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# Knowledge, attitude and practices of Swiss dairy farmers towards intramammary antimicrobial use and antimicrobial resistance: A latent class analysis

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ABSTRACT

Understanding farmers' mindsets is important to improve antimicrobial stewardship in the dairy industry. This cross-sectional study aimed to determine farmers' knowledge, attitude, and practices with respect to lactational intramammary antimicrobial use (AMU) and antimicrobial resistance (AMR) in Swiss dairy herds. Based on their approach towards subclinical mastitis (SCM) and non-severe cases of clinical mastitis (CM), subgroups of farmers were identified and compared regarding their knowledge, attitude and practices towards AMU and AMR. After conducting qualitative interviews to develop a questionnaire, an online survey was sent to 1296 randomly selected Swiss dairy farmers. Information was gathered on demographic data and farmers' knowledge, attitude, and practices towards AMU and AMR. A latent class analysis was performed to identify subgroups of farmers based on management of SCM and non-severe CM cases. Based on the results of 542 completed questionnaires, poor knowledge with respect to AMU and AMR was identified, as well as discrepancies between farmers' perceptions and their actual practices. Farmers approached cows with SCM and non-severe CM similarly, indicating they perceived both mastitis states as the same disease. Intramammary antimicrobial products containing cefquinome, which is a highest priority critically important antimicrobial, were among the 3 most commonly applied intramammary antimicrobials. Five latent classes of farmers were identified based on their management towards SCM and non-severe CM. One group of farmers (18.5% of respondents) indicated that they did not treat those mastitis cases, one group only treated SCM cases (13.8% of respondents), one group only treated non-severe CM cases (28.6% of respondents) and the largest group treated both mastitis states (39.1% of respondents). The latter group was subdivided into a latent class of farmers following guidelines for AMU/AMR (25.5% of respondents) and a group of farmers that were not strictly following these guidelines (13.7% of respondents). Regional differences between farmers, according to altitude and language region, explained some of the variation in latent class membership. Latent class membership was associated with farmers' attitude to use antimicrobials as little as possible and with using antimicrobials only after performing bacteriological and susceptibility testing. This study gave detailed insight into Swiss farmers' knowledge, attitude, and practices regarding AMU and AMR and provides opportunities to improve antimicrobial stewardship in Swiss dairy herds. The identified groups of farmers, based on their management practices regarding SCM and non-severe CM, may help to design tailored intervention strategies for improving prudent AMU in the heterogeneous population of dairy farmers in Switzerland.

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## 1. Introduction

Mastitis is the most common reason for administering antimicrobials to dairy cows (Mitchell et al., 1998; Menéndez González et al., 2010; Kuipers et al., 2016). Immediate antimicrobial treatment is advocated for severe clinical mastitis (CM) cases because of an anticipated quick recovery and animal welfare aspects. Antimicrobial treatment of subclinical mastitis (SCM) and non-severe CM cases, however, is not always needed (Lago et al., 2011a, 2011b). Use of intramammary antimicrobials in dairy cows may contribute to increased antimicrobial resistance (AMR) of pathogens frequently found in milk (Oliver and Murinda, 2012; Saini et al., 2012, 2013). Prudent antimicrobial use (AMU) should therefore be pursued from a precautionary point of view.

Dairy farming in Switzerland is characterized by relatively small dairy herds with a proportion of, especially the smallest, herds being in mountainous regions that may not be well serviced by veterinarians (Gordon et al., 2013). The Swiss dairy population is known for its good udder health status though, with somatic cell counts being among the lowest in the world (Gordon et al., 2013). Nevertheless, sales of intramammary antimicrobials seem to be high compared to other European countries (European Medicines Agency, 2017). The herd level application of blanket dry cow treatment (Gordon et al., 2012) as well as the incidence rate of CM are relatively low in Switzerland (Gordon et al., 2013). Antimicrobial use during lactation, on the other hand, appears to be high (Menéndez González et al., 2010). It is therefore hypothesized that the high usage of intramammary antimicrobials is mainly due to the lactational treatment of SCM and non-severe CM. Although all antimicrobial treatments must be recorded in a treatment journal on farm, a centralized database on the usage of antimicrobials is not yet available in Switzerland. Monitoring and benchmarking the usage of antimicrobials in dairy herds is therefore not possible on a national scale.

A variety of intramammary antimicrobial products, including products containing beta-lactam antimicrobials, macrolides, lincosamides, polypeptide antimicrobials and aminoglycosides are registered for treatment of mastitis in Switzerland. Swiss farmers are allowed to store most of these products, if they have a written agreement with a veterinarian including two compulsory farm visits per year (Federal Food Safety and Veterinary Office, 2014), and administer them without veterinary prescription. Third and fourth generation cephalosporins and macrolides, which are considered as highest priority critically important (HPCI) for human medicine (World Health Organization, 2017), may be used for mastitis treatment and can also be kept on stock at the farm.

Several studies have demonstrated the importance of farmers' attitude towards mastitis and mastitis management and investigated potential intervention and communication strategies towards these subjects. A key strategy is to identify and implement herd-specific measures to improve udder health in dairy herds (Green et al., 2007; Lam et al., 2013; Tschopp et al., 2015). Also, farmers have different perceptions of udder health problems (Jansen et al., 2009) which play an important role when designing effective intervention programs (Lam et al., 2011). Attempting to improve udder health may, however, also lead to an increased number of antimicrobial treatments (Tschopp et al., 2015). A sustainable udder health program must therefore target a high udder health status, combined with prudent AMU (van den Borne et al., 2017). Insights in dairy farmers' knowledge, attitude and practices towards the lactational use of intramammary antimicrobials is therefore pivotal to reach this goal. Moreover, the heterogeneous population of dairy farmers likely has different needs and characteristics. Identifying subgroups of farmers regarding their practices of intramammary AMU during lactation may aid to the design of interventions strategies to enhance prudent AMU in dairy herds.

The aims of this study were to 1) describe farmers' knowledge, attitude, and practices towards the lactational use of intramammary antimicrobials in Swiss dairy herds, 2) compare farmers' mindsets and management strategies regarding SCM and non-severe CM, 3) identify groups of farmers based on their practices towards SCM and non-severe CM, and 4) describe these subgroups of farmers with respect to their knowledge and attitude regarding AMU and AMR.

## 2. Materials and methods

The data collection of this study consisted of 2 phases. First, qualitative interviews were conducted to determine the range of potential answers regarding knowledge, attitude and practices of Swiss dairy farmers towards intramammary AMU during lactation. This information was then used to develop the questionnaire for the second phase of the study in which farmers' knowledge, attitude and practices were assessed using a cross-sectional online questionnaire.

### 2.1. Interviews

An interview protocol was created to facilitate conducting the semi-structured qualitative interviews among a convenience sample of dairy farmers. Interviews were initiated with general open-ended questions, such as *"One of your cows has an increased somatic cell count but it doesn't show any visible signs of inflammation. What will you do?"* Interviewees were then asked to deliberate freely on this topic. Initial responses were further investigated by asking farmers more open-ended questions. In-depth questions, such as *"Why do you treat such a cow? With what do you treat it? And based on which criteria do you apply certain antimicrobials?"* were also asked if not already mentioned. Lastly, farmers were asked whether there was anything else important to mention at the end of the interview.

Interviewed farmers had previously participated in another study (Gordon et al., 2012), and then gave their consent to be approached for participation in further studies. Farmers were invited to participate by a letter explaining the purpose of the study. Farmers were subsequently interviewed, at their own farms, until answers became saturated, which occurred after interviewing 13 farmers, including 4 interviews with organic dairy farmers. Interviews were conducted in German, with farmers from the cantons of Bern, Basel-Country, Solothurn and Aargau from January to May 2014. The interviews lasted approximately 1 h, were voice recorded and transcribed in full.

### 2.2. Questionnaire

The online questionnaire asked for demographic data, knowledge, attitude and practices of treatment of SCM and non-severe CM cases, and on AMU and AMR in general. Questions concerning management decisions when treating SCM and non-severe CM with antimicrobials could only be answered by those respondents who had applied antimicrobials to cows with these stages of mastitis during the last 6 months before the survey. Additionally, the farmers were asked two questions about their preferred way to acquire knowledge with respect to antimicrobial stewardship.

To assess which intramammary antimicrobials were commonly used in Swiss dairy herds, farmers were asked which intramammary antimicrobial products they (or their veterinarian) had applied during the last 6 months before the survey. Pictures and product names of all antimicrobials available for the treatment of mastitis in Switzerland were presented. Subsequently, farmers were asked to rank the 3 most frequently used products. Intramammary antimicrobial products were thereafter grouped based on their active ingredients into HPCI and other antimicrobials (World Health Organization, 2017). Except for the ranking, a similar approach was used to quantify which groups of antimicrobials farmers had in stock. Based on their treatment records, farmers were also asked to indicate how many cows they treated for SCM and non-severe CM in the first 6 months of 2014. Incidence rates of farmer-reported treated mastitis cases were subsequently calculated based on the farmer-reported number of treated mastitis cases in the first 6 months of 2014, multiplied by two, divided by the herd size, assuming a constant herd size during the entire year, and multiplied by 100 to express the incidence rate per 100 cow-years at risk.

The questionnaire included a total of 62 questions, of which 38 were categorical, 7 were quantitative and for 17 a 6-point-Likert-scale was used. The online survey was developed in German and translated to French by a professional translator with a background in agriculture. The questionnaire was pre-tested by 4 farmers who participated in the qualitative interviews and was adapted according to their feedback. The questionnaire (in German or French) is available upon request from the corresponding author. The online survey was conducted using Sawtooth Software (Orem, Utah, United States of America).

### 2.3. Target population and sample size estimation

The sampling frame for the online survey consisted of Swiss dairy farmers who, in May 2014, were regularly marketing milk through a milk processing company, had a herd size of ≥11 dairy cows and an email address deposited at the organization responsible for the national milk quality payment schemes (85% of all Swiss dairy herds in September 2014; personal communication of TSM Treuhand Ltd., Bern, Switzerland). Seasonal communal pasture holdings and herds located in the Italian speaking Canton of Ticino were excluded.

The sample size needed for a cross-sectional study, to estimate a proportion of 50% from the sampling frame of 20,365 dairy herds with 5% precision and 95% confidence, was calculated to be 385 herds using Win Episcope 2 software. Given an expected response rate of 30%, 1283 dairy farmers needed to be contacted. Using a stratified (by Swiss Canton) random sampling approach in Microsoft Excel (Microsoft Corp., Redmond, Washington, USA), 1296 dairy herds (with stratum sample sizes proportional to the cantonal dairy herd population) were eventually requested to participate in the online survey.

### 2.4. Data collection

According to Swiss legislation, no ethical approval was required for this study since no sensitive data were collected. Every farmer received a personalized email explaining the purpose of the study and a link to the online survey in November 2014. Farmers received reminder emails 2 and 4 weeks later if they had not completed the survey. The survey was closed in January 2015. To increase response rate, participants were notified that vouchers of an agricultural wholesaler would be provided to 110 randomly selected participants who completed the survey. Additionally, participants were promised a summary of the project's results at the end of the study.

### 2.5. Statistical analysis

Responses were downloaded from the webserver and checked for consistency and completeness. Incomplete surveys and observations of 4 farmers indicating that they did not own any cows (and were therefore assumed to be out of business) were excluded from further analyses. Counts and proportions were calculated for categorical variables using frequency and contingency tables. Central measures of tendency were calculated for continuous variables. Wilcoxon rank sum tests and $\chi^2$-tests were used to determine differences in farmers' attitude and practices towards SCM and non-severe CM using NCSS 12 (NCSS, LLC, Kaysville, Utah, USA). $P$-values < 0.05 were considered statistically significant.

Farmers' actual knowledge regarding AMU and AMR was assessed using 7 statements with which farmers could agree, with "Yes", "No" and "I don't know" as possible answers. Two statements were reverse-coded. These were inversed first, after which all responses were binary coded by merging the incorrect and "I don't know" answers. The 7 binary coded responses were finally summed into an overall AMU/AMR knowledge score, on a 0–7 scale.

Latent class analysis, a useful method to analyse latent relationships between observed categorical variables (Oberski, 2016), was performed to identify subgroups of farmers managing SCM and non-severe CM. This helps to understand how the latent classes' characteristics differ from each other. Ten categorical questionnaire items describing farmers' practices towards SCM and non-severe CM were included in a complete-case exploratory latent class analysis. A series of latent class models with increasing number of classes, from 2 to 7, was performed to determine the best fitting model. The model with the lowest Bayesian information criterion (BIC), adjusted-BIC (aBIC), and Akaike information criterion (AIC), and a high entropy, was selected (Nylund et al., 2007). The selected model was repeatedly estimated using increasing random start values until the log likelihood was replicated several times to assure a final model solution (Nylund et al., 2007). Thirteen demographic covariates were added to this latent class analysis model one at a time using univariable multinomial logistic regression models to identify predictors explaining latent class membership. Covariates having a $P < 0.15$ in the likelihood-ratio test were subsequently offered to a backward multivariable model selection procedure until all covariates were significantly ($P < 0.05$) contributing to the final model. Confounding was evaluated and defined as a change in model estimates of more than 20% when removing a covariate from the model. A variable was retained in the model if confounding was present. For the final statistical model, item response probabilities were computed and interpreted to describe the classes. Posterior probabilities for each farmer being in each latent class were computed and the class with the highest posterior probability was assigned to each respondent. Latent class analysis was conducted using PROC LCA 1.3.2 (Lanza et al., 2007) in SAS 9.4 (SAS Institute Inc, Cary, North Carolina, USA).

Relationships between latent class membership and 10 attitude items, and both subjective and objective knowledge on AMU and AMR were assessed using a Kruskal-Wallis one-way ANOVA on ranks. A Bonferroni adjustment ($P < 0.004$) was applied to correct for multiple comparisons. Differences between classes were assessed by the post hoc, multiple comparison Dwass, Steel, Critchlow-Fligner procedure in PROC NPAR1WAY in SAS 9.4 (SAS Institute Inc, Cary, North Carolina, USA).

## 3. Results

### 3.1. Demographic composition

Of 1296 farmers contacted, 542 (41.8%) completed the survey of which 478 (out of 1085; response rate: 44.1%) and 64 (out of 211; response rate 30.3%) were filled in by German and French-speaking farmers, respectively. Many farms (40.2%; n = 218; 95%-CI: 36.2–44.4%) were in lowland regions; 19.2% (n = 104; 95%-CI: 16.1–22.7%) in areas with hills and 40.1% (n = 220; 95%-CI: 36.5–44.8%) in mountainous regions. Free-stall housing systems were used in 37.8% (n = 205; 95%-CI: 33.8–42.0%) of farms, 47.4% (n = 257; 95%-CI: 43.2–51.6%) had a tie-stall housing system, with the remaining farms having both types of housing systems. For 95.2% (n = 516; 95%-CI: 93.1–96.7%) of farmers, dairy farming was their main source of income. Additional production types were crop farming (47.8%; n = 259; 95%-CI: 43.6–52.0%) and other livestock species (29.7%; n = 161; 95%-CI: 26.0–33.7%). Most famers produced under the "Integrierte Produktion (IP Suisse)" label program (76.9%; n = 417; 95%-CI: 73.2–80.3%), a program that promotes a sustainable and integrative farming by focusing on animal- and environmental-friendly farming activities, including the promotion of biodiversity, animal welfare, the reduction of greenhouse gasses, and the avoidance of pesticides. Conventional production (10.0%; n = 54; 95%-CI: 7.7–12.8%), organic farming (11.6%; n = 63; 95%-CI: 9.2–14.6%) and other production systems (1.5%; n = 8; 95%-CI: 0.7–2.9%) were also represented. Median farmer-reported herd size was 24 dairy cows (range 6–150) and farmers' age ranged from 23 to 70 years (median 48

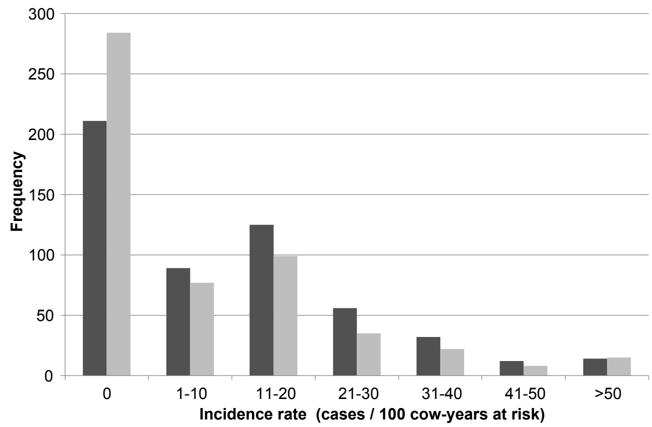


**Fig. 1.** Histogram of farmer-reported incidence rate (cases per 100 cow-years at risk) of treated subclinical mastitis (light grey) and non-severe clinical mastitis (dark grey) in 542 Swiss dairy farms in 2014.

years). Most respondents had a certificate of competence (43.5%; n = 236; 95%-CI: 39.4–47.7%) or had completed a professional degree (29.9%; n = 162; 95%-CI: 26.2–33.9%), which are both federally approved agricultural degrees. Other farmers (26.6%; n = 144; 95%-CI: 23.0–30.4%) had completed a higher agricultural education.

### 3.2. Management decisions regarding SCM and non-severe CM

In 60.9% of the herds (n = 328; 95%-CI: 56.3–64.5%), one or more cows received treatment for non-severe CM in the first 6 months of 2014. Significantly more farmers had treated a cow for non-severe CM than they had treated a cow for SCM in the first 6 months of 2014 (47.4%; n = 256; 95%-CI: 43.1–51.4%; $P < 0.0001$). In herds in which cows were treated, median farmer-reported incidence rate was 16.0 per 100 cow-years at risk (mean = 20.2; range 2.5–133.3) for treated non-severe CM cases and 14.3 (mean 19.6; range 2.2–108.7) for treated SCM. Distributions of farmer-reported incidence rates of treated SCM and non-severe CM cases in all 542 herds are shown in Fig. 1. Considering all herds (and thus including herds that did not treat SCM or non-severe CM), median farmer-reported incidence rate was 8.9 per 100 cow-years at risk (mean = 13.1; range 0–240.0) for treated non-severe CM cases and 0 (mean = 9.6; range 0–160.0) for treated SCM cases during lactation.

Categorical management decisions regarding cows with SCM or non-severe CM are shown in Table 1. The most important reason for a farmer to call a veterinarian for an antimicrobial treatment of a case of mastitis differed between SCM and non-severe CM ($P = 0.005$). A first unsuccessful treatment was often mentioned as the most important reason (SCM: 26.2% (95%-CI: 20.4–33.0%); non-severe CM: 33.8% (95%-CI: 28.5–39.6%)). Increased somatic cell counts (SCM: 32.2% (95%-CI: 25.9–39.3%); non-severe CM: 26.6% (95%-CI: 21.8–32.1%)) or a positive Californian Mastitis Test (SCM: 19.7% (95%-CI: 14.6–26.0%)) were also frequently mentioned. In herds that treated SCM or non-severe CM with antimicrobials, additional costs was a decisive factor for not calling a veterinarian to initiate treatment, but this did not differ between SCM and non-severe CM ($P = 0.49$; Table 1). More than 60% of the farmers indicated that milk samples for bacteriological testing were taken by themselves or their veterinarian before initiation of treatment. This proportion was slightly higher for non-severe CM cases than for SCM cases whereas the proportion of farmers not taking a milk sample for bacteriological testing was higher for SCM ($P = 0.02$). The most important reason for farmers to not take a milk sample for bacteriological testing before antimicrobial treatment was that they experienced that treatment of SCM (46.3; 95%-CI: 37.2–55.7%) and non-severe CM (45.4%; 95%-CI: 37.1–54.0%) is also successful without. Routinely collecting a milk sample post-treatment to evaluate bacteriological cure was not frequently done (SCM: 7.4% (95%-CI: 3.8–13.9%); non-severe CM: 6.2% (95%-CI: 3.2–11.7%)). When treating SCM or non-severe CM, approximately half of the herds (63.8% for SCM, 51.5% for non-severe CM) had less than 5% of SCM and non-severe CM cases treated by a veterinarian (Fig. 2).

Table 2 shows that most factors influencing management decisions (on a 6-point Likert scale) regarding intramammary treatment were not different for SCM or non-severe CM. Age (mean: 3.1 SCM; 2.8 non-severe CM) and pregnancy status of the cow (mean: 4.0 SCM; 3.6 non-severe CM), however, were considered more important for treatment decisions of SCM than of non-severe CM. Farmers indicated that the result of a bacteriological test and the recommendations of their veterinarian were the most important factors in their decision-making processes. Costs and having antimicrobials in stock were considered less important. Antimicrobial treatment was ceased based on the veterinarian's recommendations or the farmer's own judgment (Table 2). Poor prognosis and the cow's pregnancy status were indicated as important decisive factors regarding culling of cows with SCM or non-severe CM.

Intramammary antimicrobial products containing a combination of neomycin and procaine-penicillin, a combination of gentamicin and procaine-penicillin, and cefquinome were the 3 most frequently used intramammary antimicrobials in Switzerland (Appendix 1). Of the HPCI antimicrobials, cefquinome was mentioned most frequently as first choice.

### 3.3. Knowledge about AMU and AMR

Distributions of answers to the 7 statements making up the AMU/AMR knowledge score are presented in Fig. 3. Farmers knew that bacteria vary in their susceptibility to different antimicrobials but 59.8% (n = 318; 95%-CI: 55.6–63.8%) did not know what an antimicrobial susceptibility test was. Most respondents (79.0%; n = 428; 95%-CI: 75.3–82.2%) also did not know that HPCI antimicrobials are used for the treatment of mastitis. For 58.5% (n = 317; 95%-CI: 54.3–62.6%) of farmers, antimicrobial resistance means that bacteria are not susceptible to antimicrobials. By means of another statement, 76.9% (n = 417; 95%-CI: 73.2–80.3%) answered that it was synonymous for them with an unsuccessful treatment. The fact that antimicrobial resistance may emerge from the incorrect application of antimicrobials (86.9%; n = 471; 95%-CI: 83.8–89.5%) and that antimicrobial resistance in veterinary medicine poses a potential risk to public health (63.7%; n = 345; 95%-CI: 59.5–67.6%) was clear to most farmers. In addition to these 7 statements, most farmers (86.0%; n = 466; 95%-CI: 82.8–88.7%) knew that antimicrobials are meant to treat bacteria. Some, however, thought that antimicrobials can also be used to treat viruses (28.6%; n = 155; 95%-CI: 25.0–32.5%), fungi (16.8%; n = 91; 95%-CI: 13.9–20.2%), and parasites (16.1%; n = 87; 95%-CI: 13.2–19.4%). Thirteen farmers (2.4%; 95%-CI: 1.4–4.0%) also filled in the "other" option, in which "inflammations" (n = 7) was mostly commonly stated.

Farmers' agreed only moderately (mean = 3.8; SD = 1.1) with the perceived knowledge statement *"I have the opinion that I have sufficient knowledge about antimicrobials and the development of antimicrobial resistance"*. Although the mean AMU/AMR knowledge score (mean = 3.7; SD = 1.4; range 0–7) was similar to the mean perceived knowledge score, their correlation was low (Spearman rank correlation coefficient = 0.11; $P < 0.007$).

### 3.4. Attitude towards AMU and AMR

Table 3 shows the respondents' attitudes towards AMU and AMR. Most farmers had the opinion that antimicrobials are emergency drugs and should only be used after consulting a veterinarian (mean = 5.0). Most farmers indicated to use antimicrobials as little as possible (mean = 5.3), partly to save costs (mean = 3.7). Farmers also agreed with the

**Table 1**
Management decisions of Swiss dairy farmers towards treatment of non-severe clinical mastitis and subclinical mastitis in 2014 – categorical variables. For all questions, only a single answer could be provided.

| | Non-severe clinical mastitis | | Subclinical mastitis | | *P*-value[1] |
|---|---|---|---|---|---|
| | N | % | N | % | |
| "What is the most important factor for you to call your veterinarian for a visit related to a cow with mastitis" | (278)[2] | | (183) | | 0.005 |
| Economic value of the cow | 18 | 6.5 | 13 | 7.1 | |
| Positive result of Californian Mastitis Test | 25 | 9.0 | 36 | 19.7 | |
| Increased somatic cell count | 74 | 26.6 | 59 | 32.2 | |
| Reduced milk yield | 12 | 4.3 | 3 | 1.6 | |
| Clinical signs | 34 | 12.2 | 13 | 7.1 | |
| Previous own treatment was unsuccessful | 94 | 33.8 | 48 | 26.2 | |
| Other reasons | 21 | 7.6 | 11 | 6.0 | |
| "What is the most important factor for you to not call your veterinarian for a visit related to a cow with mastitis?" | (334) | | (258) | | 0.487 |
| Additional costs | 191 | 57.2 | 130 | 50.4 | |
| Additional workload for me when the veterinarian is coming | 2 | 0.6 | 2 | 0.8 | |
| It takes longer before cow receives treatment | 40 | 12.0 | 39 | 15.1 | |
| Other reasons | 101 | 30.2 | 87 | 33.7 | |
| "Do you, or your veterinarian, take a milk sample for bacteriological testing before treating a cow with mastitis?" | (367) | | (287) | | 0.024 |
| Yes | 237 | 64.6 | 179 | 62.4 | |
| No | 19 | 5.2 | 31 | 10.8 | |
| Sometimes | 111 | 30.3 | 77 | 26.8 | |
| "What is the most important reason for you to not take a milk sample for bacteriological testing before treating a cow with mastitis?" | (130) | | (108) | | 0.655 |
| It is too expensive | 9 | 6.9 | 7 | 6.5 | |
| It takes too long before laboratory results arrive | 38 | 29.2 | 37 | 34.3 | |
| I have good experiences without | 59 | 45.4 | 50 | 46.3 | |
| My veterinarian hasn't explained the benefits of a milk sample to me | 0 | 0.0 | 2 | 1.9 | |
| Other reasons | 24 | 18.5 | 12 | 11.1 | |
| "Do you, or your veterinarian, take a milk sample after treating a cow with mastitis to evaluate bacteriological cure?" | (130) | | (108) | | 0.631 |
| Yes | 8 | 6.2 | 8 | 7.4 | |
| No | 85 | 65.4 | 75 | 69.4 | |
| Sometimes | 37 | 28.5 | 25 | 23.2 | |

[1] Based on the $\chi^2$ test.
[2] Total number of respondents for this questionnaire item.

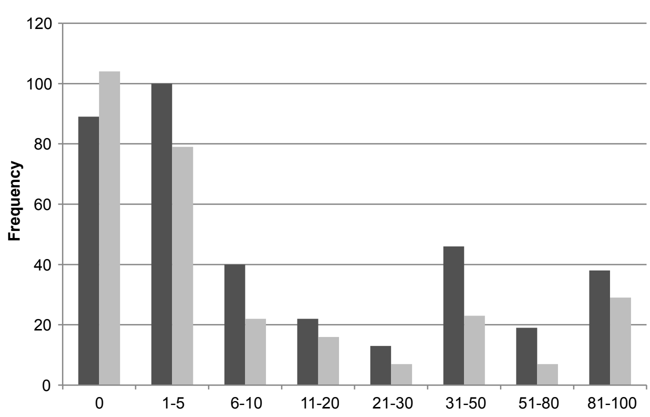


**Fig. 2.** Histogram of farmer-reported percentage of intramammary antimicrobial treatments performed by a veterinarian for subclinical mastitis (light grey; n = 287) and non-severe clinical mastitis (dark grey; n = 367) in Swiss dairy farms.

statement that antimicrobials should only be used after performing an antimicrobial susceptibility test (mean = 4.2). They thought it is very important to adhere to the duration of therapy as indicated by the veterinarian (mean = 5.4) or the package leaflet (mean = 5.1). Most farmers think it is the duty of the veterinarian to mention to the herdsmen that they suspect an udder health problem in the herd (mean = 4.3). It was found that most farmers thought that there is a problem with AMR (mean = 4.1), but they only moderately agreed with the statement that usage of antimicrobials is too high in Swiss dairy farms (mean = 3.4).

### 3.5. AMU and AMR practices

An antimicrobial susceptibility test was requested in all mastitis cases by 18.3% (n = 99; 95%-CI: 15.2–21.7%) of farmers while 42.6% (n = 231; 95%-CI: 38.5–46.8%) of farmers let their veterinarian decide, 22.9% (n = 124; 95%-CI: 19.5–26.6%) never requested a test and 16.2% (n = 88; 95%-CI: 13.3–19.6%) did that sometimes. For 80.3% of farmers (n = 435, 95%-CI: 76.7–83.4%) their veterinarian provided a treatment protocol. For 22.5% (n = 122; 95%-CI: 19.2–26.2%) of farmers, the protocol was provided in a written form, whereas for 57.8% (n = 313; 95%-CI: 53.6–61.8%) of farmers it was communicated orally. Half (51.5%; n = 279; 95%-CI: 47.2–55.7%) of the dairy farmers indicated that they did not store any antimicrobials on their farm; 12.7% (n = 69; 95%-CI: 10.1–15.8%) stored HPCI intramammary antimicrobials while 35.8% (n = 194; 31.9–39.9%) stored non-HPCI intramammary antimicrobials only.

### 3.6. Latent class membership

The latent class analysis model with 5 latent classes had the lowest AIC, BIC and aBIC and a high entropy and was therefore selected as the final model (Appendix 2). This final model, presented in Table 4, identified a group of farmers that did not treat SCM and non-severe CM in the 6 months preceding the start of the survey (latent class 1; n = 100; 18.5%; 95%-CI: 15.4–21.9%), a group that only treated SCM cases (latent class 2; n = 75; 13.8%; 95%-CI: 11.1–17.0%), a group that only

**Table 2**
Management decisions of Swiss dairy farmers towards non-severe clinical mastitis and subclinical mastitis in 2014 – ordinal variables. For all questions, farmers had to indicate for each option whether they agreed with it. Statements were rated on a Likert scale from 1 (fully disagree) to 6 (fully agree).

| | Non-severe clinical mastitis | | Subclinical mastitis | | *P*-value[1] |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| "How decisive are the following criteria for you to use intramammary antimicrobials when treating a cow with mastitis?" | (356)[2] | | (272) | | |
| Additional medical costs | 2.5 | 1.3 | 2.7 | 1.4 | 0.17 |
| Length of the milk withdrawal period | 3.0 | 1.4 | 3.0 | 1.4 | 0.92 |
| Age of the cow | 2.8 | 1.5 | 3.1 | 1.4 | 0.01 |
| Milk yield | 3.6 | 1.5 | 3.7 | 1.4 | 0.36 |
| Pregnancy status | 3.6 | 1.6 | 4.0 | 1.5 | 0.004 |
| Availability of replacement heifers | 3.0 | 1.5 | 3.2 | 1.4 | 0.12 |
| Recommendations by the veterinarian | 4.4 | 1.3 | 4.6 | 1.1 | 0.35 |
| Positive bacteriological status of milk sample | 4.8 | 1.2 | 4.9 | 1.0 | 0.34 |
| Lactation stage | 3.7 | 1.4 | 3.8 | 1.4 | 0.41 |
| Previously unsuccessful treatments | 3.9 | 1.6 | 3.9 | 1.7 | 0.73 |
| On-farm availability of antimicrobials | 2.0 | 1.3 | 2.0 | 1.2 | 0.63 |
| "I cease treatment with antimicrobials …" | (356) | | (272) | | |
| … when somatic cell counts are normal again | 3.9 | 1.6 | 4.1 | 1.5 | 0.13 |
| … when the Californian Mastitis Test gives a negative result | 4.1 | 1.5 | 4.1 | 1.5 | 0.46 |
| … according to the recommendations in the package leaflet | 3.9 | 1.7 | 3.9 | 1.6 | 0.97 |
| … according to the recommendations of my veterinarian | 4.9 | 1.2 | 5.0 | 1.0 | 0.42 |
| … if I consider a case to be cured | 4.2 | 1.5 | 4.2 | 1.5 | 0.91 |
| "How decisive are the following criteria for you to cull a cow with mastitis?" | (347) | | (255) | | |
| Additional costs | 3.5 | 1.4 | 3.3 | 1.5 | 0.20 |
| Poor prognosis | 5.1 | 1.0 | 5.1 | 0.9 | 0.27 |
| Availability of replacement heifers | 3.7 | 1.5 | 3.6 | 1.4 | 0.27 |
| Age of the cow | 4.1 | 1.3 | 4.0 | 1.3 | 0.49 |
| Milk yield | 4.3 | 1.2 | 4.3 | 1.3 | 0.96 |
| Lactation stage | 3.9 | 1.3 | 3.9 | 1.4 | 0.60 |
| Pregnancy status | 5.1 | 1.1 | 5.0 | 1.2 | 0.22 |

[1] Based on the Wilcoxon rank sum test.
[2] Total number of respondents for this questionnaire item.

treated non-severe CM cases (latent class 3; n = 155; 28.6%; 95%-CI: 24.0–32.5%), and a larger group of farmers that treated both mastitis states. The latter group was subdivided into a group of farmers who were following guidelines for prudent AMU (latent class 4; n = 138; 25.5%; 95%-CI: 22.0–29.3%) and into those who do not strictly follow these guidelines (latent class 5; n = 74; 13.7%; 95%-CI: 11.0–16.8%). Latent class 1 was not only characterized by not treating SCM or non-severe CM but also had the lowest probability for storing any antimicrobials on farm. Latent class 2 (only treating SCM cases) and 3 (only treating non-severe CM) were characterized by a moderate probability of taking a milk sample before treatment initiation. In both latent classes, in 63% of the SCM and non-severe CM cases a milk sample was

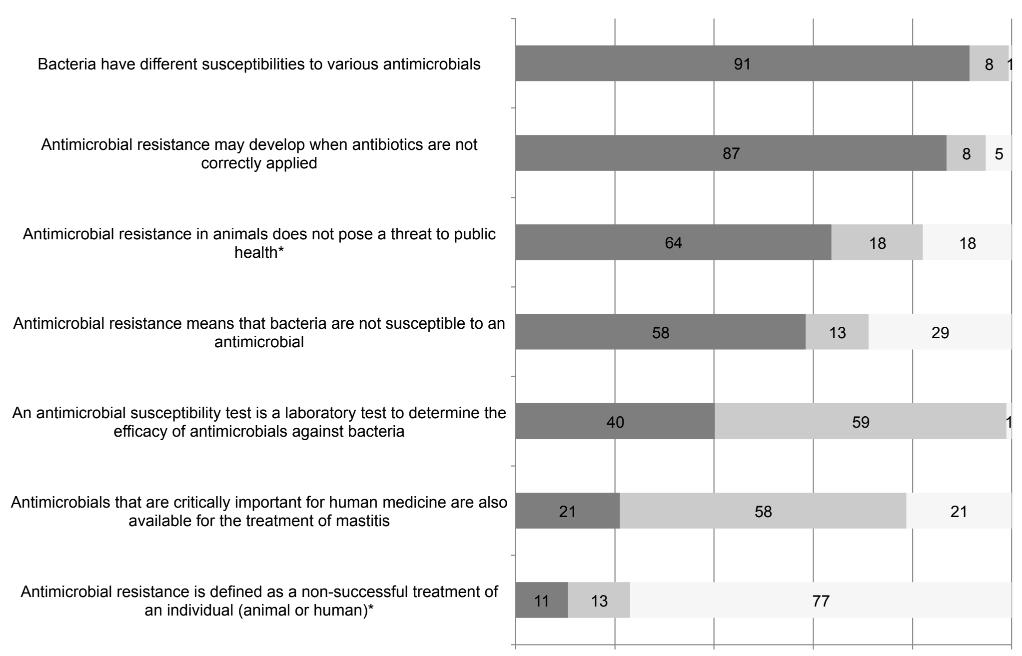


**Fig. 3.** Correctness of Swiss farmers' answers (n = 542) with respect to 7 statements on knowledge of antimicrobials and antimicrobial resistance. Bars represent proportions of correct answers (dark grey), incorrect answers (white), and the option "I don't know" (light grey). *False reverse-coded statement.

**Table 3**
Description of statements regarding the attitude of 542 Swiss dairy farmers towards antimicrobial use and antimicrobial resistance in 2014.

| | Mean | SD |
|---|---|---|
| "I think there is a nation-wide problem with antimicrobial resistance regarding mastitis pathogens" | 4.1 | 1.3 |
| "I think the usage of intramammary antimicrobials is too high in Swiss farms" | 3.4 | 1.3 |
| "For me it is important to adhere to the therapy duration indicated in the package insert" | 5.1 | 1.0 |
| "For me it is important to adhere to the therapy duration as instructed by my veterinarian" | 5.4 | 0.8 |
| "For me, antimicrobials are medications which can be routinely used without consulting a veterinarian" | 1.9 | 1.2 |
| "For me, antimicrobials are emergency medications and should only be used for a targeted therapy and after consulting a veterinarian." | 5.0 | 1.2 |
| "I try to use antimicrobials as little as possible" | 5.3 | 0.9 |
| "To keep costs low, I use antimicrobials as little as possible" | 3.7 | 1.6 |
| "Antimicrobials should only be used after taking a milk sample and conducting a susceptibility test" | 4.2 | 1.3 |
| "It is the duty of the veterinarian to talk to me when he/she assumes an udder health problem in my herd" | 4.3 | 1.4 |

Statements were rated on a Likert scale from 1 (fully disagree) to 6 (fully agree).

taken for bacteriological testing. Latent class 4 (treating both mastitis states – following guidelines for AMU/AMR) was characterized as having a high probability of systematically taking a milk sample before treatment initiation (88% in case of SCM and 97% in case of non-severe CM). Latent class 5 (treating both mastitis states – not strictly following guidelines for AMU/AMR) less frequently took a milk sample before treatment initiation and had the highest probability for storing antimicrobials on farm, including the HPCI antimicrobials. This group also had the lowest probability for having a treatment protocol and the highest probability for not requesting an antimicrobial susceptibility test when submitting a milk sample for laboratory testing.

Two covariates explained latent class membership in the final multinomial logistic regression model (Table 5). Relative to farmers from mountainous regions, farmers from lowland regions had higher odds for belonging to latent class 3 (only treating non-severe CM; OR = 2.2), latent class 4 (treating both mastitis states – following guidelines for AMU/AMR; OR = 3.2) and latent class 5 (treating both mastitis states – not strictly following guidelines for AMU/AMR; OR = 4.1). Farmers from hilly regions also had 2.6 times higher odds for latent class 4 membership (treating both mastitis states – following guidelines for AMU/AMR) than farmers from mountainous regions. Farmers from the French-speaking region of Switzerland had 4 times higher odds to belong to latent class 5 (treating both mastitis states – not strictly following guidelines for AMU/AMR) compared to German-speaking farmers.

Latent class membership was associated with farmers' knowledge and attitude (Table 6). Members of latent class 4 (treating both mastitis states – following guidelines for AMU/AMR) less strongly tried *"to use antimicrobials as little as possible"* compared with latent class 2 (only treating SCM) and 3 (only treating non-severe CM) members. Respondents grouped in latent class 2 (only treating SCM) and 4 (treating both mastitis states – following guidelines for AMU/AMR) agreed more strongly with *"using antimicrobials only after taking a milk sample and performing a susceptibility test"* than latent class 5 respondents (treating both mastitis states – not strictly following guidelines for AMU/AMR). There were no differences between the 5 latent classes concerning farmers' subjective and objective knowledge or any of the other attitude items included in the analysis.

## 4. Discussion

This study scrutinized farmers' knowledge, attitude and practices regarding the use of intramammary antimicrobials in Swiss dairy herds and determined subgroups of farmers regarding their lactational treatment practices towards SCM and non-severe CM. Within the relatively large group of farmers that treated both mastitis states in the last 6 months before conducting the survey, there was a subgroup that complied with guidelines for antimicrobial stewardship (latent class 4) and a smaller group that was less compliant (latent class 5). Besides a reduction in the use of antimicrobials (by treating less SCM or non-severe CM cases), there is potential for improving prudent AMU in latent class 5 (treating both mastitis states – not strictly following guidelines for AMU/AMR) whereas farmers belonging to latent class 4 were already following guidelines for AMU/AMR. The identification of the heterogeneity of farmers regarding their approach towards treating SCM and non-severe CM cases is an important observation because latent class membership was associated with several aspects of farmers' attitude towards AMU/AMR. Although identified relationships cannot be considered causal given the cross-sectional design of the survey and the fact that bias may occur by conducting a questionnaire study, this study identified areas that may be targeted to improve prudent AMU in subgroups of farmers. Other studies need to confirm whether subgroups of farmers can also be observed in other countries.

Knowledge, attitude, and practices did not differ much between subgroups of farmers. Therefore, a generic approach is needed also to change the mindset of the entire dairy farmer population. This does not only include educating farmers on different aspects of AMU/AMR, but also implementing regulations, setting new social norms, and providing farmers with tools helping them to optimize AMU and AMR (Lam et al., 2017). Options for social norm change include, amongst others, mass-media strategies, facilitating public debate, publicly awarding good examples, and setting benchmarks and reference points (Young, 2015; Lam et al., 2017). Examples of tools to optimize AMU/AMR practices include herd-specific treatment protocols and a central database registering on-farm usage of antimicrobials to allow monitoring and benchmarking. Such a system, which will be based on prescription data of veterinarians, has become operational in Switzerland in 2019. A coordinated approach, as is preferred by Swiss dairy farmers and veterinarians (van den Borne et al., 2017), including these different approaches is expected to result in improved antimicrobial stewardship.

Regional and language differences were both observed between latent classes. Herds located in mountainous regions were more frequently owned by farmers not treating SCM or non-severe CM cases than herds in hilly or lowland regions. Farms located in Swiss mountainous regions are often smaller and less professional than herds located at lower altitude (Gordon et al., 2012). Smaller herds may have had no non-severe CM or SCM cases, simply because they are smaller, but herd size was not associated with latent class membership in the statistical analysis. Farmers with herds at higher altitude may lack the confidence to initiate an antimicrobial treatment, since they experience less mastitis cases, or they may consider it too costly for a veterinarian to visit the herd because they are less accessible. These farmers may therefore decide that cases of non-severe CM or SCM do not need treatment at all. The difference in latent class membership between the French- and German-speaking regions may be caused by the various milk quality requirements in different regions of Switzerland. A significant proportion of the milk in the French-speaking region of Switzerland is processed into raw milk cheese, which has more strict milk quality requirements compared to the requirements in the German-speaking region where milk is generally pasteurized. Farmers in the French-speaking part of the country may thus be more under pressure to treat SCM and non-severe CM cases with antimicrobials to meet these

**Table 4**
Item response probabilities of 542 Swiss farmers' practices of AMU/AMR[1] according to their latent class membership for treating non-severe clinical mastitis (CM) and subclinical mastitis (SCM) in 2014.

| Variable | Category | Latent Class | | | | |
|---|---|---|---|---|---|---|
| | | Does not treat SCM or non-severe CM (18.5%) | Treats SCM but not non-severe CM (13.8%) | Treats non-severe CM but not SCM (28.6%) | Treats both – following guidelines for AMU/AMR (25.6%) | Treats both – not strictly following guidelines for AMU/AMR (13.5%) |
| Treatment of non-severe CM | Yes | 0.001 | 0.002 | 1.000 | 1.000 | 0.999 |
| | No | 0.999 | 0.998 | 0.000 | 0.001 | 0.001 |
| Veterinarian treats non-severe CM cases | No treatment of non-severe CM | 0.999 | 0.998 | 0.000 | 0.001 | 0.001 |
| | No vet on farm | 0.000 | 0.000 | 0.258 | 0.217 | 0.258 |
| | Vet treats some cases | 0.001 | 0.001 | 0.658 | 0.646 | 0.727 |
| | Vet treats all cases | 0.000 | 0.000 | 0.084 | 0.137 | 0.014 |
| Collection of milk sample before treating non-severe CM cases | No treatment of non-severe CM | 0.999 | 0.998 | 0.000 | 0.001 | 0.001 |
| | No | 0.000 | 0.000 | 0.065 | 0.000 | 0.123 |
| | Sometimes | 0.000 | 0.001 | 0.303 | 0.027 | 0.823 |
| | Yes | 0.001 | 0.001 | 0.632 | 0.973 | 0.054 |
| Treatment of SCM | Yes | 0.001 | 0.999 | 0.001 | 0.999 | 0.999 |
| | No | 0.999 | 0.001 | 0.999 | 0.001 | 0.001 |
| Veterinarian treats SCM cases | No treatment of SCM | 0.999 | 0.001 | 0.999 | 0.001 | 0.001 |
| | No vet on farm | 0.000 | 0.293 | 0.000 | 0.351 | 0.454 |
| | Vet treats some cases | 0.001 | 0.613 | 0.000 | 0.490 | 0.544 |
| | Vet treats all cases | 0.000 | 0.093 | 0.000 | 0.158 | 0.000 |
| Collection of milk sample before treating SCM cases | No treatment of SCM | 0.999 | 0.001 | 0.999 | 0.001 | 0.001 |
| | No | 0.000 | 0.133 | 0.000 | 0.043 | 0.206 |
| | Sometimes | 0.000 | 0.240 | 0.000 | 0.073 | 0.666 |
| | Yes | 0.001 | 0.626 | 0.000 | 0.884 | 0.126 |
| Having antimicrobials in stock | No antimicrobials in stock | 0.620 | 0.547 | 0.503 | 0.527 | 0.341 |
| | Yes, only non-critical antimicrobials | 0.300 | 0.387 | 0.361 | 0.384 | 0.352 |
| | Yes, including critical antimicrobials | 0.080 | 0.067 | 0.136 | 0.090 | 0.308 |
| Having a treatment protocol | Yes, provided in written | 0.120 | 0.293 | 0.232 | 0.238 | 0.258 |
| | Yes, provided orally | 0.670 | 0.547 | 0.510 | 0.583 | 0.616 |
| | No | 0.210 | 0.160 | 0.258 | 0.179 | 0.126 |
| Obtaining antimicrobials from local veterinarian | Yes | 0.978 | 0.957 | 0.993 | 1.000 | 0.947 |
| | No | 0.022 | 0.043 | 0.007 | 0.000 | 0.053 |
| Requesting antimicrobial susceptibility test when submitting a milk sample | Yes, always | 0.160 | 0.147 | 0.194 | 0.211 | 0.173 |
| | Sometimes | 0.150 | 0.253 | 0.168 | 0.126 | 0.145 |
| | The vet decides about that | 0.490 | 0.387 | 0.381 | 0.462 | 0.408 |
| | No | 0.200 | 0.213 | 0.258 | 0.201 | 0.275 |

[1] Antimicrobial use/antimicrobial resistance.

**Table 5**

Covariates associated with Swiss dairy farmers' (n = 542) latent class membership regarding antimicrobial use and antimicrobial resistance (AMU/AMR) in the final multivariable multinomial logistic regression model.

| | Lowland vs mountainous regions | Hilly vs mountainous regions | French vs German speaking |
|---|---|---|---|
| Latent Class | Odds Ratio | Odds Ratio | Odds Ratio |
| 5. Treats both – not strictly following guidelines for AMU/AMR | 4.1 (2.0–8.4) | 1.3 (0.5–3.5) | 3.9 (1.5–9.8) |
| 4. Treats both – following guidelines for AMU/AMR | 3.2 (1.7–5.9) | 2.6 (1.3–5.3) | 1.9 (0.8–4.5) |
| 3. Treats non-severe CM[1] | 2.2 (1.2–3.9) | 1.4 (0.7–2.7) | 1.2 (0.5–3.0) |
| 2. Treats SCM[2] | 1.1 (0.6–2.3) | 0.7 (0.3–1.6) | |
| | | | 7.%2 (0.2–2.3) |
| 1. Does not treat | Reference | Reference | Reference |

95%-confidence intervals are presented between brackets.

[1] Clinical mastitis.

[2] Subclinical mastitis.

requirements. Whether or not stricter milk quality requirements lead to higher usage of antimicrobials remains speculation and needs further study.

Both farmers' perceived knowledge and their actually tested knowledge on AMU/AMR was moderate. Farmers were aware of certain aspects of AMU/AMR but were lacking knowledge on other relevant aspects, including the fact that HPCI antimicrobials were used to treat mastitis. Farmers' knowledge on AMU and AMR may improve through national communication and education campaigns and discussions with their veterinarians (Higham et al., 2018). The use of HPCI antimicrobials for instance, is assumed to become substantially lower if it is given attention through regulations and education on potential public health effects (Lam et al., 2017).

Most farmers indicated to use antimicrobials as little as possible, partly in order to reduce costs (Jones et al., 2015). This, however, conflicts with the high sales of intramammary antimicrobials in Switzerland (European Medicines Agency, 2017). Additionally, farmers only moderately agreed with the statement that intramammary AMU was too high in Swiss dairy herds. This indicates that there may be a misconception between perceived and actual intramammary AMU, especially when placed in an international perspective. Treatment decisions of farmers are influenced by the societal context they are in (Vaarst et al., 2007; Jansen and Lam, 2012) which likely is also true for Swiss dairy farmers. Swiss dairy farmers generally receive a bonus when their bulk milk somatic cell counts is < 100,000 cells/mL. Given the low average herd size and the large effect of an individual cow, farmers may treat cows during lactation to reduce somatic cell count levels to obtain a financial bonus on their bulk milk result, with high AMU as a result. Incorporating AMU as an additional criterion for receiving a financial bonus is expected to result in an additional reduction in AMU (van den Borne et al., 2017). Also, the initiation of a national database to monitor and benchmark the usage of antimicrobials will facilitate national and international comparisons and will showcase the high usage of intramammary antimicrobials during lactation. This can be a starting point for a discussion on decreasing the usage of antimicrobials in Swiss dairy herds.

Most farmers in the current study had the opinion that there is a nation-wide problem with AMR of mastitis pathogens and stated that AMR is the unsuccessful treatment of an animal, rather than the ability of antimicrobials to kill or inhibit bacteria. However, resistance levels of antimicrobials commonly used to treat major mastitis pathogens in Switzerland are generally below 10% (Corti et al., 2003; Moser et al., 2013a; Overesch et al., 2013) with only penicillin resistance in *Staphylococcus aureus* and resistance levels in non-aureus staphylococci being higher (Frey et al., 2013; Moser et al., 2013b; Overesch et al., 2013). Antimicrobial resistance is only one possible explanation for treatment failure (Barkema et al., 2006; van den Borne et al., 2010) and incorrectly interpreting AMR as treatment failure may therefore explain the discrepancy between farmers' perceived and actual AMR levels of mastitis pathogens.

Bacteriological identification and susceptibility testing are considered cornerstones of prudent AMU (Prescott, 2008; Oliver et al., 2011; Teale and Moulin, 2012). More than sixty percent of farmers in the current study reported to always take a milk sample before treating a cow with antimicrobials. This percentage is high compared to the Netherlands for instance (Griffioen et al., 2016), but similar to observations from Scandinavia (Vakkamäki et al., 2017; Emanuelson et al., 2018), and is promising from a prudent AMU perspective. On the other hand, farmers often have difficulties interpreting results from bacteriological tests (Jansen et al., 2010). It is therefore likely that in Switzerland, where farmers generally have small herds and little experience with laboratory results, that veterinarians are consulted in many cases before initiation of treatment. Susceptibility testing was not routinely requested by farmers and over 40% of farmers let their veterinarian decide whether to perform a susceptibility test. Together with the observation that most farmers consider it a responsibility of veterinarians to address assumed udder health problems with farmers, this opens opportunities for veterinarians to support their clients and to discuss AMU. This study reemphasized the importance of veterinary practitioners on farmers' antimicrobial stewardship (Friedman et al., 2007; Jones et al., 2015; Higham et al., 2018) and that there is room for improvement regarding the communication between farmers and veterinarians (Lam et al., 2011; Pothmann et al., 2013; Tschopp et al., 2015).

Antimicrobial treatment initiation has previously been described to differ between severe and non-severe CM cases (Vaarst et al., 2002; Jones et al., 2015). In our current study, we found that, although the majority (80%) of farmers in our study differentiated between SCM and non-severe CM, treatment decisions of both mastitis states were similar. This discrepancy between the diagnosis and management approach may be explained by the fact that farmers see SCM and non-severe CM as different stages of the same disease (Vaarst et al., 2002).

This study focused on the lactational treatment of non-severe CM and SCM mainly. Farmers' knowledge, attitude, and practices regarding severe CM and dry cow treatment were not assessed given the length of the questionnaire and the indications for a high usage of intramammary antimicrobials during lactation in Swiss dairy herds (Menéndez González et al., 2010; European Medicines Agency, 2017). No conclusions on the mindset of farmers regarding the treatment of severe CM or at dry-off can therefore be drawn from this study. Furthermore, the number of treated mastitis cases, rather than the number of disease cases, was surveyed when determining incidence rates. This was done because focus was on farmers' mindset regarding AMU/AMR, not on their mindset regarding udder health. This, however, may complicate making comparisons with incidence rate estimates from other studies.

The overall response rate (42%) was in between the response rates of two previously conducted questionnaires in the same target population of Swiss dairy herds (47% and 37%, respectively; Gordon et al., 2012; van den Borne et al., 2017) and therefore as expected. Remarkably, a difference in response rate was observed between the

**Table 6**
Swiss dairy farmers' (n = 542) latent class membership and their relationship with objective knowledge, subjective knowledge and 10 attitude variables. Values represent means of a 1 (fully disagree) to 6 (fully agree) Likert scale unless indicated otherwise.

| | Latent class | | | | | |
|---|---|---|---|---|---|---|
| | Does not treat | Treats subclinical mastitis | Treats non-severe clinical mastitis | Treats both – following guidelines for AMU/AMR[1] | Treats both – not strictly following guidelines for AMU/AMR | $P^2$ |
| AMU/AMR knowledge score | 3.58 | 3.61 | 3.79 | 3.78 | 3.93 | 0.58 |
| "I have sufficient knowledge about antimicrobials and resistance" | 3.80 | 3.83 | 3.74 | 3.73 | 3.80 | 0.93 |
| "I think there is a nation-wide problem with antimicrobial resistance regarding mastitis pathogens" | 4.03 | 4.40 | 4.14 | 4.09 | 4.19 | 0.42 |
| "I think the usage of intramammary antimicrobials is too high in Swiss farms" | 3.40 | 3.52 | 3.30 | 3.31 | 3.49 | 0.61 |
| "For me it is important to adhere to the therapy duration indicated in the package insert" | 5.25 | 5.21 | 4.99 | 5.05 | 5.12 | 0.16 |
| "For me it is important to adhere to the therapy duration as instructed by my veterinarian" | 5.42 | 5.55 | 5.37 | 5.46 | 5.22 | 0.09 |
| "For me, antimicrobials are medications which can be routinely used without consulting a veterinarian" | 1.85 | 1.84 | 1.92 | 1.82 | 2.41 | 0.02 |
| "For me, antimicrobials are emergency medications and should only be used for a targeted therapy and after consulting a veterinarian." | 5.02 | 5.21 | 5.00 | 5.08 | 4.78 | 0.03 |
| "I try to use antimicrobials as little as possible" | 5.36 | $5.59^a$ | $5.41^a$ | $5.14^b$ | 5.30 | 0.001 |
| "To keep costs low, I use antimicrobials as little as possible" | 4.00 | 3.75 | 3.66 | 3.41 | 3.61 | 0.09 |
| "Antimicrobials should only be used after taking a milk sample and conducting a susceptibility test" | 4.09 | $4.36^b$ | 4.06 | $4.45^b$ | $3.70^a$ | 0.001 |
| "It is the duty of the veterinarian to talk to me when he/she assumes an udder health problem in my herd" | 4.41 | 4.49 | 4.29 | 4.36 | 3.91 | 0.06 |

Latent classes with different superscripts within a row differ significantly based on the post hoc Dwass, Steel, Critchlow-Fligner procedure ($P < 0.05$).
[1] Antimicrobial use/antimicrobial resistance.
[2] Based on a Kruskal-Wallis one-way ANOVA.

German- (44%) and French-speaking farmers (30%) though. There are cultural differences between the two regions, which potentially could explain this observation, but a difference in response rate was not observed before (Gordon et al., 2012). French-speaking farmers, however, were more likely to belong to latent class 5 (treating both mastitis states – not strictly following guidelines for AMU/AMR) compared to German-speaking farmers. It may thus be possible that farmers from the French-speaking region were less willing to participate in this survey concerning a highly societal sensitive topic. The results of this questionnaire should therefore be interpreted in light of this potential response bias.

Most farmers treated both SCM and non-severe CM before calling their veterinarian for a visit. Additional costs were stated to be a decisive factor for this, which was also described earlier (Raymond et al., 2006; Friedman et al., 2007). Factors, such as animal welfare and good stockman ship may, however, also play a role (Espetvedt et al., 2013). The fact that antimicrobial treatment is mostly initiated by farmers without the support of evidence-based guidelines or a prescription of a veterinarian may pose a risk for a suboptimal intramammary AMU. Practices conflicting with a prudent antimicrobial use are, for instance, when farmers use antimicrobials off-label or without applying a bacteriological test. Antimicrobials may be used more judiciously when prescribed by veterinarians. Farmers find written treatment protocols helpful in reducing errors when treating intramammary infections (Raymond et al., 2006; Jones et al., 2015) but only 22% of farmers had such a protocol in the current study. Promoting the use of written treatment protocols is assumed to further improve antimicrobial stewardship (Oliver et al., 2011) and to bring conformity among treatment practices in Swiss dairy herds.

As in other countries (Higham et al., 2018), cefquinome, one of the HPCI antimicrobials (World Health Organization, 2017), was commonly used to treat mastitis in Switzerland. Comparable to other countries (Mevius and Heederik, 2014), the Swiss authorities implemented a stricter legislation that prohibits keeping HPCI antimicrobials in stock on the farm. Usage of HPCI is therefore expected to decrease.

## 5. Conclusions

This study identified subgroups of farmers with respect to the treatment of SCM and non-severe CM which were associated with some attitude questionnaire items. This allows a targeted approach to subgroups of farmers when developing strategies to improve prudent intramammary AMU in Switzerland. Swiss farmers lacked knowledge on certain items of AMU and AMR, including the usage of HPCI antimicrobials for the treatment of mastitis. The relatively high use of diagnostics to identify IMI gives opportunities for veterinarians to provide more services to farmers and discuss options to improve antimicrobial stewardship in Swiss dairy herds. This study provides important insights into farmers' mindsets towards AMU/AMR. Its results can be used to develop strategies to reduce, replace and refine intramammary antimicrobial usage in dairy herds.

## Declaration of competing interest

The authors declare that they have no conflict of interest.

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**Appendix 1 Application of intramammary antimicrobials in Swiss dairy herds for the treatment of non-severe clinical and subclinical mastitis in 2014**

| Antimicrobials | Mastitis | Ranked 1 | | Ranked 2 | | Ranked 3 | | Not ranked (> 3) | | *P* -value[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | |
| Ampicillin, cloxacillin | Non-severe | 22 | 6.5 | 18 | 7.4 | 14 | 9.0 | 11 | 6.0 | 0.36 |
| | Subclinical | 13 | 5.6 | 12 | 7.8 | 6 | 8.8 | 2 | 4.2 | |
| Amoxicillin, clavulanic acid | Non-severe | 26 | 7.7 | 16 | 6.6 | 20 | 12.9 | 19 | 10.3 | 0.03 |
| | Subclinical | 18 | 7.7 | 14 | 9.2 | 9 | 13.2 | 1 | 2.1 | |
| Cloxacillin, colistin | Non-severe | 29 | 8.6 | 35 | 14.5 | 7 | 4.5 | 15 | 8.2 | 0.76 |
| | Subclinical | 15 | 6.4 | 13 | 8.5 | 7 | 10.3 | 3 | 6.3 | |
| Cefquinome[2] | Non-severe | 41 | 12.1 | 25 | 10.3 | 12 | 7.7 | 13 | 7.1 | 0.20 |
| | Subclinical | 28 | 12.0 | 21 | 13.7 | 6 | 8.8 | 3 | 6.3 | |
| Cefoperazone[2] | Non-severe | 10 | 3.0 | 15 | 6.2 | 8 | 5.2 | 12 | 6.5 | 0.32 |
| | Subclinical | 6 | 2.6 | 11 | 7.2 | 4 | 5.9 | 2 | 4.2 | |
| Cefalexin | Non-severe | 2 | 0.6 | 1 | 0.4 | 2 | 1.3 | 2 | 1.1 | (-) |
| | Subclinical | 2 | 0.9 | 0 | 0.0 | 2 | 2.9 | 0 | 0.0 | |
| Cefalixin, kanamycin | Non-severe | 5 | 1.5 | 11 | 4.5 | 15 | 9.7 | 9 | 4.9 | 0.07 |
| | Subclinical | 6 | 2.6 | 10 | 6.5 | 3 | 4.4 | 4 | 8.3 | |
| Cefapirin | Non-severe | 5 | 1.5 | 2 | 0.8 | 0 | 0.0 | 4 | 2.2 | (-) |
| | Subclinical | 4 | 1.7 | 3 | 2.0 | 0 | 0.0 | 0 | 0.0 | |
| Dihydrostreptomycin, nafcillin, procaine penicillin | Non-severe | 12 | 3.6 | 4 | 1.7 | 3 | 1.9 | 9 | 4.9 | 1.00 |
| | Subclinical | 6 | 2.6 | 6 | 3.9 | 2 | 2.9 | 0 | 0.0 | |
| Gentamicin, procaine penicillin | Non-severe | 74 | 21.9 | 38 | 15.7 | 18 | 11.6 | 10 | 5.4 | 0.62 |
| | Subclinical | 47 | 20.2 | 20 | 13.1 | 6 | 8.8 | 6 | 12.5 | |
| Kanamycin, spiramycin[2] | Non-severe | 6 | 1.8 | 22 | 9.1 | 23 | 14.8 | 17 | 9.2 | 0.06 |
| | Subclinical | 8 | 3.4 | 13 | 8.5 | 5 | 7.4 | 6 | 12.5 | |
| Lincomycin, neomycin | Non-severe | 12 | 3.6 | 6 | 2.5 | 9 | 5.8 | 8 | 4.3 | 0.40 |
| | Subclinical | 6 | 2.6 | 5 | 3.3 | 3 | 4.4 | 2 | 4.2 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Neomycin, procaine penicillin | Non-severe | 76 | 22.5 | 33 | 13.6 | 12 | 7.7 | 12 | 6.5 | 0.25 |
| | Subclinical | 56 | 24.0 | 16 | 10.5 | 6 | 8.8 | 4 | 8.3 | |
| Procaine penicillin | Non-severe | 16 | 4.7 | 12 | 5.0 | 7 | 4.5 | 37 | 20.1 | 0.23 |
| | Subclinical | 16 | 6.9 | 5 | 3.3 | 5 | 7.4 | 15 | 31.3 | |
| Spiramycin[2] | Non-severe | 2 | 0.6 | 4 | 1.7 | 5 | 3.2 | 6 | 3.3 | (-) |
| | Subclinical | 2 | 0.9 | 4 | 2.6 | 4 | 5.9 | 0 | 0.0 | |
| Total responses | Non-severe | 338 | 100.0 | 242 | 100 | 155 | 100 | 184 | 100 | |
| | Subclinical | 233 | 100.0 | 153 | 100 | 68 | 100 | 48 | 100 | |

Farmers were asked which intramammary antimicrobial products they applied when treating subclinical and non-severe clinical mastitis. They subsequently created a ranking of the 3 most frequently applied.

[1] Based on the $\chi^2$ test.

[2] Antimicrobials critically important for human medicine with highest priority (World Health Organization, 2017).

## Appendix 2 Fit statistics of different subscale latent class analysis models

| Classes | AIC | BIC | aBIC | Entropy |
|---|---|---|---|---|
| 2 | 2862.9 | 3056.2 | 2913.3 | 1.0 |
| 3 | 2107.8 | 2399.8 | 2184.0 | 1.0 |
| 4 | 1456.2 | 1847.1 | 1558.2 | 1.0 |
| 5 | 1346.8 | 1836.4 | 1474.6 | 0.98 |
| 6 | 1382.3 | 1970.7 | 1535.8 | 0.98 |
| 7 | 1392.1 | 2079.3 | 1571.4 | 0.93 |

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