similar policy in Flanders. Flemish respondents were significantly more pessimistic about the probable adverse effects on animal health and welfare of a halving of antibiotic use in animal husbandry compared to Dutch veterinarians. They also appeared to be more pessimistic with respect to the antibiotic use reduction that would reasonably be possible in animal husbandry in the coming years compared to their Dutch colleagues. Flemish veterinarians reported significantly more often to have no difficulty to apply antibiotics preventively in order to avoid infectious diseases compared to the Dutch.
Asked after possible solutions for the high use of antibiotics, especially improvements in housing and climate, increasing biosecurity (especially in Flanders), and the targeted eradication of certain specific infectious diseases were mentioned.
A part of the found differences between Flemish and Dutch veterinarians may have been driven by differences in policies. Where Dutch veterinarians were working under an imposed reduction policy, Flemish veterinarians were working under a policy which aimed to raise awareness on prudent antibiotic use, without strict reduction targets. The fact that Dutch veterinarians had personally experienced how a substantial reduction in antibiotic use could relatively easy be established without obvious adverse effects on animal health and productivity, may have positively changed their attitude towards being more supportive of the current policy.
The impression exists that Flemish farmers and veterinarians have a higher degree of risk aversion and thus are more likely to use antibiotics to prevent an eventual complication. The positive experiences of the reduction policy in the Netherlands could be shared with Flemish colleagues to show how a reduction in antibiotic use is achievable without adverse effects on animal health and productivity.

In **Chapter 5 and 6** the design and results are described of an intervention study conducted on conventional dairy farms in the Netherlands. The study facilitated the collaboration between farmer, veterinarian, and feed adviser in a such called advisory team through training and by adding a professional facilitator.
In a randomized cross-over study, two groups of dairy farmers, with a higher than average use of antibiotics, followed the intervention in two successive years. In the other year, these groups acted respectively as controls or as monitoring group.
At the start of the intervention period, a structured animal health plan was drafted by the advisory team under the guidance of a facilitator. The implementation of this plan has been followed for one year by the facilitator and then evaluated with the team.
It became clear that teams who managed to work well and constructively together were better able to implement their action plan and managed to achieve more

objectives at the end of the intervention period. A key factor for success is ownership of a farmer regarding the animal health plan. For advisers, it is important to assess the needs and possibilities of a farmer and to subsequently tune the advice on the specific context of a farmer. At the same time, advisers should be critical to identify points of improvements and communicate those properly to the farmer.
The immediate effect of the intervention on the use of antibiotics at farm level was less clear. It might take more time before management measures sort effects on antibiotic use. Observational data over the two years of the study, all farms in the study on average managed to reduce their antibiotic use with 17%. It could be observed that farms which managed to gradually reduce their antibiotic use were also able to simultaneously slightly improve animal health parameters. Considering udder health, a significantly positive relationship existed between reducing antibiotic use and reducing the incidence rate of mastitis. This implies that antibiotic use can be reduced while simultaneously sustaining or even improving animal health in a structured approach of animal health.
A remarkable finding is that little relationship was found between antibiotic use and animal health parameters on the study farms. We hypothesize that not only animal health, but also the degree of risk perception and risk averseness affects the use of antibiotics on dairy farms. This is confirmed by several other recent publications. Future research needs to be focused more on these aspects related to the influence of knowledge, attitude and behaviour on antibiotic use in animal husbandry.

In **Chapter 7** the results are being discussed. It is clear that reducing antibiotic use in animal husbandry has much to do with behavioural changes of both veterinarians and farmers. From behavioural sciences, it is well known that human behaviour is rather difficult to change. Coercion is not always the most effective approach and therefore, ways should be found to stimulate voluntary behaviour changes.
It is important to distinguish between internal motives that induce an intention to change a behaviour and external influences which can limit or enable the actual change in behaviour. Many of these internal and external influences can be influenced when insight is obtained into how these factors play a role in behavioural changes.
In the reduction of antibiotic use in animal husbandry, many of these factors play an important role. Attitudes on possible risks of antibiotic use for public health, fear of complications after omitting an antibiotic treatment, uncertainty on the effects of certain preventive measures, the level of perceived pressure from the social environment, and the degree to which a person believes to be able to be a good veterinarian or farmer with less use of antibiotics all play a role in the internal motivation to work at a reduction of antibiotic use.
External factors can be traced back to cultural and societal influences like regulations, public opinion on antibiotic use in animal husbandry, organization and logistics of the animal production chain and finally the abilities of veterinarians and farmers to actually reduce the use of antibiotics.
Clear communication on the value and necessity of reducing antibiotic use and the risks related to the use of antibiotics in animal husbandry to farmers and veterinarians is crucial. Mapping and communicating best practices might support veterinarians and

farmers in making decisions which influence antibiotic use. To prevent animal diseases as much as possible, it is important that animal health at farm level is approached in a structural way in a collaborative effort between a farmer and the different advisers. Future studies should provide more insights into the role of various internal and external factors on antibiotic use in farm animals. Finally, there is the urgency for an international uniform policy to reduce antimicrobial resistance at the global level.

Nederlandse samenvatting

Vanaf de 2e Wereldoorlog werden antibiotica op steeds grotere schaal ingezet in de veehouderij. Ondanks toenemende zorgen dat grootschalig antibioticagebruik bij dieren kon selecteren voor antibioticaresistentie met mogelijke transmissie naar mensen, was Nederland in 2007 één van de meest gebruikende landen binnen Europa. Samen met de ontdekking van grote reservoirs van methicilline resistente *Staphylococcus aureus* (MRSA) en Extended Spectrum Beta Lactamase (ESBL) producerende bacteriën in de Nederlandse veestapel leidde dit tot politieke en maatschappelijke druk om het antibioticagebruik in te perken. In 2010 formuleerde de Nederlandse overheid strikte reductiedoelstellingen waarmee in 2013 het antibioticagebruik zou moeten zijn gehalveerd. Het opstellen en uitvoeren van maatregelen werd grotendeels aan de diersectoren overgelaten.
Onderdeel van de maatregelen waren transparantie en benchmarking in antibioticagebruik op individueel bedrijfsniveau. Preventief antibioticagebruik werd verboden en er werden restricties opgelegd ten aanzien van welke antibiotica toegepast mochten worden bij dieren. Veehouders mochten enkel diensten en medicijnen betrekken bij één dierenarts(enpraktijk) waarmee ze jaarlijks een bedrijfsgezondheidsplan en een bedrijfsbehandelplan moesten opstellen en evalueren. Hiermee kreeg de bedrijfseigen dierenarts meer inzicht in diergezondheid en het antibioticagebruik op bedrijfsniveau. Voor dierenartsen werd een kwaliteitssysteem opgericht. Onderdeel hiervan was het ontwikkelen van specifieke veterinaire richtlijnen als ondersteuning voor behandelkeuzes en als stimulans voor verantwoord antibioticagebruik.
Deze initiatieven hebben geleid tot een reductie in antibioticagebruik van 58,4% tussen 2009 en 2015 en blijkt tevens dat resistentieniveaus van commensale *Escherichia coli* isolaten in landbouwhuisdieren in de routinemonitoring langzaam afnemen. De laatste twee jaren vlakt de daling in het antibioticagebruik af. Wel blijft er veel variatie is tussen bedrijven en dierenartsen in antibioticagebruik. Om het antibioticagebruik verder te laten dalen zijn nieuwe en gerichte maatregelen op bedrijfsniveau nodig. Omdat dierenartsen poortwachters zijn voor het antibioticagebruik in de veehouderij, is een goed begrip van factoren die van invloed zijn op hun voorschrijfgedrag essentieel voor gerichte beleidsmaatregelen.

In **hoofdstuk 2** wordt een kwalitatieve studie beschreven onder landbouwhuisdierenartsen uit de verschillende veehouderijsectoren. Dierenartsen zagen zichzelf in de eerste plaats als dokter voor zieke dieren en als diergezondheidsconsulent voor veehouders. Ze vonden het hun morele en professionele plicht om zieke dieren zo goed mogelijk te behandelen en wilden daarbij antibiotica in kunnen zetten om eventueel lijden te kunnen voorkomen. Dierenartsen benadrukten het belangrijk te vinden om regelmatig met de veehouder mee te kunnen kijken naar (mogelijke risicofactoren voor) diergezondheid en gebaseerd op hun bevindingen veehouders gericht te kunnen adviseren. Een grote frustratie was

dat adviezen om dierziekten te voorkomen vaak niet worden overgenomen door veehouders. Dit leidde regelmatig tot een situatie waarin een behandeling met antibiotica onontkoombaar werd. Een belangrijk motief voor veehouders om adviezen niet uit te voeren lag volgens de respondenten in de economische sfeer, werkdruk en in conflicterende adviezen van andere adviseurs. Daarnaast lukt het dierenartsen niet altijd om veehouders te overtuigen van de effectiviteit van bepaalde maatregelen.
Dierenartsen bevinden zich in een lastig spanningsveld tussen de maatschappelijke druk om zorgvuldig met antibiotica om te gaan en de competitieve omgeving binnen de veehouderij waarin veel draait om de economie. Dierenartsen zijn afhankelijk van hun veehouders voor hun inkomen en een expliciete vraag om een antibioticakuur weigeren voelt dan heel moeilijk.
Dierenartsen verschilden in hun opvattingen over de consequenties van antibioticagebruik bij dieren. Enkelen waren erg bezorgd over de mogelijke bijdrage van veterinair antibioticagebruik aan het resistentieprobleem en waren erg gemotiveerd om zoveel mogelijk antibioticagebruik te reduceren. Anderen hadden hun twijfels. Enkelen ventileerden ook de angst dat de forse reductiedoelstellingen ten koste zouden gaan van diergezondheid en dierwelzijn.

De resultaten van dit kwalitatief onderzoek zijn verwerkt in een vragenlijst onder landbouwhuisdierenartsen die in Nederland werkzaam waren in 2012 (**hoofdstuk 3**). De respondenten waren in te delen in 3 groepen: dierenartsen die voornamelijk werkzaam waren in de intensieve veehouderij, voornamelijk in de melkveehouderij en generalisten die zich met allerlei diersoorten bezig hielden.
Jonge dierenartsen, dierenartsen werkzaam in de melkveehouderij en de generalisten leken zich meer onzeker te voelen om onafhankelijk van de wensen en verwachtingen van veehouders therapiebeslissingen te nemen in vergelijking met oudere dierenartsen en dierenartsen werkzaam in de intensieve veehouderij.
In vergelijking met jongere dierenartsen leken oudere dierenartsen minder bezorgd over een mogelijke bijdrage van veterinair antibioticagebruik aan de resistentieproblematiek; leken ze minder aarzeling te voelen om antibiotica in te zetten bij een onzekere diagnose of zelfs als preventieve maatregel om dierziekten te voorkomen en gaven ze vaker aan zich zorgen te maken over een mogelijk verlies van de veterinaire apotheek.
Dierenartsen in de intensieve veehouderij zagen een verbetering van voerkwaliteit en benchmarken van het antibioticagebruik als kansrijke oplossingsrichtingen voor een lager antibioticagebruik in de veehouderij. Dierenartsen in de melkveehouderij en generalisten scoorden naast benchmarken het verbeteren van huisvesting en klimaat in stallen als belangrijke maatregel.
In de intensieve veehouderij worden conflicterende adviezen door andere niet-veterinaire adviseurs als zeer belangrijke reden gezien waarom veterinaire adviezen niet door veehouders worden overgenomen; daarnaast werd aangegeven dat het uitvoeren van deze adviezen door veehouders regelmatig als te tijdrovend kan worden beschouwd. De dierenartsen binnen de melkveehouderij en de generalisten gaven aan dat belangrijke belemmeringen zijn te vinden in de perceptie van

veehouders rondom de kosten en tijdsinvestering die het uitvoeren van de maatregelen met zich mee zou kunnen brengen.
Toekomstige interventies zouden zich kunnen richten op het ondersteunen van jonge dierenartsen om als onafhankelijke professional goed afgewogen keuzes te kunnen maken zonder hierin gestuurd te worden door wensen en opvattingen van een veehouder en andere adviseurs. Oudere dierenartsen zouden wellicht gebaat zijn bij meer voorlichting over de risico's van antibioticagebruik bij dieren en mogelijkheden om minder afhankelijk te zijn van de veterinaire apotheek.

De voorgaande vragenlijst werd in dezelfde periode ook uitgestuurd in Vlaanderen (België) (**hoofdstuk 4**). Waar Nederlandse dierenartsen voornamelijk onvoldoende klimaatcondities, economische motieven van veehouders en onvoldoende weerstand van jonge dieren als oorzaak zagen voor een hoog antibioticagebruik, zagen Vlaamse collega's naast slechte klimaatomstandigheden voornamelijk onvoldoende bioveiligheids-maatregelen en de risicomijdende mentaliteit van veehouders om snel naar antibiotica te grijpen als belangrijke oorzaak. Bijna twee-derde van de Nederlandse respondenten stond achter het beleid om het antibioticagebruik in de veehouderij te halveren tegenover slechts een-derde van de Vlaamse dierenartsen die achter een gelijksoortig beleid zou staan als dat in Vlaanderen geïntroduceerd zou worden. Vlaamse dierenartsen waren significant pessimistischer vergeleken met Nederlandse dierenartsen dat het halveren van het antibioticagebruik ten koste zou gaan van diergezondheid en dierwelzijn en bleken ook pessimistischer ten aanzien van welke antibioticareductie redelijkerwijs haalbaar zou zijn in de komende jaren. Dierenartsen uit Vlaanderen rapporteerden aanzienlijk minder moeite te hebben met de inzet van een preventieve antibioticakuur om infectieziekten te voorkomen in vergelijking met Nederlandse dierenartsen.
Gevraagd naar oplossingsrichtingen voor het hoge antibioticagebruik werden vooral het verbeteren van huisvesting en klimaat, het verbeteren van bioveiligheid (voornamelijk in Vlaanderen), en de gerichte eradicatie van bepaalde infectieziekten genoemd.
Een deel van de gevonden verschillen tussen Vlaamse en Nederlandse dierenartsen kan ingegeven zijn door verschillen in beleidsmaatregelen waarbij Nederlandse dierenartsen werken onder een opgelegd reductiebeleid, daar waar Vlaamse dierenartsen werken onder een beleid dat zich richt op bewustwording en zonder opgelegde doelstellingen. Het feit dat de Nederlandse dierenartsen aan den lijve hadden ervaren dat een aanzienlijke antibioticareductie relatief eenvoudig en zonder veel nadelige effecten op diergezondheid en productiviteit kon worden behaald, heeft wellicht hun attitude ten aanzien van het beleid positief veranderd.
De indruk bestaat dat Vlaamse veehouders en dierenartsen een hogere mate van risicoaversie hebben en daardoor eerder geneigd zijn antibiotica in te zetten om eventuele complicaties te voorkomen. De positieve ervaringen met antibioticareductie in Nederland zouden kunnen worden gedeeld met Vlaamse collega's om te laten zien dat antibioticareductie haalbaar is zonder nadelige effecten op diergezondheid en productiviteit.

In **hoofdstuk 5 en 6** zijn de opzet en resultaten beschreven van een interventiestudie uitgevoerd op gangbare melkveebedrijven in Nederland. De studie faciliteerde de samenwerking tussen veehouder, dierenarts en voervoorlichter in een zogenaamd driehoeksoverleg door training en door het toevoegen van een procesbegeleider.
In een gerandomiseerde cross-over studie hebben 2 groepen melkveehouders met een hoger antibioticagebruik dan gemiddeld in 2 opvolgende jaren deze interventie gevolgd. In het andere jaar fungeerden deze groepen als respectievelijk controle of follow-up groep. Bij de start van het studiejaar werd door de driehoek een gestructureerd diergezondheidsplan opgesteld onder leiding van een procesbegeleider. De uitvoering van dit plan werd gedurende een jaar opgevolgd door de procesbegeleider en daarna met de driehoek geëvalueerd.
Duidelijk werd dat teams die in een driehoeksoverleg goed en constructief samen konden werken beter in staat bleken hun actieplan te implementeren en meer doelstellingen wisten te behalen. Een belangrijke succesfactor is eigenaarschap van de veehouder ten aanzien van het plan. Belangrijk voor adviseurs is de behoeften en mogelijkheden van een veehouder te peilen en daar met adviezen op aan proberen te sluiten, maar tegelijkertijd voldoende kritisch zijn om verbeterpunten te benoemen.
Het directe effect van de interventie op het antibioticagebruik was minder duidelijk. Mogelijk kost het meer tijd voordat managementmaatregelen effect hebben op het antibioticagebruik. Over de 2 studiejaren heen wisten de bedrijven in de studie 17% minder antibiotica te gebruiken. Zichtbaar was dat bedrijven die het antibioticagebruik geleidelijk wisten te verminderen, dit samen konden laten gaan met een voorzichtige verbetering van diergezondheid. Voor uiergezondheid bleek zelfs een positief verband tussen verlaging van antibioticagebruik en vermindering van het aantal mastitisgevallen. Dit impliceert dat met behulp van een gestructureerde gezondheidsaanpak antibioticagebruik is te reduceren en diergezondheid is te bestendigen of zelfs te verbeteren.
Een opvallende bevinding is dat er weinig relatie werd gevonden tussen het antibioticagebruik en diergezondheidskenmerken op de studiebedrijven. Een hypothese is dat niet alleen diergezondheid, maar ook de mate van risicoperceptie en de mate van risicomijdend gedrag van een veehouder het antibioticagebruik op melkveebedrijven beïnvloedt. Dit wordt bevestigd door een aantal andere recente studies. Toekomstig onderzoek zal zich meer op deze aspecten gerelateerd aan de invloed van kennis, houding en gedrag op antibioticagebruik dienen te richten.

In **hoofdstuk 7** worden de gevonden resultaten bediscussieerd en afgezet tegen andere wetenschappelijke literatuur. Duidelijk is dat het reduceren van antibioticagebruik in de veehouderij veel te maken heeft met gedragsveranderingen van zowel dierenartsen als veehouders. Uit de gedragswetenschappen is bekend dat gedrag van mensen vaak moeilijk is te veranderen. Dwang is niet altijd het meest effectieve middel en daarom moet gezocht worden naar stimulansen voor vrijwillige gedragsveranderingen. Het is belangrijk onderscheid te maken tussen interne motieven die een intentie tot gedragsveranderingen induceren en externe factoren die een daadwerkelijke gedragsverandering mogelijk maken. Veel van deze interne en

externe factoren kunnen worden beïnvloed wanneer inzicht is verkregen in hoe deze factoren een rol spelen in de gedragsverandering.
In de reductie van antibioticagebruik in de veehouderij spelen veel van deze zaken een rol. Opvattingen over de mogelijke risico's van antibioticagebruik voor de volksgezondheid, angst voor complicaties wanneer antibiotica wordt weggelaten, onzekerheid over gevolgen van bepaalde preventieve maatregelen, de mate van gepercipieerde sociale druk vanuit de direct omgeving en de mate waarin iemand gelooft in staat te zijn een goede dierenarts of veehouder te zijn met minder gebruik van antibiotica speelt allemaal een rol bij de interne motivatie om werk te maken van antibioticareductie.
Externe factoren zijn terug te leiden tot culturele en maatschappelijke invloeden zoals regelgeving en publieke opinie omtrent antibioticagebruik, de organisatie en logistiek van de dierlijke productieketen en tenslotte de mogelijkheden die een dierenarts of veehouder heeft om antibioticagebruik daadwerkelijk te reduceren.
Duidelijke communicatie omtrent de nut en noodzaak van antibioticareductie en de risico's van antibioticaresistentie richting dierenartsen en veehouders is van groot belang. Het in kaart brengen en communiceren van *best practices* kan dierenartsen en veehouders ondersteunen in het maken van beslissingen die van invloed zijn op het antibioticagebruik. Om dierziekten zoveel mogelijk te voorkomen is het van belang dat diergezondheid op bedrijfsniveau gestructureerd wordt aangepakt in een constructieve samenwerking tussen een veehouder en de verschillende adviseurs.
Toekomstig onderzoek zal meer inzicht moeten verschaffen over de rol van verschillende interne en externe factoren op het antibioticagebruik bij landbouwhuisdieren. Tenslotte is er de urgentie van internationaal eenduidig beleid om het gevaar van antibioticaresistentie op mondiaal niveau terug te dringen.

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Een proefschrift schrijven is soms hard zwoegen en regelmatig vroeg ik mij net als Prediker in de Bijbel af of het wel zo nuttig was een proefschrift te schrijven. Zou de wereld hier echt beter van worden? Maar dan geeft Prediker in al deze twijfel ook een woord van hoop: “Het is daarom nog maar het beste voor een mens dat hij zich te goed doet en volop geniet van alles wat hij moeizaam heeft verworven”, “het is het loon dat God je heeft gegeven” (Prediker 2: 24 en 9:9). Het is aan anderen te oordelen of dit proefschrift ‘nuttig’ is; genieten van het maken hiervan heb ik zeker gedaan! Ik heb enorm mooie en interessante dingen mogen meemaken die ik niet had willen missen. Het heeft mij als mens en dierenarts in ieder geval gevormd.

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Curriculum Vitae

David Christiaan Speksnijder was born on March 31, 1983 in Bergambacht, the Netherlands. According to his parents, the first words he could say was “koetje boe” (cow moo). After finishing his high school in 2001, a short career in the Royal Dutch Air Force and as dairy farm worker, he started his study at the Faculty of Veterinary Medicine at Utrecht University in 2003. During his study, David was volunteer and board member of the Dutch foundation DIO (Veterinary Medicine in Development Cooperation), part of Vétérinaires sans Frontières Europe.

After graduation as Doctor of Veterinary Medicine in 2009, he started working as a ruminant veterinarian in a small mixed practice in Wijchen, the Netherlands. Soon, David switched practice and started working at Veterinary Clinic (DAP) Tweestromenland in the same town. In June 2011, David started his PhD project on antimicrobial prescribing behaviour of farm animal veterinarians and measures to influence antimicrobial consumption in farm animals. In the meanwhile, he continued working as veterinarian in DAP Tweestromenland until mid-2016 when he completely started working in academia.

Over the last years, David participated in several Dutch working groups related to veterinary antimicrobial use and veterinary guideline development. As consultant, he was also involved in several international projects to support mainly developing countries with the development of (policy) measures to contain further development of antimicrobial resistance. Currently David works as veterinarian, teacher and researcher at the Faculty of Veterinary Medicine.