Survey on dairy farmers‘ management practices for and satisfaction with the detection of clinical mastitis by automatic milking systems in Bavaria, Germany

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Abstract

The objectives of this study were to identify (i) management practices for the detection of clinical mastitis (**CM**) in dairy farms with automatic milking systems (**AMS**), and (ii) the farmers' personal assessment of their work with the AMS as well as the mastitis detection performance of the AMS through an online survey. Complete responses of 47 of the 108 contacted Bavarian dairy producers were available for analysis. Warning lists of AMS, highlighting cows with potential udder health problems, were checked twice a day by 68% and once per day or less frequently by 27% of the farmers. Checking warning lists reportedly took five minutes per day (median). Besides the presence of flakes on the milk filter (75%), data from the AMS (78%) was another important factor that farmers considered for their decision to assess an indicated cow in the barn. Electrical conductivity (**EC**; 50%), milk color/ blood presence (49%), and, if available, somatic cell count (66%) were selected most frequently as "extremely important" from provided options in the survey. Flagged cows were commonly checked within 12 hours of the alert (23%) in the barn. Most commonly, these cows were assessed by organoleptic examination of the udder and/or the first milk strains (50%). Most farmers (68%) agreed with the statement of being very satisfied with the detection performance of CM by the AMS. However, almost half of the farmers (44%) perceived the number of false-positively flagged cows by the AMS as too high. While farmers were overall positive towards the detection of CM in AMS, some management factors such as the frequency of monitoring the warning list and cows in the barn could be intensified.

Keywords: dairy cows; milking robots; mastitis monitoring; questionnaire

Introduction

Dairy farmers are responsible for the health of their animals [1], the production of a high-quality food, and maintaining the profitability of their farm [2, 3]. Clinical mastitis (**CM**) of dairy cows affects all of these production areas as it impacts animal welfare and food quality and causes high economic losses [4–6]. Rapid diagnosis and appropriate treatment of CM are therefore crucial [7]. In conventionally milking dairy farms, the milker monitors udder health of each animal during the milking preparation process, e.g., by prestripping. This way, food safety is – from a legal point of view – ensured by organoleptic examination of the udder and milk for pathological changes [8]. Due to the increasing popularity of automatic milking systems (**AMS**), fewer humans are physically present at the milking of cows. This is related to both the Europe-wide trend of decreasing number of farms whilst simultaneously increasing farm sizes [9]. Another reason is that farmers might seek a better work-life balance through the installation of an AMS that allows for flexible working hours [10, 11]. Hence, also in Bavaria, the proportion of farms with AMS has risen from 3% to 16% in the last decade [12]. In farms using an AMS, the inspection of milk and udder health relies on the performance of the AMS sensors due to the absence of a milker [13–15]. The AMS indicates animals via warning lists to farmers if the animals are likely to have udder health problems. The sensor technology is able to detect and indicate inflammatory processes that may be minor and without visible changes to the milk [16]. However, the detection of CM by AMS has its limitations [17, 18]. For this reason, the German Federal Ministry of Food, Agriculture and Consumer Protection established a list of action items for dairy farms with AMS to ensure adequate udder health and an ongoing monitoring in 2012 [19].

Since the final (physical) assessment and maintenance of udder health (e.g., treatment decisions, consultation of farm veterinarian) remain the responsibility of the farmer, the "interaction" between AMS and humans is crucial. Few studies have addressed the role of the farmer on udder health in AMS herds: In 2012, Mollenhorst et al. investigated

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the requirements for CM detection systems desired by farmers and concluded that CM alerts should have a low false positive rate, occur in a short time, and be graded by severity [20]. A Dutch study found that most Dutch farmers milking with an AMS made inspection decisions based on intuition and only the minority of farmers reported using non-AMS information about cows or detailed alerts to decide which cows to visually inspect [21]. However, which data of different AMS are important to farmers for the detection of CM and how farmers deal with these warnings has not been investigated yet.

Therefore, the objectives of this study were (i) to evaluate management practices for the detection of CM in Bavarian AMS farms, and (ii) to present farmers' personal assessment of their work with the AMS and the performance of mastitis detection of their AMS.

Materials and Methods

Herd selection and contact: Dairy farms equipped with AMS, that participated (n=114) in a previous study of the Bavarian Animal Health Services [17], were invited by personal e-mail to participate in this anonymous online survey. The personal invitation e-mail included a description of the study objectives, a note that subjects should also be the primary users of the AMS on their farms, and a link to the online survey. In addition, it provided information about the chance to participate in a prize draw for ten milk sample test kits in case of successful participation on the survey. To maintain anonymity of the main survey, an URL to a second independent input mask of the survey tool was provided at the end of the questionnaire for participating the prize draw. There, the respondents could enter their e-mail address, which was used to randomly select and contact the winners at the end of the survey period.

Questionnaire development: A survey with 22 questions was developed for the study. Question content, structure and organization of the questionnaire were revised and validated based on feedback from specialists and AMS manufacturer support personnel (n=8) as well as existing literature. The survey covered six main topics: general herd structure (3 questions), work with the dairy herd in the barn (4), work with the AMS software (4), mastitis diagnostic (6), personal opinion (2), and demographic data (3). Open ended and closed questions as well as Likert scale answer options [22] were included.

Subsequently, the questionnaire was pretested in personal interviews with three not-study-related AMS-using farmers, and the adapted version was transferred into the open-source online tool LimeSurvey (LimeSurvey Project Team/Carsten Schmitz, 2012). This online version was pretested with two farmers and four other specialists (veterinarians and AMS manufacturer staff). The final survey in the target population ran from June 18th to July 17th, 2021. To increase participation in the survey, a reminder e-mail was sent to all participants one week before the deadline [23]. The final version of the survey (in German) is available as a PDF file as supplements under https://openjournals.hs-hannover.de/milkscience/issue/view/ 198.

The questionnaire content and implementation procedure were approved by the ethical committee of the Freie Universität Berlin (ZEA-Nr.2021-009).

Statistical Analysis: The raw survey data were exported to MS Excel (microsoft.com) and analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC; USA). Only fully completed surveys were included in the final statistical analysis. The data were then checked for plausibility and excluded if illogical errors were found. Continuously measured items were evaluated for normal distribution by Q-Q-plots and the Kolmogorov-Smirnov test by PROC UNIVARIATE. Descriptive summary statistics were used by PROC FREQ and PROC MEANS. Associations between AMS, gender, and age and continuous variables were analyzed with a Mann-Whitney U test by PROC NPAR1WAY WILCOXON test and for three or more groups by using the Kruskal Wallis test. Correlations between ordinal variables were assessed with non-parametric statistic Spearman's rho using PROC CORR SPEARMAN. The significance level was set at $P<0.05$. Figures were designed using Tableau version 2022.1 (Tableau Software, Seattle, Washington, USA).

Results and Discussion

Survey response rate: In the previous study [17], 114 herds had participated. Of these, e-mail addresses from 111 farmers were available. However, due to invalid or incorrect e-mail addresses, three farms could not be contacted. Therefore, a total of 108 farmers were invited and 62 participated (57%). Since 15 of the 62 collected questionnaires were incomplete, 47 questionnaires remained for the statistical analysis.

Of the 15 excluded surveys, five were completely empty, five responders had answered only 14% of the questions, and the remaining five dropped out after answering up to 50% of the questions. This net response of 43.1% was above the average response rate of other web-based questionnaires with dairy producers [24, 25]. This could be due to the underlying design which included a clearly defined and understandable study topic, professional layout, provision of the estimated processing time, invitation via a personalized e-mail, follow-up contact with resending survey link, length of the questionnaire minimized, and a prize draw as an incentive to participate [26–28]. The fact that the farmers were more interested in the topic as they had already participated in the earlier study certainly provided another incentive to complete the survey. Considering the selection process and response rate, any generalization of the results of this study should be done with caution.

Demographic data and herd structure of the sample: The participants were predominantly male (79%) and reported to be in the age category 31 to 50 years (62%). They had been working with AMS for a median of four (interquartile range [**IQR**]: 3-8) years. The majority of producers reported that they worked almost exclusively alone in monitoring the AMS udder health lists (80%) as well as subsequently inspecting the indicated cows in the barn (76%). This implies that the respondents to the questionnaire were remarkably familiar with the topic. At the time of the survey the herds milked 65 cows (median, IQR: 59-74). This herd size is consistent with the normal herd size for the most common use of one AMS, i.e., 60 cows/AMS unit, and the Bavarian average number of cows on AMS farms [12, 14]. The median annual bulk tank somatic cell count was reported to be 165 (IQR: 105-190) x1000 cells/mL for the herds in 2020 and was below the Bavarian average [12]. This may be due to the fact that the AMS of these herds were all maintained regularly by their AMS companies and the farmers were concerned about the udder health of their herd, which was expressed in the participation in the previous study.

Daily management of monitoring the udder health of the AMS herd: The majority of the surveyed farmers reported conducting daily measures in adherence to the list of measures aimed at ensuring udder health. It includes to check the AMS udder health warning lists and the herd for udder health in the barn at least twice per day. The check of the AMS warning list took a median of 5 minutes daily (IQR 5-10 min./day) and was performed by 68% of the farmers twice a day, as recommended. Also, the additional assessment of the herd for udder health in the barn took a median of 10 minutes per day (IQR 5-20 min./day) and was performed by 53% of respondents twice per day. There

was a positive correlation between the amount of time spent checking warning lists and the amount of time spent checking the udders of the herd each day: the more time spent on warning lists, the longer it took to check the udder health of the herd in the barn (Spearman's rho=0.4; p=0.01). This could be an indication that more intensive use of the udder health warning lists lead to longer and possibly more careful udder health control of the herd. Alternatively, this could also be due to the high number of warnings needing to be checked. However, the time taken and the frequency with which the recommended measures are carried out allow only a cautious assessment of the quality of daily udder health monitoring. About 70 to 80% of CM cases are flagged by the system, but the number of false-positive cases is fairly high [17]. The farmer should therefore follow the guidelines of the catalogue of measures to look at data and cows at least twice a day, since each milking adds information about that animal's health and will help to increase overall accuracy of warnings. The better the farmer knows cows on the list, the better potential udder health problems could be detected and false positive alerts distinguished by the farmer. In addition, detection of udder health problems by AMS is limited by the sensor technology used [18, 29]. For instance, AMS currently do not detect udder-related diseases such as udder cleft dermatitis or acute trauma to the skin. Also, irregular control of the herd may result in slower and delayed detection and treatment of, for example, immobilized cows due to acute CM caused by *Escherichia coli*-infection, which can no longer visit the AMS. This has both economic and animal welfare consequences as the severity of the disease increases rapidly [30–32]. For these reasons, in addition to frequent monitoring of AMS warning lists, the farmer must continue to physically monitor his herd in his daily routine to identify problem cows or to prevent the spread of (udder) disease. Therefore, it is concerning, that about one third of the respondents checked only once a day or less the udder health warning lists (27%) or their herd in the barn (34%) for udder health problems.

Detection management of new CM cases: Given the absence of a specific AMS alert for cows with CM, which results in legally unmarketable milk, the decision to take action on an indicated cow ultimately rests with the farmer. Consequently, farmers were asked about their handling of new AMS udder health alerts. Newly indicated cows in this study were defined as having not generated an udder health warning in the previous seven days. Approximately 53% of the participants reported often performing a check within 12 hours of the warning, while 42% of farmers only went to look at flagged cows after four or more consecutive warnings. This observation is consistent with findings of other studies, where farmers were selective about assessing indicated cows in the barn due to the high workload coupled with the low specificity of the detection of mastitis by AMS [21, 33]. However, this behavior does not meet the suggested measures, which advise an immediate examination of all indicated cow [19]. One has to assume that if cows on warning lists are not examined immediately in the barn, many specifically milder mastitis cases will likely be overlooked. This assumption is supported by the finding that AMS farms detected mostly severe cases of CM [34].

The decision to assess flagged cows in the barn was based on various factors. Of particular importance was examination of the milk filter for abnormal milk components such as flakes or clots ("very important" (74%)) and additional AMS data (78%). In contrast monthly test day data or the milk yield of the cow relative to herd mates were reportedly of minor importance to farmers in this study. While Steeneveld et al. did not find non-AMS data helpful in distinguishing between true-positive and true-negative alerts [33], another study found that inclusion of somatic cell count (**SCC**) of monthly test day data was related to CM detection performance of AMS [17]. There, the inclusion of monthly test day data was identified as a previously overlooked tool that has potential to improve udder health monitoring. To assess the importance of AMS data for the decision to check a newly indicated cow in the barn, the respondents were asked to rate the importance of AMS data on a seven-point Likert scale (1=extremely unimportant to 7=extremely important) as well as the answer options "no answer" and "sensor data not available". The list of the AMS data provided to farmers to be ranked

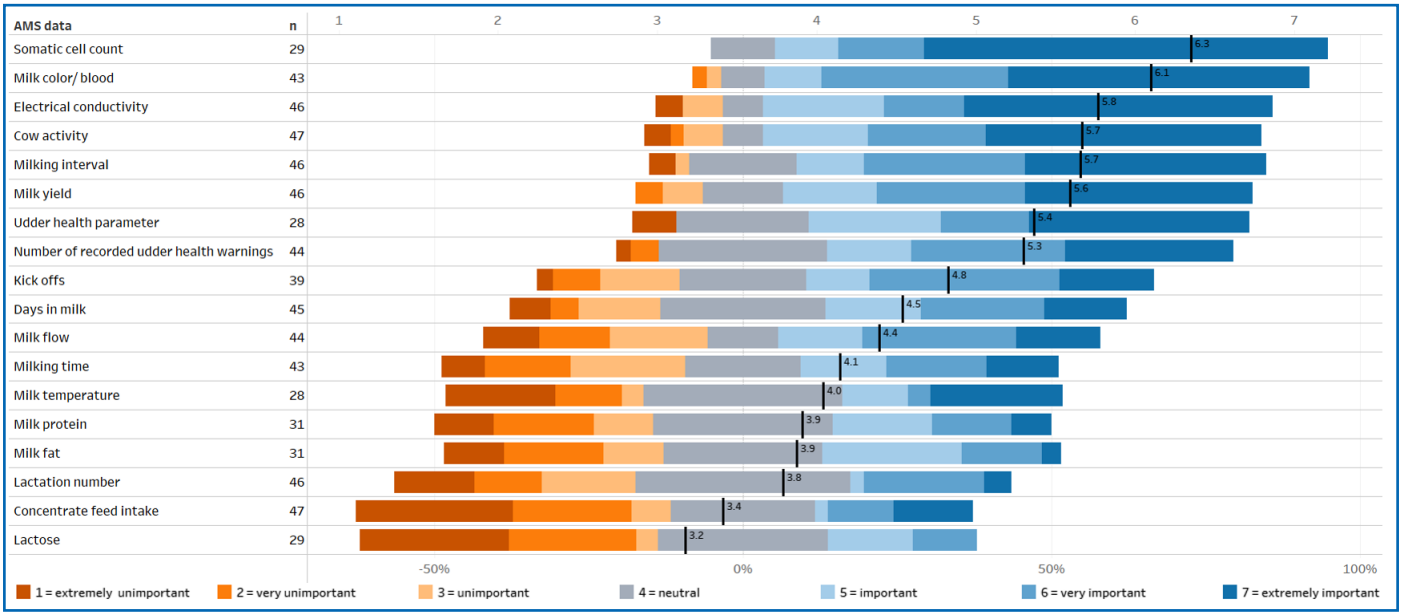

Figure 1: Comparison of the subjective relevance of information displayed to farmers (n=47) on udder health lists of the automatic milking system (AMS). Percentage rating of subjective importance of the participants, which AMS data is helpful for assessing whether an indicated cow will be also controlled in the barn (Gantt percent, lower axis). Importance on a seven-point Likert scale shown in stacked bar charts, sorted in descending order by average Likert score values (upper axis) shown as a black line. The number of answers is not equal in total, since the answer options "sensor data not available" and "no answer" were excluded from the respective bars.

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included the most common commercially available sensors and AMS data. Other sensors are offered by some AMS manufacturers that also have reported to be helpful in detecting udder health problems such as sensors for lactate dehydrogenase [16] or rumination activity [35]. They were not considered in our study because they are not widely available as upgradeable sensor technology. Based on the average answer scoring (**AAS**), the most important information was the SCC (AAS: 6.3; n=29) for farms of this study equipped with such a device (38%), followed by blood or color sensor alerts (AAS: 6.1; n=43), and the electrical conductivity (**EC**; AAS: 5.8; n=46). Other information was ranked lower in relevance (Figure 1). This is in line with the study of Steeneveld and Hogeveen [36], who investigated the frequency of sensors in daily use and found SCC and EC data were frequently used while fat, protein and milk temperature were less commonly used sensor information. Other studies have shown that the use of the SCC [37, 38] as well as the EC [39] can help to detect udder health problems. The value of the milk color sensor on its own is considered controversial in other studies, as the detection of CM by this sensor alone does not seem suitable due to the influence of fat color [40–42]. However, combining the information from different sensor data is considered a good tool to detect udder health problems [43, 44]. Based on the finding that no sensor data had a high rejection rate, it can be assumed that some farmers combine different information provided by AMS in their decision-making process. The inclusion of additional AMS data showed improved detection performance for CM in some studies [7, 17] and thus can be considered a good state of practice to identify CM. In conclusion, the majority of farmers were applying suitable management procedures to detect CM in AMS herds. Although not all udder health alerts were addressed promptly, they were evaluated in conjunction with sufficient AMS data and information obtained from the barn. In addition, a more extensive utilization of DHIA data for this purpose should be considered.

Examination of new udder health warnings in the barn: The examination of the indicated cow for udder health in the barn was done at least "often" by inspection and palpation of the udder (87% of the study participants), by evaluation of the foremilk for abnormal milk such as flakes or blood (78%), or a California Mastitis Test (**CMT**, 64%), while a quarter milk sample for pathogen determination in the laboratory was almost never taken by about 42% of farmers. Since detection of even mild CM cases by sensory clinical examination has a sensitivity of 80% [45], the farmer's assessment of udder health status is considered sufficient and in general agreement with the methodology proposed by Hogeveen et al. [46]. However, AMS and their udder health alerts are supposedly designed as an early warning system. Therefore, the AMS often detects invisible changes in the milk composition, which can indicate, for example, subclinical mastitis. A purely organoleptic examination of the milk for abnormalities of the indicated cows will therefore lead to a high number of false positive alerts. In this case, regular monitoring of all cows or specific CMT-based checking of those cows that have an AMS warning but no (or not yet visibly detectable) clinical symptoms will be useful to confirm early signs of new infections and subclinical udder inflammation [47, 48].

Agreement with statements about mastitis detections management: Farmers were able to rank statements related to mastitis detections management according to their personal experiences and subjective feelings using a Likert scale from 1 to 5 (1=strongly disagree to 5=strongly agree). Most farmers saw themselves as competent in the understanding (AAS: 4.1) and use (AAS: 4.4) of the displayed data and in spending sufficient time (AAS: 4.0) at interpreting the udder health lists (Figure 2). Interestingly, farmers that reported to be less confident with the AMS lists take longer in working time with the AMS program (Spearman rho=0.4; p=0.01) and udder health assessments in the barn (Spearman rho=0.4; p=0.02). One explanation could be that those farmers with limited operating ability of the AMS program tried to compensate for this with more time spent on the computer and for assessing the herd in the barn. On the other hand, the unidentified different levels of education and character of the participants as well as influences of the operational structure may be a cause of slower handling of tasks than others. The lowest AAS was achieved by the

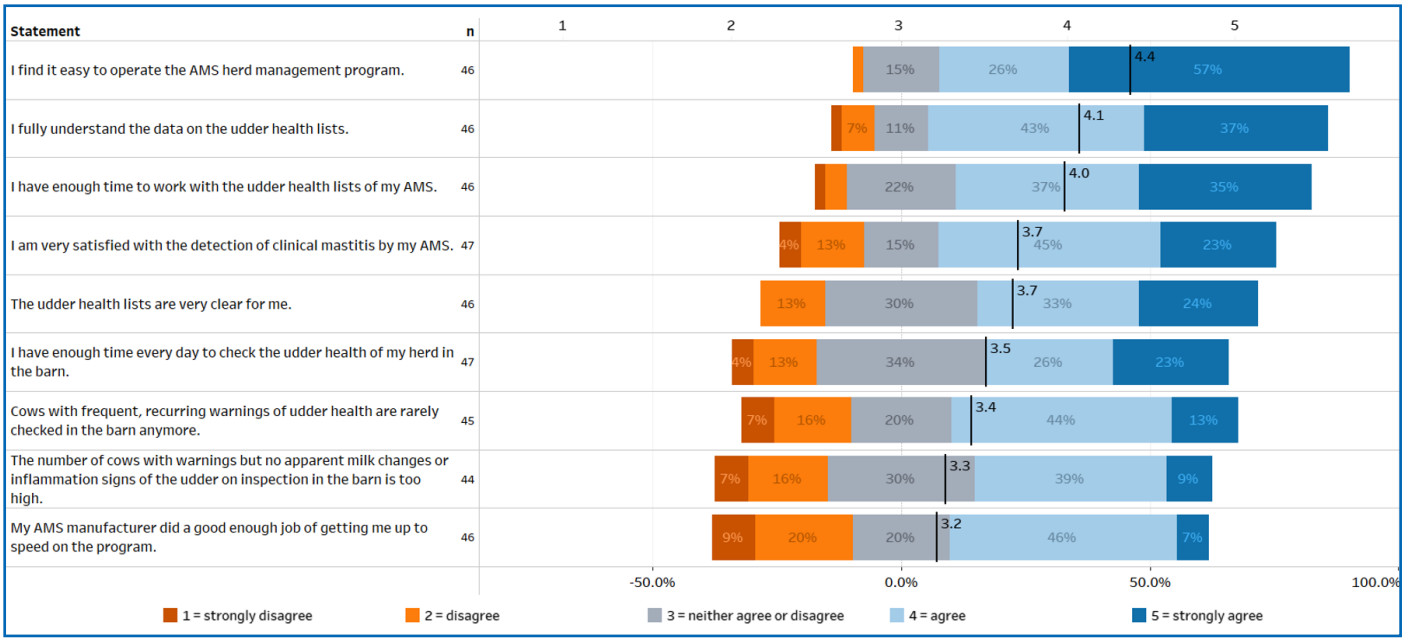

Figure 2: Agreement with various statements regarding udder health management on dairy farms operating with automatic milking systems of 47 dairy farmers. Percentage assessment of subjective agreement with these statements (Gantt percent, lower axis). Agreement on a five-point Likert scale shown in stacked bar charts, sorted in descending order by average Likert score values (upper axis) shown as a black line. The number of answers is not equal in total, since the answer option "no answer" were excluded from the respective bars.

statement on good instruction by the AMS companies with 3.2. Here 29% of the subjects disagreed with having had a good instruction. This result is seen as critical, because a good instruction how to best use a highly complex system, that constitutes a central part of the daily work in AMS farms, has to been considered essential for farmers to work economically and efficiently.

The majority of respondents (68%) were satisfied with the detection of CM by the AMS; only 17% of the respondents did not agree with this statement. A comparison of the agreement scores between the AMS manufacturers showed no difference. Overall, this is consistent with Mollenhorst et al., who found that Dutch farmers are overall satisfied with the detection of udder health problems [20]. Nevertheless, the data found here must be interpreted with caution, as they are based on the personal assessment of the farmers through their experience in daily work with AMS. Furthermore, the satisfaction with the CM detection of an AMS leaves room for different interpretations and does not allow direct conclusions on the quality of the CM detection. An AMS gives warnings after analyzing a milking process, which cannot be directly checked for correctness due to the absence of a human during milking. The farmer could only estimate the sensitivity of an AMS for the detection of CM, i.e., at least the pathological occurrence of organoleptically abnormal milk, with considerable additional effort. On the other hand, it is much easier to compare the alerts with the udder health status of the cow in the barn. In this regard, our study showed that a large proportion of farmers (48%) agreed with the statement that the number of false positive alerts for CM was too high, and only 23% of farmers disagreed. This is in line with the results of other studies that have reported low specificity for detection of CM by AMS [17, 49], as well as farmers' desire for improved specificity for detection of udder health problems by AMS [20]. However, in herds where farmers agreed with poor CM detection rates or excessive numbers of false-positive cows flagged, no associations were found with other counteracting management practices, such as more frequent or longer inspection of cows in the barn. Critical in the evaluation of statements is that 57% of farmers agreed that "chronic" cows (i.e., cows that repeatedly produced an alert but do not show visibly signs of CM) were no longer checked in the barn in case of further alerts. However, cows with subclinical or chronic mastitis, which can trigger the alert of the AMS, may also develop acute CM [50] and would be likely overlooked. This would affect animal welfare and food safety.

Limitations: This questionnaire provides valuable insights but may not definitively determine the presence of recorded management practices and farmers' perceptions on their farms. Since the recording of management practices related to udder health monitoring, the assessment of own skills, and the CM detection performance of the AMS are based exclusively on farmers' subjective experiences, these results should be evaluated carefully. As a result, we cannot completely avoid the possibility of bias and misinterpretation. Therefore, due to its content structure, the questionnaire could also be answered from the point of view of the detection of subclinical mastitis. However, this was addressed by the clear formulation of the study objective in the invitation e-mail as well as the topic in the respective group headings. Furthermore, to prevent a purely intuitive processing of the questionnaire, instructions were given at the beginning of question groups that encouraged to refer to personal experiences from daily work with AMS. To prevent agreement bias, i.e., the likelihood that respondents would agree with the statement regardless of its content, we also used extensive pretesting of the questionnaire, the use of a five-point Likert scale, and two reversed statements in the question group on personal evaluation of statements [51, 52]. Nevertheless, a generalization of our results to all dairy farms with AMS should be made with caution due to the small sample size and pre-selection by participation in the first study. Thus, only farms with one of the four most common, regularly maintained AMS systems in Bavaria were included in the study. These farmers participated voluntarily in both studies and may therefore be more interested in udder health than other farmers. However, humans and commercially available AMS operate under similar conditions regardless of region, and thus the results of this study provide important insights for the dairy industry and leads for further studies addressing the factors that are critical for farmers to diagnose mastitis through AMS.

Conclusion

The majority of participating farms performed the daily management practices recommended to ensure udder health with AMS. However, some of the farmers reported not immediately checking cows newly indicated by the AMS as having udder health problem in the barn. Instead they used a combination of AMS data and knowledge about the cow for a decision. Also, one-fifth of the farmers reported monitoring their herd in the barn and on the warning lists once or less per day. These practices are considered insufficient for maintaining udder health on AMS farms in relation to officially recommended measures. Farmers perceived the detection of clinical mastitis by the AMS to be satisfactory. This was independent of the AMS type. They rated themselves as having a good understanding of their AMS software program around udder health monitoring. Nevertheless, some felt insufficiently instructed in the use of the AMS software by their manufacturer. Overall, this survey showed that good udder health monitoring practices were being implemented on the majority of the participating AMS farms.

Disclosure of Conflicts of Interest

The study was made possible with financial support of the Free State of Bavaria and the Bavarian Joint Founding Scheme for the Control and Eradication of Contagious Livestock Diseases (Bayerische Tierseuchenkasse). The authors declare no conflict of interest.

Compliance with Ethical Standards

The survey was anonymous and was conducted in compliance with ethical standards and legal privacy protections and was approved by the Ethics Committee of Freie Universität Berlin (ZEA-No.2021-009)

Annex - Questionaire (Language German)

The questionnaire is available as separate pdf-file under following link: https://openjournals.hs-hannover.de/milkscience/issue/view/198

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