Preventive Veterinary Medicine 147 (2017) 142–148

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

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

Farmers' knowledge and expectations of antimicrobial use and resistance are strongly related to usage in Dutch livestock sectors

Tineke Kramer[a,b,*], Leonie E. Jansen[b], Len J.A. Lipman[a], Lidwien A.M. Smit[a], Dick J.J. Heederik[a], Alejandro Dorado-García[a]

[a] Institute for Risk Assessment Sciences (IRAS), Yalelaan 2, 3584 CM Utrecht, The Netherlands
[b] Public Health Service Region Utrecht, De Dreef 5, 3704 HA Zeist, The Netherlands

ARTICLE INFO

Keywords:
Antimicrobial usage
Farmers
Livestock
Knowledge
Risk perception
Attitude

ABSTRACT

Comprehensive strategies to improve on-farm antimicrobial use (AMU) are needed to contain antimicrobial resistance (AMR). Little is known about farmers' motivating and enabling factors, and about their influence on AMU. In a cross-sectional online survey, Dutch dairy, veal and pig farmers (n = 457) reported their on-farm AMU as "Defined Daily Dose Animal" per year ($DDDA_F$) and completed a detailed questionnaire on their view, knowledge and behavior towards AMU and AMR. Exploratory factor analysis (EFA) on the questionnaire items identified four psychological factors labeled as 'referent beliefs', 'perceived risk', 'knowledge', and 'undesired attitude to regulations'. Linear regression was done to explore the relationship between the obtained factors and on-farm AMU across the three animal sectors. Dairy farmers showed the highest factor scores for 'knowledge' and the lowest for 'perceived risk'. 'Knowledge' scores were significantly and inversely related to AMU (P = 0.0004). Borderline significant associations with AMU were found for 'perceived risk' and 'undesired attitude to regulations' (negative and positive relationships respectively). There were no apparent differences for these relationships between the three livestock sectors. Behavioral interventions in farmers such as educational campaigns or increased support by veterinarians could empower farmers with more prudent and rational practices, eventually reducing AMU in food animals.

1. Introduction

The transmission of antimicrobial resistant bacteria from livestock into the environment and food chain is a public health concern. In the last years, potential risks of antimicrobial resistance (AMR) transmission at the animal-human interface have been extensively documented (EMA/EFSA, 2017). Lowering on-farm antimicrobial use (AMU) in livestock production is regarded as the most logical intervention for containing the AMR threat originating from animals. As an example, veterinary AMU has halved since 2010 in the Netherlands, due to stringent regulations (Nethmap/Maran, 2016) and data suggest it has led to noticeable reductions in resistance levels in livestock (Dorado-Garcia et al., 2016). In addition to these regulatory and technical farm interventions (e.g. increased biosecurity), behavioral interventions aimed at sustainable AMU reduction should be considered as part of comprehensive One Health AMR action plans.

Evidence from human medicine relating psychological factors to potential misuse or overuse of antimicrobials is unequivocal. Studies describe that patients' expectations, or perceived expectations by the physician, are strong drivers for prescription of antimicrobials in human medicine (Britten and Ukoumunne, 1997; Cockburn and Pit, 1997; Mangione-Smith et al., 1999; Cho et al., 2004; Welschen et al., 2004). Knowledge, beliefs and previous experiences with antimicrobials of the patients as end-users influence these expectations (Cals et al., 2007). In veterinary medicine, comparable drivers (e.g. (perceived) pressure from farmers as end-users), have been shown to influence the veterinarian to prescribe (Speksnijder et al., 2015; Coyne et al., 2016; McDougall et al., 2017).

Farmers are important actors in modulating their on-farm AMU. Together with the veterinarian, Dutch farmers design and implement the so called "farm treatment plan" (FTP) which contains farm specific protocols for AMU. Additionally, in many countries, farmers have direct influence on AMU through either purchasing or dosing and administrating antimicrobials independently, or under indirect supervision of the veterinarian. These decisions are not fully rational and are in any case partly driven by motivational and enabling factors (Panter-Brick et al., 2006).

In dairy farmers, but mostly in pig farmers, some aspects of

* Corresponding author at: Institute for Risk Assessment Sciences, Department Veterinary Public Health, Yalelaan 2, 3584 CM Utrecht, The Netherlands.
E-mail address: T.kramer@uu.nl (T. Kramer).

http://dx.doi.org/10.1016/j.prevetmed.2017.08.023
Received 28 June 2017; Received in revised form 30 August 2017; Accepted 30 August 2017
0167-5877/

psychological factors towards AMU and AMR have been described (Friedman et al., 2007; Moreno, 2014; Jones et al., 2015; Visschers et al., 2015; Dupont et al., 2017). However, their impact on AMU across multiple livestock sectors has not been quantified before. These studies identified knowledge gaps among farmers on how to use antimicrobials, concluded that farmers may benefit from further education on AMU, and stressed the important role of the veterinarian and possibly also farmer specific guidelines for AMU.

Therefore, the aims of this study were to characterize farmers' motivating and enabling factors towards AMU and AMR in three major animal production sectors (dairy cattle, veal calves and pigs) and to explore the impact of these psychological factors on their on-farm AMU.

2. Material and methods

2.1. Selection of farmers

Farmers (N = 4041) were selected from the membership database of the Dutch Federation of Agriculture and Horticulture (LTO) based on farm size (>100 calves, >200 sows, >800 fattening pigs, >100 dairy cattle or >40,000 broilers). They were randomly selected across all three regional LTO offices in the country. Fig. 1 shows the process for selecting the study population and data cleaning steps. Since not all LTO offices kept track of how many farmers per sector they invited to participate, the response rates per sector could not be defined.

2.2. Online questionnaire and data collection

Questions were included following discussions with experts and analysis of questionnaires of previous studies focusing on the general public or human patients (Cals et al., 2007; Grigoryan et al., 2007; McNulty et al., 2007; Radosevic et al., 2009; Andre et al., 2010; Chan et al., 2012; Widayati et al., 2012; European commission, 2013; Napolitano et al., 2013; Wun et al., 2013; Hoffmann et al., 2014). The questionnaire consisted of general or human health items and veterinary and farm related questions. The main topics were knowledge, risk perception, attitude and (intended) behavior towards AMU and AMR. Box 1 further explains these main domains of the questionnaire.

The questionnaire concluded with general characteristics of the farm and farmer, leading to a total of 121 items. Responses included dichotomous and categorical outcomes (yes/no; a/b/c) and ordinal

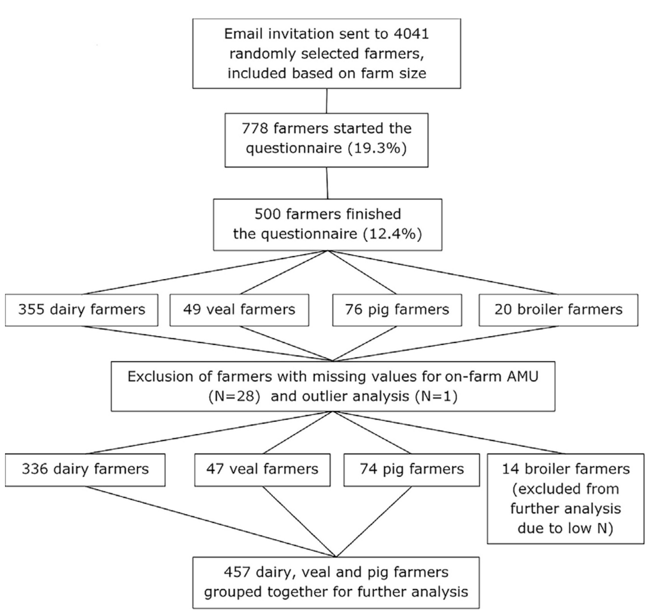

Fig. 1. Flowchart for the selection of the study population and data cleaning steps. Percentages in brackets are the response rates.

outcomes (5-point Likert scale type). A pilot study was performed among a selected panel of farmers (N = 26) to test and improve the comprehensibility of the questions. Medical terms and clinical diagnoses were explained in information boxes to improve the understanding of the items when appropriate. The full questionnaire is provided in the appendix in Supplementary material.

A web-based survey software program (NetQ Healthcare, Utrecht, The Netherlands) was used for the data collection. Farmers received an email invitation to fill out the anonymous internet-based questionnaire between February and March 2015. It was made impossible to skip questions or go back in the questionnaire, to prevent missing values and editing of previous answers. Since items for sector membership and self-reported on-farm AMU were among the last questions, only complete observations (N = 500) were included. Missing values for AMU were screened, which resulted in the exclusion of 28 farmers. One additional farmer had extremely unlikely answers for all knowledge questions and was excluded from the definite analysis (Fig. 1). Sensitivity analysis including this outlier did not change the final model estimates (results not shown).

2.3. Statistical analysis

Statistical analysis was performed using SAS software, Version 9.4 (SAS Institute Inc., Cary, NC, USA). To identify latent psychological constructs from the questionnaire items, exploratory factor analysis (EFA) was done with PROC FACTOR for dairy, veal and pig farmers combined (N = 336, N = 47 and N = 74 respectively). EFA was chosen because of a lack of a priori theory in this field on item structure. Items from the questionnaire (Appendix A in Supplementary material) with ordinal scales and binary outcomes were used. When Spearman correlation between two items was >0.7, only one of them was kept based on perceived importance and previous knowledge. Items with communalities <0.3 after an initial EFA were removed. The factorability of the remaining items was examined with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. The factor extraction was done as described elsewhere (Suhr, 2006), starting with initial extraction and determination of the number of factors to retain. Orthogonal (varimax) rotation was performed to improve the factor structure. Cross-loadings of an item with a gap of >0.2 between the primary and secondary factor loading were considered insignificant. A factor was defined by a minimum of 3 items loading >0.4 and a minimum of 5% of variance explained by the factor. Cronbach's alpha's were calculated to test internal consistency of factors' composition. From the final set of 66 items, with a KMO of 0.7, factor scores were calculated. Distribution of factor scores by sector was explored with boxplots. An analysis of variance (ANOVA) and post hoc Tukey tests were used to identify significant differences in mean factor scores overall and between sectors. A selection of *a priori* important items excluded from factor analysis were analyzed descriptively.

AMU was self-reported by the farmer in the form of the most recent "Defined Daily Dose Animal" per year on the farm ($DDDA_F$). The Netherlands Veterinary Medicines Authority (SDa) calculates this value for benchmarking of individual livestock farms. The SDa was founded in 2010 and acts as an independent agency for prudent AMU in Dutch animal sectors. Farmers are informed of their $DDDA_F$ through sectoral quality organizations. The $DDDA_F$ can be interpreted as an approximation of the number of days an animal on a farm receives antimicrobial treatment per year. A more detailed description on the calculation of $DDDA_F$ is described elsewhere (Bos et al., 2013). To deal with the right-skewed distributions and the large differences in $DDDA_F$ range by animal species, $DDDA_F$ values were log-transformed [$\ln(x + 1)$] across all sectors and standardized around a mean of 0 and standard deviation of 1 per sector.

The relationships between the obtained factors, as explanatory variables, and the transformed AMU, as outcome, were explored with a linear regression model for all sectors together using PROC GLM.

Box 1
Main domains of the questionnaire with explanation.

Knowledge of:
antimicrobial therapeutics, antimicrobial effectiveness, AMR, causes of common human infections.
Risk perception of:
the threat of AMR for public health and animal health, the chance of getting infected with or becoming a carrier of resistant bacteria, sources of resistant bacteria.
Attitude towards:
AMU, who can best judge whether or not an antimicrobial treatment is necessary, antimicrobial regulations, effectiveness of antimicrobials with common infections, who is responsible to tackle AMR, the necessity of antimicrobials with common infections.
Behavior concerning AMU, specifically towards:
finishing a treatment, management of remnants, (intention to) use antimicrobials without prescription, differing from specific regulations as the FTP or withdrawal time.

Interaction terms with animal sectors were explored to identify possible differential effects of factors on AMU by sector. Potential confounding by gender, age and education level was assessed. The model fit was evaluated by model diagnostics, significance (F-value), significance of estimates and explained variance (R^2). A *p*-value below 0.05 was considered statistically significant.

3. Results

3.1. Study population

Following a selection process displayed in Fig. 1, a total of 457 farmers were included (336 dairy, 47 veal and 74 pig farmers). Broiler farmers were excluded due to a low response. The general characteristics of the study population are shown in Table 1. Notably, the level of education in dairy farmers appeared significantly higher than in veal and pig farmers. No significant differences between sectors were found for gender or smoking as a possible risk behavior.

3.2. Exploratory factor analysis

After EFA of the final set of 66 items, four factors remained. These reflected motivational and enabling constructs towards AMU and AMR for dairy, veal and pig farmers together. The variable composition of the factors was interpreted and captured under the following names: 'referent beliefs', 'perceived risk', 'knowledge' and 'undesired attitude to regulations'. The individual item composition of factors can be viewed in Table 2. The factors together explained 50% of the variance, and had no significant cross-loading items.

The first factor ('referent beliefs') captured the tendency of farmers for valuing external sources other than the veterinarian in giving antimicrobials to animals. No significant differences in this factor were found between sectors (Fig. 2). When looking at its individual items, the opinion of feed suppliers and other farm advisors was significantly more valued among veal and pig farmers as compared to dairy farmers (Table 2).

Factor 2 ('perceived risk') reflected the level of perceived risk towards AMR at the farmers' personal level, their animals and at the broader public health. Overall, veal and pig farmers significantly perceived higher risk from AMR than dairy farmers (Fig. 2). Veal farmers specifically perceived the risk of getting infected with resistant bacteria originating from their animals higher than pig and dairy farmers, while both veal and pig farmers thought they had a higher likelihood of carrying resistant bacteria as compared to dairy farmers (Table 2). Veal farmers also perceived the risk of infection and carriage of resistant bacteria in their animals as higher than dairy and pig farmers did.

The third factor ('knowledge') illustrated knowledge of infection routes of resistant bacteria and of the effectiveness of antimicrobials with common human infections. It also captured expectations of the farmer as a patient when it comes to personal AMU. Mean 'knowledge' factor scores were higher in dairy and pig farmers than in veal farmers (Fig. 2). When looking at the individual questions composing the factor, pig farmers were most knowledgeable of the fact that people infected with resistant bacteria can be a source of increased resistant infections in humans (Table 2). Veal farmers more often thought that antimicrobials were effective against common viral human infections, and more often expected antimicrobials from their GP when having the flu or a cold, as compared to the other sectors. These items reflect undesirable expectations and loaded negatively on this factor.

Finally, Factor 4 ('undesired attitude to regulations'), embodied a disregard for antimicrobial regulations, both at the personal and farm level. Differences between sectors were borderline significant ($P = 0.068$) with slightly higher overall disregard in dairy farmers. This is reflected in some of the individual items in Table 2, where dairy farmers seemed to disagree with these regulations more than the other farmers. They were significantly more in favor of freely available antimicrobials for their animals either through the internet or their veterinarian, than veal and pig farmers. Also, dairy farmers intended to use freely available antimicrobials without consulting their veterinarian more often than veal farmers.

Table 1
General characteristics of the study population.

Sector	% (n)	Age farmer		Gender% male (n)	Current smoking% (n)	Level of education% of sector (n)			
		mean	sd			University	Higher professional education	Professional education	Basic education
Dairy farmers	73.5 (336)	46.6*	8.8	90.8 (305)	6.3 (21)	3.3 (11)	32.1 (108)	56.3 (189)	8.3 (28)
Veal farmers	10.3 (47)	48.4	8.6	91.5 (43)	14.9 (7)	2.1 (1)	19.2 (9)	57.5 (27)	21.3 (10)
Pig farmers	16.2 (74)	49.4*	8.4	90.5 (67)	6.8 (5)	1.4 (1)	23.0 (17)	62.2 (46)	13.5 (10)
Total/mean	457	48.4	8.6	90.8	7.2 (33)	2.8 (13)	29.3 (134)	57.3 (262)	10.5 (48)

Notes: Values within a column with an * differ significantly at $P < 0.05$. Overall *p*-values were 0.03 (age), 0.98 (gender), 0.10 (current smoking) and 0.003 (education level). For the calculation of the differences in mean education level, "university" and "higher professional education" were grouped together, since the number of farmers with "university" were too low to view as a separate category.

Table 2
Questionnaire items per factor including the internal reliability (Cronbach's α), scales, mean response values, standard deviations (sd), *p*-values (P), item-total correlation (ITC) and factor loading.

Factors and their composing items	Item scale	Mean (sd)				P	ITC	Loading
		All farmers	Dairy farmers	Veal farmers	Pig farmers			
Factor 1: 'Referent beliefs', valuing external sources other than the vet in treating animals with antimicrobials (Cronbach's α = 0.84)								
When deciding to apply antimicrobials in my animals, I value the opinion of: …	1 totally disagree − 5 totally agree							
LTO[a]		2.06 (1.06)	2.11 (1.09)	1.87 (0.95)	1.96 (0.93)	0.2335	0.71	0.76
Journals		2.28 (1.13)	2.32 (1.13)	2.09 (1.23)	2.26 (1.02)	0.4031	0.67	0.71
Colleagues		2.55 (1.19)	2.57 (1.20)	2.47 (1.16)	2.51 (1.16)	0.8073	0.61	0.67
Clients		2.57 (1.35)	2.58 (1.40)	2.47 (1.27)	2.57 (1.18)	0.8675	0.57	0.62
The Netherlands Food and Consumer Product Safety Authority		2.14 (1.17)	2.21 (1.19)	1.87 (1.03)	2.04 (1.10)	0.1313	0.54	0.61
Feed suppliers or other farm advisors		2.43 (1.19)	2.28[a] (1.15)	3.06[b] (1.28)	2.70[b] (1.14)	<0.0001	0.55	0.60
Friends[b]		1.43 (0.72)	1.48 (0.77)	1.23 (0.52)	1.35 (0.58)	0.0526	0.49	0.49
Factor 2: 'Perceived risk', increasing AMR risk perception (Cronbach's α = 0.71)								
The chance that I get an infection with a resistant bacteria is:	1 very small − 5 very big	2.31 (0.81)	2.27 (0.80)	2.49 (0.91)	2.36 (0.80)	0.1827	0.56	0.64
The chance that I get infected with a resistant bacteria through my livestock is:[c]	1 very small − 5 very big	2.29 (0.89)	2.19[a] (0.83)	2.81[b] (1.04)	2.41[a] (0.95)	<0.0001	0.53	0.62
The chance that I carry a resistant bacteria with me is:	1 very small − 5 very big	2.35 (0.91)	2.23[a] (0.83)	2.72[b] (1.02)	2.69[b] (1.03)	<0.0001	0.48	0.59
The threat of antibiotic resistance to public health in The Netherlands is:	1 very small − 5 very big	2.89 (0.87)	2.91 (0.85)	2.87 (0.80)	2.78 (0.97)	0.5033	0.40	0.52
I think the problem of antibiotic resistance is not too big	1 totally disagree − 5 totally agree	2.78 (1.01)	2.78 (0.99)	2.77 (1.09)	2.78 (1.02)	0.9955	0.36	−0.45
Factor 3: 'Knowledge', knowledge of infection routes and effectiveness of antimicrobials, and expectations at personal level (Cronbach's α = 0.64)								
You can become infected with a resistant bacteria through people that carry resistant bacteria	0 incorrect − 1 correct	0.62 (0.49)	0.63 (0.48)	0.53 (0.50)	0.65 (0.48)	0.4004	0.44	0.53
You can become infected with a resistant bacteria through animals (pets/livestock) that carry resistant bacteria	0 incorrect − 1 correct	0.65 (0.48)	0.65 (0.48)	0.57 (0.50)	0.72 (0.45)	0.2755	0.45	0.52
You can become infected with a resistant bacteria through people that are infected with a resistant bacteria	0 incorrect − 1 correct	0.77 (0.42)	0.76 (0.42)	0.66[a] (0.48)	0.86[b] (0.34)	0.0293	0.38	0.51
How often do you think antimicrobials are needed with the flu?	0 always, often, sometimes − 1 rarely, never	0.75 (0.44)	0.77 (0.42)	0.64 (0.49)	0.72 (0.45)	0.1311	0.30	0.40
When I have the flu, antimicrobials help me function in daily life (work/family life/study)[d]	1 totally disagree − 5 totally agree	1.75 (0.91)	1.74 (0.92)	2.06 [a] (1.05)	1.61 [b] (0.74)	0.0247	0.33	−0.44
I expect antimicrobials when I visit the GP with the flu[e]	1 totally disagree − 5 totally agree	1.67 (0.85)	1.65[b] (0.83)	1.98 [a] (0.94)	1.61[b] (0.82)	0.0318	0.35	−0.47
Factor 4: 'Undesired attitude to regulations', disregard for antimicrobial regulations (Cronbach's α = 0.65)								
It is good that antimicrobials for my animals are available without prescription through the internet (not including the web shop of my veterinarian)	1 totally disagree − 5 totally agree	1.69 (1.05)	1.76[a] (1.11)	1.36[b] (0.70)	1.59 (0.91)	0.034	0.43	0.52
It would be good if antimicrobials are available without prescription at the veterinarian	1 totally disagree − 5 totally agree	2.37 (1.32)	2.52[a] (1.33)	1.72[b] (1.14)	2.05[b] (1.22)	<0.0001	0.49	0.51
If antimicrobials would be available without a prescription, I would use antimicrobials in my animals without consulting my veterinarian	1 totally disagree − 5 totally agree	2.44 (1.23)	2.52[a] (1.22)	2.04[b] (1.20)	2.31 (1.25)	0.0274	0.41	0.44
It is good that antimicrobials for myself are available without prescription through the internet[f]	1 totally disagree − 5 totally agree	1.28 (0.64)	1.27 (0.60)	1.21 (0.46)	1.41 (0.89)	0.1813	0.31	0.41
If antimicrobials would be available without a prescription, I would use antimicrobials for myself without consulting a doctor	1 totally disagree − 5 totally agree	1.79 (1.01)	1.83 (1.04)	1.68 (0.84)	1.72 (0.97)	0.4998	0.39	0.40

Notes: The letters a-f indicate items which correlated >0.7 with another questionnaire item(s) which was removed before the factor analysis:
[a] When deciding to apply antimicrobials in my animals, I value the opinion of the internet.
[b] When deciding to apply antimicrobials in my animals, I value the opinion of family.
[c] The chance that my livestock gets an infection with resistant bacteria is AND the chance that my livestock carries resistant bacteria is.
[d] When I have a cold, antimicrobials help me function in daily life (work/family life/study).
[e] I expect antimicrobials when I visit the GP with a cold.
[f] It would be good if antimicrobials are available without prescription at the pharmacy.
Values within a row with different letters (a and b) differ significantly at $P < 0.05$.

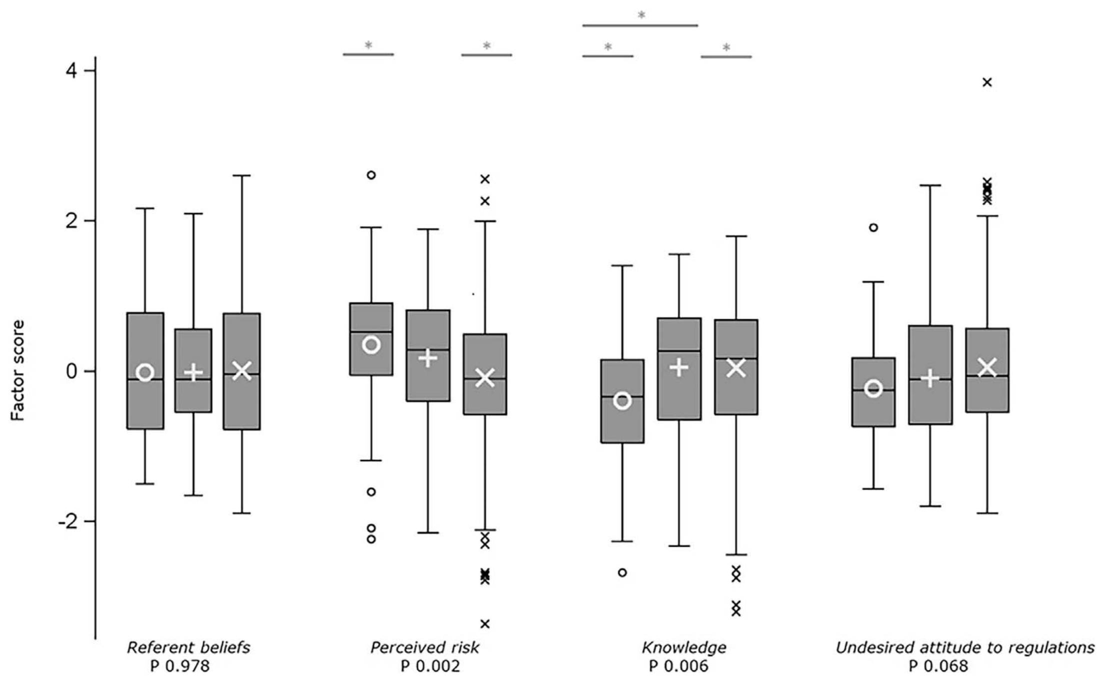

Fig. 2. Factor scores in the 4 obtained factors by animal production sector. Mean (O = veal farmers, + = pig farmers, x = dairy farmers), median, 10th, 25th, 75th,90th percentiles, and outliers. An increase in scores of factor 1–4 indicate higher referent beliefs, increased risk perception, more knowledge or more disregard for antimicrobial regulations, respectively. P-values display the ANOVA outcomes comparing the mean factor scores per sector. Lines with an * indicate which sector score means differed significantly at P < 0.05.

3.3. Motivational and enabling factors as determinants for on-farm AMU

Absolute $DDDA_F$ values in dairy farmers were normally distributed with a mean of 2.4 (SD = 1.2). The $DDDA_F$ in veal and pig farmers had a right-skewed distribution with a median of 14.0 (IQR = 18.0) for veal farmers overall and a median of 3.4 (IQR = 5.8) for pig farmers. Table 3 shows how the $DDDA_F$ values of the study population compare to the national SDa data of 2015 (Autoriteit Diergeneesmiddelen, 2016). For rose veal farms, this comparison was not made since no distinction was made in specific farm type in the study population (e.g. rose starter, finisher or combination veal calves) and these types differ greatly in their AMU.

In the model, 'knowledge' was the most significant factor and was inversely related to AMU (P = 0.0004) (Table 4). 'Perceived risk' and 'undesired attitude to regulations' showed inverse and positive associations with AMU respectively, and were both borderline significant (P = 0.06). 'Referent beliefs' (Factor 1) was not statistically associated to AMU (P > 0.28). These relationships did not differ significantly between sectors, as tested with interaction terms. Adjusted results for gender, age, smoking and education level only lead to marginal changes in estimate size and significance (< 10%) (results not shown).

Table 3
$DDDA_F$ by farm type from national SDa data of 2015 as compared to the $DDDA_F$ of the study population.

	SDa 2015		Study population	
	$DDDA_F$		$DDDA_F$	
Farm type	Mean	Median	Mean	Median
Dairy cattle	2.2	2.1	2.4	2.4
Pigs	4.7*	2.4*	4.7*	3.4*
Veal calves white	25.1	24.3	23.4	21

Notes. *mean and median of pigs were made up by fattening pig farms and multiplier pig farms.

Table 4
Results of the linear regression analysis of the motivational and enabling factors on AMU (standardized (ln $DDDA_F$ +1)).

Psychological factors	ß	SE	P
Factor 1 'Referent beliefs'	0.0526	0.0487	0.2806
Factor 2 'Perceived risk'	−0.0956	0.0509	0.0610
Factor 3 'Knowledge'	−0.1814	0.0513	0.0004
Factor 4 'Undesired attitude to regulations'	0.0961	0.0517	0.0636

Notes. Model statistics: F = 5.54, P = 0.0002, R^2 = 0.05. Psychological factors resulting from EFA. SE, standard error. Model assumptions were satisfied.

4. Discussion

This work shows significant differences between dairy, veal and pig farmers regarding their AMR and AMU knowledge and expectations, risk perception, and attitude towards regulations. Remarkably, this set of psychological factors had quantifiable impacts on on-farm AMU, which demonstrates the potential of behavioral interventions for a prudent and sustainable AMU at the farm level.

Among the motivational and enabling factors identified, 'knowledge' was the strongest component of the relationship with AMU. Incorrect knowledge and undesired expectations in human medicine have been previously identified as strong drivers for prescription by physicians (Britten and Ukoumunne, 1997; Cockburn and Pit, 1997; Mangione-Smith et al., 1999; Cho et al., 2004; Welschen et al., 2004). The findings in the current study support the hypothesis that comparable drivers may exist in the farmer − veterinarian relationship.

Notably, in dairy and pig farmers, specific AMR knowledge was higher, and expectations concerning AMU were more desirable, as compared to veal farmers. Lower 'knowledge' scores in farmers could be partially explained by a lower education level although they were not strongly correlated (Pearson's rho = 0.25). Moreover, a certain amount of "automatism" and disconnection to the individual treatment may contribute to a reduced awareness when using antimicrobials in the veal sector.

During the last years, pig and veal calf farming have received heightened public attention because of the high rates of LA-MRSA (Livestock-associated Methicillin-Resistant *Staphylococcus aureus*) carriage among the farmers and their animals (Graveland et al., 2011). From 2006, pig and veal calf farmers have also been intensively targeted by the Dutch "Search and Destroy" policy, including them as a risk group for isolation when hospitalized (van de Sande-Bruinsma et al., 2015). As a likely consequence of these circumstances, this work showed a significantly increased risk perception in veal and pig farmers. This risk perception was inversely related to on-farm AMU, which is in line with previous findings (Visschers et al., 2016).

A negative attitude towards regulations was associated with increased AMU across animal sectors. This disregard could weaken the trust in the veterinarian as a coach and advisor. A strengthened farmer-veterinarian relationship is desirable for ensuring more responsible antimicrobial practices. A recent recommendation is that veterinarians should adopt a more mutualistic, relationship-centered communication instead of a paternalistic, directive style (Bard et al., 2017). The authors think such a supportive communication style may benefit attitudinal change towards acceptance of regulations and therewith lower the pressure on veterinarians to prescribe antimicrobials. Additionally, farmers should be more actively involved in designing and evaluating policy regulations, as they have an important role in the successful realization of interventions.

Disregard for antimicrobial regulations was most apparent in dairy farmers. The authors think this might be related to the sector's recent up-scaling and intensification, resulting for example in less stable milk prices and more societal criticisms on intensified farm layout (Dutch environmental federation, 2016; Centraal bureau voor de Statistiek, 2017a). Intensification of veal and pig production took place earlier in time and these sectors have not suffered fundamental changes in structure, as compared to the recent economic pressures in dairy.

Based on the authors' findings, the importance of partnership-based communication and education of farmers when it comes to specific AMU knowledge, expectations and regulations must be stressed. The veterinarian has an important role in this farmer coaching and knowledge dissemination. To illustrate this, virtually all farmers (97.8%) indicated that they valued the opinion of the veterinarian when deciding to apply antimicrobials in their animals. Moreover, a majority of farmers (86%) indicated that the veterinarian can best judge whether or not their animals need antimicrobials.

A relatively small proportion of the total variance in on-farm AMU was explained by the four psychological factors identified in this study. This is a common limitation when attempts are made to capture psychological constructs (Cohen, 1988). Effects of the psychological factors on AMU in this study must be seen in relative terms because of the transformations of the outcome variable. Moreover, associations could not be adjusted for technical determinants (e.g. biosecurity, farm management practices). Evaluations of the importance of farm technical parameters together with psychological factors should be targeted in future research. Notwithstanding these constraints, the model demonstrated solid relationships between factors and on-farm AMU.

Due to the nature of the data collection strategy, purely based on an on-line participation, the response rate was low. However, the extent of the subject selection bias is considered to be limited. The absolute AMU ($DDDA_F$) per sector in the study population was comparable to the national SDa levels in 2015. In case of selection bias due to better educated or more motivated responders, one would have expected participants to have lower $DDDA_F$ levels than the national average, which was not the case. Moreover, the proportion of farmers by sector in the study sample was comparable to the number of farms by sector at the national level (74.3%, 21.4% and 7.4% for dairy, pig and veal farms respectively in 2015) (Centraal bureau voor de Statistiek, 2017b).

Finally, sample sizes in veal and pig farmers were smaller than in dairy farmers. Considering that these sectors deal with most AMR problems and have a considerably higher AMU, future research should increase the focus on these sectors and also include broiler farmers.

5. Conclusions

Farmers' knowledge and expectations, risk perception and attitude towards AMU and AMR affect on-farm AMU. Although these psychological characteristics differ by type of livestock production, overall and across all sectors, an increased 'knowledge' score was the most significant determinant for low levels of AMU at the farm level. Therefore, knowledge of AMU and AMR, and expectations on antimicrobial effectiveness should be heavily targeted in the communication with the veterinarian and through educational campaigns for farmers. Moreover, farmers should be more actively involved in the design and evaluation of antimicrobial regulations, since they play a paramount role in the effectiveness of these measures, in the prudent veterinary use of antimicrobials, and eventually in the minimization of the AMR threat for public health.

Acknowledgements

This research was supported by the program budget of the Centre for Infectious Disease Control (CIb) at the National Institute for Public Health and the Environment (RIVM).

The authors wish to thank LTO for contributing to the communication with the farmers and express gratitude to all participating farmers for filling out the survey.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.prevetmed.2017.08.023.

References

Andre, M., Vernby, A., Berg, J., Lundborg, C.S., 2010. A survey of public knowledge and awareness related to antibiotic use and resistance in Sweden. J. Antimicrob. Chemother. 65, 1292–1296.
Autoriteit Diergeneesmiddelen, 2016. Het gebruik van antibiotica bij landbouwhuisdieren in 2015 (The use of antimicrobials in food production animals in 2015). The Netherlands Veterinary Medicines Institute Utrecht.
Bard, A.M., Main, D.C., Haase, A.M., Whay, H.R., Roe, E.J., Reyher, K.K., 2017. The future of veterinary communication: partnership or persuasion? A qualitative investigation of veterinary communication in the pursuit of client behaviour change. PLoS One 12, e0171380.
Bos, M.E., Taverne, F.J., van Geijlswijk, I.M., Mouton, J.W., Mevius, D.J., Heederik, D.J., 2013. Consumption of antimicrobials in pigs, veal calves, and broilers in the Netherlands: quantitative results of nationwide collection of data in 2011. PLoS One 8, e77525.
Britten, N., Ukoumunne, O., 1997. The influence of patients' hopes of receiving a prescription on doctors' perceptions and the decision to prescribe: a questionnaire survey. Br. Med. J. 315, 1506–1510.
Cals, J.W., Boumans, D., Lardinois, R.J., Gonzales, R., Hopstaken, R.M., Butler, C.C., Dinant, G.J., 2007. Public beliefs on antibiotics and respiratory tract infections: an internet-based questionnaire study. Br. J. Gen Pract. 57, 942–947.
Centraal bureau voor de Statistiek, 2017a. Grotere melkveebedrijven en meer melk (Bigger dairy farms and more milk). (Accessed 05.09.17) https://www.cbs.nl/nl-nl/nieuws/2017/18/grotere-melkveebedrijven-en-meer-melk.
Centraal bureau voor de Statistiek, 2017b. Landbouw; gewassen, dieren, grondgebruik en arbeid op nationaal niveau (Agriculture; Crops, Animals, Land Use And Labour At The National Level). (Accessed 05.05.17) http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81302NED&D1=387-409,470-495&D2=0,5,10,13-15&HDR=G1&STB=T&VW=T.
Chan, Y.H., Fan, M.M., Fok, C.M., Lok, Z.L., Ni, M., Sin, C.F., Wong, K.K., Wong, S.M., Yeung, R., Yeung, T.T., Chow, W.C., Lam, T.H., Schooling, C.M., 2012. Antibiotics nonadherence and knowledge in a community with the world's leading prevalence of antibiotics resistance: implications for public health intervention. Am. J. Infect. Control. 40, 113–117.
Cho, H.J., Hong, S.J., Park, S., 2004. Knowledge and beliefs of primary care physicians pharmacists, and parents on antibiotic use for the pediatric common cold. Soc. Sci. Med. 58, 623–629.
Cockburn, J., Pit, S., 1997. Prescribing behaviour in clinical practice: patients' expectations and doctors' perceptions of patients' expectations–a questionnaire study. Br. Med. J. 315, 520–523.
Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. Lawrence Erlbaum Associates Hillsdale, New Jersey.
Coyne, L.A., Latham, S.M., Williams, N.J., Dawson, S., Donald, I.J., Pearson, R.B., Smith, R.F., Pinchbeck, G.L., 2016. Understanding the culture of antimicrobial prescribing in agriculture: a qualitative study of UK pig veterinary surgeons. J. Antimicrob.

Chemother. 71, 3300–3312.
Dorado-Garcia, A., Mevius, D.J., Jacobs, J.J., Van Geijlswijk, I.M., Mouton, J.W., Wagenaar, J.A., Heederik, D.J., 2016. Quantitative assessment of antimicrobial resistance in livestock during the course of a nationwide antimicrobial use reduction in the Netherlands. J. Antimicrob. Chemother. 71, 3607–3619.
Dupont, N., Diness, L.H., Fertner, M., Kristensen, C.S., Stege, H., 2017. Antimicrobial reduction measures applied in Danish pig herds following the introduction of the Yellow Card antimicrobial scheme. Prev. Vet. Med. 138, 9–16.
Dutch environmental federation, 2016. The Situatie in de melkveehouderij (The situation in the dairy sector). (Accessed 05.09.17) http://milieufederatie.nl/friksbeheer/wp-content/uploads/2016/01/Situatie-in-de-melkveehouderij-december-2015.pdf.
EMA/EFSA, 2017. EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impactson food safety (RONAFA). EFSA J. 85–88.
European commission, 2013. Special Eurobarometer 407 Antimicrobial Resistance. Directorate-General for Health and Consumers.
Friedman, D.B., Kanwat, C.P., Headrick, M.L., Patterson, N.J., Neely, J.C., Smith, L.U., 2007. Importance of prudent antibiotic use on dairy farms in South Carolina: a pilot project on farmers' knowledge, attitudes and practices. Zoonoses Public Health 54, 366–375.
Graveland, H., Duim, B., van Duijkeren, E., Heederik, D., Wagenaar, J.A., 2011. Livestock-associated methicillin-resistant Staphylococcus aureus in animals and humans. Int. J. Med. Microbiol. 301, 630–634.
Grigoryan, L., Burgerhof, J.G., Degener, J.E., Deschepper, R., Lundborg, C.S., Monnet, D.L., Scicluna, E.A., Birkin, J., Haaijer-Ruskamp, F.M., 2007. Attitudes, beliefs and knowledge concerning antibiotic use and self-medication: a comparative European study. Pharmacoepidemiol. Drug Saf. 16, 1234–1243.
Hoffmann, K., Ristl, R., Heschl, L., Stelzer, D., Maier, M., 2014. Antibiotics and their effects: what do patients know and what is their source of information? Eur. J. Public Health 24, 502–507.
Jones, P.J., Marier, E.A., Tranter, R.B., Wu, G., Watson, E., Teale, C.J., 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. Prev. Vet. Med. 121, 30–40.
Mangione-Smith, R., McGlynn, E.A., Elliott, M.N., Krogstad, P., Brook, R.H., 1999. The relationship between perceived parental expectations and pediatrician antimicrobial prescribing behavior. Pediatrics 103, 711–718.
McDougall, S., Compton, C., Botha, N., 2017. Factors influencing antimicrobial prescribing by veterinarians and usage by dairy farmers in New Zealand. N. Z. Vet. J. 65, 84–92.
McNulty, C.A., Boyle, P., Nichols, T., Clappison, P., Davey, P., 2007. Don't wear me out?the public's knowledge of and attitudes to antibiotic use. J. Antimicrob. Chemother. 59, 727–738.
Moreno, M.A., 2014. Opinions of Spanish pig producers on the role, the level and the risk to public health of antimicrobial use in pigs. Res. Vet. Sci. 97, 26–31.
Napolitano, F., Izzo, M.T., Di Giuseppe, G., Angelillo, I.F., 2013. Public knowledge, attitudes, and experience regarding the use of antibiotics in Italy. PLoS One 8, e84177.
Nethmap/Maran, 2016. Consumption of Antimicrobial Agents and Antimicrobial Resistance Among Medically Important Bacteria in the Netherlands/Monitoring of Antimicrobial Resistance and Antibiotic Usage in Animals in the Netherlands in 2015.
Panter-Brick, C., Clarke, S.E., Lomas, H., Pinder, M., Lindsay, S.W., 2006. Culturally compelling strategies for behaviour change: a social ecology model and case study in malaria prevention. Soc. Sci. Med. 62, 2810–2825.
Radosevic, N., Vlahovic-Palcevski, V., Benko, R., Peklar, J., Miskulin, I., Matuz, M., Papaioannidou, P., Sabo, A., Palcevska-Koceska, S., 2009. Attitudes towards antimicrobial drugs among general population in Croatia, Fyrom, Greece, Hungary,Serbia and Slovenia. Pharmacoepidemiol. Drug Saf. 18, 691–696.
Speksnijder, D.C., Jaarsma, A.D., van der Gugten, A.C., Verheij, T.J., Wagenaar, J.A., 2015. Determinants associated with veterinary antimicrobial prescribing in farm animals in the Netherlands: a qualitative study. Zoonoses Public Health 62 (Suppl 1), 39–51.
Suhr, D.D., 2006. Exploratory or confirmatory factor analysis? The Thirty-first Annual SAS® Users Group International Conference. SAS: Institute Inc, Cary, NC.
van de Sande-Bruinsma, N., Leverstein van Hall, M.A., Janssen, M., Nagtzaam, N., Leenders, S., de Greeff, S.C., Schneeberger, P.M., 2015. Impact of livestock-associated MRSA in a hospital setting. Antimicrob. Resist. Infect. Control 4, 11.
Visschers, V.H., Backhans, A., Collineau, L., Iten, D., Loesken, S., Postma, M., Belloc, C., Dewulf, J., Emanuelson, U., Beilage, E.G., Siegrist, M., Sjolund, M., Stark, K.D., 2015. Perceptions of antimicrobial usage, antimicrobial resistance and policy measures to reduce antimicrobial usage in convenient samples of Belgian French, German, Swedish and Swiss pig farmers. Prev. Vet. Med. 119, 10–20.
Visschers, V.H., Postma, M., Sjolund, M., Backhans, A., Collineau, L., Loesken, S., Belloc, C., Dewulf, J., Emanuelson, U., Grosse Beilage, E., Siegrist, M., Stark, K.D., 2016. Higher perceived risk of antimicrobials is related to lower antimicrobial usage among pig farmers in four European countries. Vet. Rec. 179, 490.
Welschen, I., Kuyvenhoven, M., Hoes, A., Verheij, T., 2004. Antibiotics for acute respiratory tract symptoms: patients' expectations, GPs' management and patient satisfaction. Fam. Pract. 21, 234–237.
Widayati, A., Suryawati, S., de Crespigny, C., Hiller, J.E., 2012. Knowledge and beliefs about antibiotics among people in Yogyakarta City Indonesia: a cross sectional population-based survey. Antimicrob. Resist. Infect. Control 1, 38.
Wun, Y.T., Lam, T.P., Lam, K.F., Ho, P.L., Yung, W.H., 2013. The public's perspectives on antibiotic resistance and abuse among Chinese in Hong Kong. Pharmacoepidemiol. Drug Saf. 22, 241–249.