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Dutch dairy farmers' need for microbiological mastitis diagnostics

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ABSTRACT

Although several microbiological mastitis diagnostic tools are currently available, dairy farmers rarely use them to base treatment decisions on. In this study, we conducted a telephone interview among 195 randomly selected Dutch dairy farmers to determine their current use of and their need for microbiological diagnostics for clinical mastitis (CM), subclinical mastitis (SCM), and dry-cow treatment (DCT), followed by the test characteristics they consider important. A structured questionnaire was used, based on face-to-face interviews previously held with other farmers. The answers were registered in a database and analyzed using descriptive statistics and univariable and multivariable models. Antimicrobial treatment decisions for CM, SCM, and DCT were mainly based on clinical signs and somatic cell count. In case of CM, 34% of farmers indicated that they currently submit milk samples for bacteriological culture (BC). This would increase to 71% if an on-farm test resulting in treatment advice within 12 h were available. For SCM, use would increase from 22 to 55%, and for DCT, from 7 to 34%, if the same 12-h test were available. For CM and DCT, the preferred test outcome was advice on which antibiotic to use, according to 58 and 15% of the farmers, respectively. For SCM, the preferred test outcome was the causative bacterium for 38% of the farmers. Farmers who currently submit CM milk samples for BC were 13.1 times more likely to indicate, as the preferred test outcome, advice on which antibiotic to use, compared with farmers who do not currently submit CM milk samples for BC. Fourteen percent of the farmers indicated not being interested at all in microbiological mastitis diagnostics for CM. For SCM and DCT, 27 and 55%, respectively, were not interested in microbiological mastitis diagnostics. Regarding test characteristics that farmers considered important, reliability was most often indicated (44–51% of the farmers). Additionally, a preferred time-to-result of ≤8 h for CM and ≤20 to 24 h for SCM and DCT and ≤7% false test outcomes were indicated as desired characteristics of microbiological mastitis diagnostics. Overall, a need seems to exist for microbiological mastitis diagnostic tests among Dutch dairy farmers, specifically for CM, and resulting in a treatment advice. The availability of a reliable diagnostic test, with a suitable time-to-result, will likely increase the use of microbiological mastitis diagnostics and eventually optimize antibiotic usage.

Key words: mastitis, microbiological diagnostics, test characteristics, reliability

INTRODUCTION

The main indications for using antimicrobial agents on dairy farms are the treatment and prevention of clinical mastitis (**CM**) and subclinical mastitis (**SCM**; Pol and Ruegg, 2007). Because the use of antimicrobial agents may lead to antimicrobial resistance (Levy and Marshall, 2004), limiting antibiotic usage based on microbiological diagnosis is advisable (Roberson, 2003). Additionally, the benefit of applying antimicrobial agents is debatable in some situations. For example, the cure rates of mild gram-negative coliform CM did not differ between groups of dairy cows that were treated with or without antimicrobial agents (Guterbock et al., 1993; Suojala et al., 2010). The same is true for SCM where the benefit of antibiotic treatment depends on the severity and duration of the infection (Barlow et al., 2009; van den Borne et al., 2010). Additionally, the preventive use of antimicrobial agents in dry-cow treatment (**DCT**) is under discussion in some countries (Scherpenzeel et al., 2014). Hence, for both treatment and prevention of IMI, a decision has to be made whether or not to use antimicrobial agents. Dependent on the legislation in a country, the decision

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to use antimicrobial agents is made by the veterinarian or the farmer. For prudent use of antimicrobial agents related to mastitis, determining whether susceptible bacteria are present through microbiological diagnosis of milk samples is critical (Lago et al., 2011a). The discussion on antibiotic usage, as well as the changing legislation, social pressure, and economic incentives of limited antibiotic usage, are factors likely to increase the role of microbiological mastitis diagnostics in the coming years.

Although several laboratory tools for microbiological diagnosis of IMI for dairy farmers and their veterinarians are available currently, these are rarely used to support treatment decisions (Owens et al., 1997; Lago et al., 2011a). The small number of milk samples submitted to bacteriological laboratories can be explained by the related costs, by the required effort of the farmer involved (Royster et al., 2014), and by the time-to-result (Neeser et al., 2006; Lago et al., 2011a). The current laboratory microbiological diagnostic methods are not considered suitable to base targeted treatment of CM in practice on, because of a time lag of >24 h between sampling and result (Viora et al., 2014). Consequently, mastitis treatment decisions are usually made empirically or based on historic bacteriological culture and susceptibility results (Owens et al., 1997). To overcome the delay due to the long time-to-result, the use of on-farm mastitis diagnostics has expanded in countries such as the United States and Canada (Roberson, 2003; Cameron et al., 2013). With on-farm mastitis diagnostics, different categories of mastitis pathogens may be identified (Viora et al., 2014), leading to faster treatment decisions (Lago et al., 2011a,b; Royster et al., 2014) and selective use of antimicrobial agents in CM (Pinzón-Sánchez et al., 2011). In many countries in Europe, however, it is still common practice to treat all cases of CM with antimicrobial agents (Viora et al., 2014), which may be due to the lack of microbiological mastitis diagnostic tests considered suitable by farmers for making treatment decisions. To our knowledge, the needs of dairy farmers with respect to this type of tests have never been described. The aim of this study was to determine the Dutch dairy farmers' current use of, and their need for, microbiological mastitis diagnostics of CM, SCM, and DCT and to determine which test characteristics they consider important.

MATERIALS AND METHODS

Study Design

A telephone interview was conducted among randomly selected Dutch dairy farmers using a structured questionnaire. The questionnaire was based on face-to-face interviews that were previously held with other farmers and are briefly discussed below. Based on that experience, the questions for the telephone interview were chosen from those used in the face-to-face interviews. These questions focused on subjects that came up as potentially important from the face-to-face interviews. The results of the telephone interviews were analyzed and are discussed in this paper.

Semi-Structured Face-to-Face Interviews

The individual face-to-face interviews were held by the first author with nonrandomly selected Dutch dairy farmers between October and December 2014, using a qualitative semi-structured questionnaire with open-ended questions. The first author is a veterinarian, which was not known by the farmers at the time of interview. The questionnaire was previously discussed with a communications expert and 2 mastitis experts. The goal of the face-to-face interviews was to gather a broad range of attitudes regarding mastitis and mastitis diagnostics, forming the base of the subsequent telephone questionnaire. The participants were selected with the goal of including farms with differences in characteristics such as herd size, milking system, farmers' focus on udder health, management style, and mastitis incidence. After interviewing 20 farmers, no new information was obtained and the interviews were stopped.

Structured Telephone Interviews

Selection of Farmers. In December 2014 and January 2015, 660 dairy farmers were randomly selected from a list of all 17,563 Dutch dairy farmers. The goal was to gather 200 participants. The farmers received a letter by mail with a short description of the study and the announcement that they might be approached by telephone for participation in a 30-min questionnaire on mastitis and microbiological mastitis diagnostics. The farmers were asked to look up their most recent bulk milk SCC, the number of CM cases in 2014, antibiotic usage in 2014 (animal daily dose, based on the national monitoring system; Speksnijder et al., 2015), and the prevalence of high-SCC cows (heifers >150,000 cells/mL, older cows >250,000 cells/mL; de Haas et al., 2008) at the last milk recording. Within 2 wk after the letters were sent, farmers were approached by telephone to ask whether they were willing to participate. If positive, either the interview was held directly or an appointment was made. If negative, the reason for being unwilling to participate was asked as well as 2 additional questions on the current herd size and perceived mastitis problems at their farm. Farmers with a herd size <20 cows (aged >2 yr) and farmers who intended to quit farming within the next 5 yr were excluded from participation.

Interview Design. The questionnaire included 59 questions, divided over 4 sections, and took 20 to 45 min to complete. The interviews were held by the first author and 2 students with a background in farm animal husbandry; it was pretested on 2 farmers. Those 2 interviews were included in the analysis because no changes were made to the questionnaire after pretesting. The general part of the questionnaire included background information on the farmer and his farm, udder health consultancy services on the farm, and udder health characteristics. The specific part of the questionnaire was divided into a part on CM, a part on SCM, and a part on DCT. Each part held 3 sections with the same structure and discussed the farmers' current treatment and diagnostic approach, their needs for microbiological mastitis diagnostics, and the desired test characteristics of microbiological mastitis diagnostics. The questionnaire is available upon request from the corresponding author. Questions on the current treatment and diagnostic approach were open ended to clarify the definitions used for determining cases and treatments for CM, SCM, and DCT.

To determine the need for microbiological mastitis diagnostics, both preferred and potential test outcomes and the intended use of microbiological mastitis diagnostics were discussed. As related to preferred test outcomes, farmers were asked which outcomes they expect to receive from such a test (open-ended question; more than one outcome could be mentioned). Additionally, 3 potential test outcomes were presented to the farmers to determine their need for each outcome: the first outcome was whether to treat with antimicrobial agents, the second was which antibiotic to use, and the third was whether to extend treatment (the latter test outcome was not discussed for DCT). The intended use of microbiological mastitis diagnostics was determined with the help of 2 hypothetical tests. Both hypothetical tests resulted in treatment advice and had a time-to-result of <12 h. One of these tests was executed at the veterinary practice and the other one on the farm.

To determine the desired test characteristics, the farmers were asked to indicate which characteristics they considered important for tests executed at the veterinary practice and on-farm (open-ended question; more than one characteristic could be mentioned). Subsequently, the farmers ranked 4 characteristics: speed, reliability, usability, and price (out-of-pocket cost), with 1 being the most important and 4 being the least important. For each of these characteristics, the overall mean was calculated to enable a comparison among them. Additionally, the farmers were asked what values they considered acceptable for those 4 characteristics; for example, what price were they willing to pay for a test.

Besides the open-ended questions, the standardized questionnaire contained closed questions, which consisted of scores on a Likert scale (Likert, 1932), and yes/no responses. The farmers were asked permission to use information on their herd size based on the Identification and Registration (I&R) census data (RVO, The Hague, the Netherlands) to be able to compare them with the average Dutch dairy farm. Results of the interview were entered in an online survey program (NetQ; http://www.netq-enquete.nl/nl/eng) and combined with the I&R data.

Data Analysis

The representativeness of the participants was evaluated by comparing the means descriptors of the participating farms with the average Dutch dairy farm (Statistics Netherlands, The Hague/Heerlen, the Netherlands; de Koeijer et al., 2014) using a one-sample t-test. Test characteristics indicated by the farmers were evaluated using a paired t-test. Differences were considered statistically significant if $P < 0.05$.

To determine differences between farmers with respect to their opinion on microbiological mastitis diagnostics, regression models were used. Multivariable logistic regression models were used for CM, whereas univariable analysis was executed for SCM and DCT. The dependent variables consisted of the farmers' need for microbiological mastitis diagnostics and the desired test characteristics. The predictor variables evaluated for these 2 dependent variables were whether the udder health situation was discussed with the veterinarian; whether bacteriological culturing was executed; perceived mastitis problems at their farm; antibiotic usage based on animal daily dose; the percentage of high-SCC cows; bulk milk SCC; access to pasture; milking with an automatic milking system; age of the farmer; the average growth in herd size during the last 2 yr; the average herd size during the last 2 yr; and the average herd replacement rate during the last 2 yr.

Multivariable model selection for CM was conducted by including all variables in the model with a P-value <0.25 (univariable). When 2 variables were highly correlated (correlation >0.5) only the variable with the lowest P-value was included in the model. A backward selection procedure was followed, where the variables with the highest P-value in the model were deleted one by one, until only significant variables ($P < 0.05$) and confounders (difference in coefficients of ≥20%) remained in the model. Significant variables were identified by comparing the goodness of fit (log-likelihood) using the likelihood ratio test ($P < 0.05$). Interaction terms were added to the model and tested for statistical significance to investigate possible effect modification. During the analysis, a minimum of 5 per cell was demanded.

RESULTS

Descriptive Statistics

In total, 459 farmers were approached by telephone, of which 210 agreed to participate in the interview (46%). Of these 210 farmers, 4 farmers had fewer than 20 adult cows (average over the last 2 yr) and 11 farmers intended to quit farming within 5 yr and were therefore excluded. A total of 195 interviews were included in the analysis. Two hundred forty-nine farmers were not willing to participate for miscellaneous reasons, of which the time constraint was mentioned most frequently (37%). Of the farmers not willing to participate, 51% were willing to answer 2 questions: their mean current herd size was 90.3 adult cows (age >2 yr) and 31% of them perceived mastitis problems on their farm.

The bulk milk SCC and the percentage of cows with high SCC were lower for the 195 participating farmers than for the average Dutch dairy farm (Table 1). Over the last 2 yr, the mean herd size of the participants increased more and the herd replacement rate was lower than that of the average Dutch dairy farm. The participating farmers were slightly younger than the average Dutch dairy farmer.

The participating farmers reported an average of 15.7 cases of CM per 100 cows per year on their farms. Thirty-one percent of them perceived mastitis problems on their farm, which was the same as indicated by the farmers who were not willing to participate. The udder health situation is discussed with the veterinarian by 87% of the participating farmers, generally during regular herd visits (67% of farmers) or in case of mastitis-related problems (29% of farmers). None of the variables had a correlation >0.5.

Farmers' Current Treatment and Diagnostic Approach

Most farmers indicated that they did not treat every case of CM with antimicrobial agents, and they reported a variety of ways to determine whether to start such treatment. The most frequently reported indication to start an antibiotic treatment of CM cases was the presence of local signs such as clots or flakes in the milk or changes in the udder (31% of farmers). Nineteen percent of the farmers indicated that they started antibiotic treatment only when a cow with CM showed general signs such as illness; 28% used other criteria, such as the conductivity of the milk or failure of an alternative treatment. Bacteriological culture results were used by 2% of the farmers. Fifteen percent of the farmers indicated that they treated every cow with CM and 5% never treated a cow with CM with antimicrobial agents. The duration of the antibiotic treatment was generally based on label instructions (37% of farm-

Table 1. Mean descriptors of the participating farms (no. of respondents in parentheses) and the average Dutch dairy farm

Outcome	Participating farms	Average Dutch dairy farm
No. of adult cows (>2 yr)	94.5[1] (166)	85[2]
Organic farming (%)	2.1[3] (192)	2[2]
Pasturing (%)	75[3] (192)	76[2]
Full-time labor units (no.)	1.6[3] (192)	1.5[2]
Automatic milking system (%)	20.8[3] (192)	18.7[4]
Farmer age (yr)	48[3]* (191)	52[5]
Bulk milk SCC (×1,000 cells/mL)	157[3]* (191)	217[6]
Cows with high SCC (%)	11.6[3]* (180)	18.9[6]
Animal daily dose	2.6[3] (182)	2.4[2]
Average herd replacement rate per year (%)	24.0[1,7]* (163)	25[5]
Average herd growth in no. of adult cows (>2 yr) per year (%)	3.7[1,7]* (163)	2.3[5]

[1]Based on Identification and Registration (I&R) census data (RVO, The Hague, the Netherlands)
[2]Statistics Netherlands, The Hague/Heerlen, the Netherlands, 2014.
[3]Self-reported by the farmers.
[4]Stichting KOM (2014).
[5]de Koeijer et al. (2014).
[6]GD Animal Health (2015).
[7]Difference in no. of cows >2 yr between the fourth trimester of 2012 and the third trimester of 2014.
*$P < 0.05$.

ers) or on the treatment protocol from the veterinarian (25% of farmers). Other farmers indicated that they took into account the recovery of cow when deciding on the duration of the treatment.

Subclinical mastitis is defined by most farmers as cows with a high individual SCC. Cut-off values used were, on average, 176,000 cells/mL for heifers [10th percentile (**P10**) 80,000; 90th percentile (**P90**) 275,000] and 284,000 cells/mL for older cows (P10: 150,000; P90: 400,000). Fifty-seven percent of the farmers never treated SCM during lactation. The other farmers indicated that they treated SCM during lactation always to sporadically. The most frequently used criteria for antibiotic treatment were a high SCC 2 to 4 times in a row (46% of farmers), a positive California Mastitis Test (22%), and a positive outcome of bacteriological culture (20%). The duration of an antibiotic treatment for SCM was based on the label instructions by 36% of the farmers or on the treatment protocol from the veterinarian (30% of the farmers).

Most farmers were satisfied with their current diagnostic approach of DCT (93%), where 85% of the farmers indicated that they did not use bacteriological diagnostics for DCT.

Thirty-four percent of the farmers indicated that they currently submitted milk samples of CM cases for bacteriological diagnosis always to regularly. For SCM and DCT, this was 22 and 7%, respectively. We detected a tendency for larger farms to submit milk samples of CM cases more frequently (data not shown).

Need for Mastitis Diagnostics

Preferred Test Outcomes. For CM, test outcomes of interest were advice on which antibiotic to use, indicated by 58% of the farmers, and the causative bacterium, indicated by 53% of the farmers. Fourteen percent of the farmers indicated that they were not interested at all in microbiological diagnostics related to CM.

For SCM, test outcomes of interest were the causative bacterium, indicated by 38% of the farmers, and advice on which antibiotic to use, indicated by 35% of the farmers. Twenty-seven percent of the farmers indicated that they were not interested at all in microbiological diagnostics related to SCM.

For DCT, test outcomes of interest were advice on which antibiotic to use, indicated by 15% of the farmers, and the bacterium present, indicated by 11% of the farmers. Fifty-five percent of the farmers indicated that they were not interested at all in microbiological diagnostics related to DCT.

Potential Test Outcomes. Based on the presented potential test outcomes, 64% of the farmers expressed their need for a microbiological diagnostic test for CM in which the test outcome was advice on which antibiotic to use (Table 2). The need for a test resulting in advice on whether to treat with antimicrobial agents was expressed by 57% of the farmers. The lowest need was expressed for a test resulting in whether to extend an antibiotic treatment (38% of farmers).

For SCM, 57% of farmers expressed their need for a test where the test outcome was advice on which antibiotic to use, and 31% expressed their need for a test resulting in whether to extend an antibiotic treatment.

Farmers expressed the lowest need for microbiological mastitis diagnostics for DCT: 31% expressed their need for a test resulting in advice on which antibiotic to use. The need for a test resulting in whether antibiotic treatment is necessary for low-SCC cows at drying off was expressed by 13% of the farmers.

Of the farmers who expressed their need for a microbiological diagnostic test for CM resulting in advice on which antibiotic to use, 72% also expressed their need

Table 2. Farmers' needs for microbiological mastitis diagnostics (%) for the presented test outcomes, related to clinical mastitis (CM; n = 195), subclinical mastitis (SCM; n = 194), and dry-cow treatment (DCT; n = 193)

	Do you need a test result that determines whether an antibiotic treatment is necessary in case of CM/SCM during lactation and in case of low or high SCC for DCT?				In case of an intended antibiotic treatment, do you need a test result that advises on the antibiotic to use in case of CM/SCM and DCT?			Do you need a test result that determines whether to extend the treatment in case of CM/SCM during lactation?	
			DCT						
Extent of interest	CM	SCM	High SCC	Low SCC	CM	SCM	DCT	CM	SCM
Always	6.2	7.7	3.6	2.1	13.8	13.4	3.6	6.2	7.2
Often	23.6	21.1	11.4	4.7	29.2	25.3	14.5	15.9	10.8
Sometimes	27.2	23.2	11.9	5.7	20.5	18.6	13.0	16.4	13.4
Sporadic	12.3	9.3	6.2	4.7	10.8	5.2	6.2	8.7	5.7
Never	25.1	35.1	62.2	78.8	23.6	34.0	56.5	47.2	57.7
I don't know	5.6	3.6	4.7	4.2	2.1	3.6	6.2	5.6	5.2

Table 3. The farmers' expressed intended use (%) of a defined hypothetical test[1] executed at the veterinary practice or on-farm in case of clinical mastitis (CM; n = 195), subclinical mastitis (SCM; n = 194), and dry-cow treatment (DCT; n = 193)

	Veterinary practice			On-farm		
Extent of use	CM	SCM	DCT	CM	SCM	DCT
Always	7.7	3.1	1.6	13.9	11.3	4.2
Often	16.9	16.5	5.2	36.4	25.8	14.0
Sometimes	28.7	26.3	13.0	21.0	17.5	16.1
Sporadic	20.0	15.0	13.0	10.8	6.7	9.8
Never	21.5	30.9	56.5	15.9	33.0	43.5
I don't know	5.1	8.3	10.9	2.1	5.7	12.4

[1]Microbiological diagnostic mastitis test with a time-to-result of 12 h, and a treatment advice as the outcome.

for such a test for SCM, and 38% for DCT. Of the farmers who expressed their need for a microbiological diagnostic test for CM resulting in whether antibiotic treatment is necessary, 62% also expressed their need for such a test for SCM, and 34% for DCT. Of the farmers who expressed their need for a microbiological diagnostic test for CM resulting in whether to extend treatment, 57% also expressed their need for such a test for SCM. Of the farmers who expressed no need for a microbiological diagnostic test for CM, 60% expressed no need for such a test for SCM, whereas 83% expressed no need for such as test for DCT.

Intended Use of Mastitis Diagnostics. Of the farmers, 53% expressed that they were willing to use (sometimes or always) the described hypothetical microbiological diagnostic test for CM if it were executed at the veterinary practice (Table 3). If executed on-farm, the intention was higher: 71% of the farmer expressed they were willing to use such a test (sometimes or always). For SCM and DCT, 46 and 20%, respectively, expressed that they were willing to use such a test at the veterinary practice, and 55 and 34%, respectively, expressed that they were willing to use an on-farm test.

Test Characteristics

Reliability was indicated most often as an important characteristic for a microbiological diagnostic test of SCM and DCT (Table 4). For CM tests executed at the veterinary practice, however, time-to-result was indicated most often as an important test characteristic.

When ranking the importance of test characteristics, reliability was considered most important for CM, SCM, and DCT. For CM, time-to-result was of second importance, followed by price (out-of-pocket cost) and usability, which were considered equally important (Table 5). For SCM, time-to-result, price (out-of-pocket cost), and usability were considered equally important. For DCT, time-to-result was considered significantly less important than price (out-of-pocket cost) and usability.

A test was considered reliable if the percentage of false test outcomes was <7% for CM, SCM, and DCT. A hands-on time of 7.5 to 10 min was considered suitable for executing a microbiological diagnostic test for CM, SCM, and DCT (P10: 3 min; P90: 15 min). Farmers considered a median of 8 h (P10: 2 h; P90: 12 h) an acceptable time-to-result for CM. For SCM, a median of 20 h was considered an acceptable time-to-result (P10: 4 h; P90: 24 h) and for DCT, a median of 24 h (P10: 5 h; P90: 48 h). Farmers considered out-of-pocket costs of €15 for CM (P10: €5; P90: €50) and SCM (P10: €5; P90: €30) acceptable. For DCT, median out-of-pocket costs of €10 (P10: €3; P90: €25) was considered acceptable.

Clinical Mastitis: Farmer Characteristics and Need for Microbiological Mastitis Diagnostics

Not surprisingly, the greatest need for microbiological mastitis diagnostics resulting in advice on which antibiotic to use was indicated by farmers who were

Table 4. Test characteristics of microbiological mastitis diagnostics indicated as important by dairy farmers (%) for clinical mastitis (CM; n = 195), subclinical mastitis (SCM; n = 194), and dry-cow treatment (DCT; n = 193)

	Test characteristic		
Item	Reliability	Time-to-result	Price[1]
Veterinary practice			
CM	46	48	23
SCM	47	30	21
DCT	44	13	17
On-farm			
CM	48	41	14
SCM	51	27	24
DCT	48	15	21

[1]Price = out-of-pocket cost.

already submitting milk samples in case of CM [odds ratio (**OR**) 13.1]. Farmers who perceived mastitis as a problem on their farm indicated a greater need for microbiological mastitis diagnostics resulting in whether it is advisable to start an antibiotic treatment (OR 2.7) or to extend an antibiotic treatment (OR 2.9). Apart from that, farmers with cows that had access to pasture indicated a greater need for a test resulting in advice on which antibiotic to use in case of an intended antibiotic treatment of CM (OR 3.1; Table 6). The proportion of variance in the need for microbiological mastitis diagnostics explained by the model was 24% for a test resulting in advice on which antibiotic to use.

With respect to the desired test characteristics, farmers who perceived mastitis as a problem on their farm were more likely to consider reliability of an outcome more important than other farmers, for both a test performed at the veterinary practice (OR 2.6; 95% CI: 1.30–5.36) and an on-farm test (OR 2.4; 95% CI: 1.27–4.48). As shown in Table 7, farmers with increased herd size during the last 2 yr were likely to consider time-to-result important more often than other farmers, for both a test at the veterinary practice (OR 1.15) and an on-farm test (OR 1.10).

DISCUSSION

This is the first study to determine the needs of dairy farmers for mastitis diagnostics. We found that a need for mastitis diagnostics was present among Dutch dairy farmers, with a preference for tests that are available on-farm and have a short time-to-result. The use of microbiological mastitis diagnostics would be twice as high as the general use of mastitis diagnostics if current tests fulfilled these criteria. It is important to note that a selection bias toward farmers interested in udder health is present in this study (Pennings et al., 2002), as indicated by the lower-than-average bulk milk SCC and prevalence of high-SCC cows. Thus, the quantitative results of this study may slightly overestimate the needs of dairy farmers. The younger age of the participating farmers and the larger herd size of the farms were as expected, because younger farmers and farmers with larger herd sizes are more often willing to respond to questionnaires (Pennings et al., 2002). Because perceiving mastitis problems is an important cue to action (Jansen et al., 2009) and, given the fact that the farmers who were not willing to participate perceived mastitis problems on their farms to the same extent as participating farmers, we consider the qualitative results of this study to be representative.

Although there are limitations on conducting a telephone interview (nonresponse bias, lack of body language), it gave the opportunity to approach a large number of people and to quantify the responses of the face-to-face interviews without losing the opportunity to elucidate ambiguities, making it possible to determine the needs of the farmers.

In this study, farmers expressed their need for rapid microbiological mastitis diagnostics. To date, bacteriological culturing has a time-to-result of ≥24 h. Testing by PCR is quicker but is not executed on farm and has the disadvantage of requiring sample transport to a laboratory. In our study, only 2% of the farmers indicated that they used microbiological culture results as the basis for treatment decisions. Although waiting 24 h for culture results has no negative effect on cure rates or cow survival (Lago et al., 2011a,b), farmers find it difficult to postpone treatment decisions (Neeser et al., 2006). A time-to-result of 12 h is considered an improvement compared with the current diagnostics available because the intended use of the hypothetical tests was twice as high as the current use of mastitis diagnostics in general. The need for fast mastitis diagnostics was found to be most explicit for CM, where farmers considered a time-to-result of ≤8 h acceptable, whereas a longer time-to-result (≤20 and ≤24 h, respectively) for SCM and DCT was considered acceptable. Although the answers of the farmers might be influenced by the predefined tests, which had

Table 5. Ranking[1] of test characteristics by dairy farmers, expressed as means (SD) of scores per characteristic for tests for clinical mastitis (CM; n = 195), subclinical mastitis (SCM; n = 194), and dry-cow treatment (DCT; n = 193)

	Test characteristic			
Item	Reliability	Time-to-result	Price[2]	Usability
CM	1.5 (0.77)^{a,C}	2.2 (0.87)^{c,B}	3.3 (0.87)^{a,A}	3.1 (0.92)^{a,A}
SCM	1.3 (0.64)^{b,B}	2.9 (0.93)^{b,A}	2.9 (1.03)^{b,A}	2.8 (0.85)^{b,A}
DCT	1.3 (0.70)^{C}	3.3 (0.86)^{a,A}	2.7 (1.04)^{c,B}	2.7 (0.81)^{b,B}

$^{a–c}$Values with different superscripts within columns differ significantly ($P < 0.05$).

$^{A–C}$Values with different superscripts within rows differ significantly ($P < 0.05$).

[1]Mean ranks: 1 is most important, and 4 is least important.

[2]Price = out-of-pocket cost.

Table 6. Dairy farmers' need for microbiological mastitis diagnostics for clinical mastitis subdivided by farm characteristics using 3 potential test outcomes

	Do you need a test result that determines whether an antibiotic treatment is necessary in case of clinical mastitis? (explained variability = 7%)			Do you need a test result that advises which antibiotic to use in case of an intended antibiotic treatment in case of clinical mastitis? (explained variability = 24%)			Do you need a test result that determines whether or not to extend treatment in case of clinical mastitis? (explained variability = 11%)		
Item	N	OR[1]	95% CI	N	OR	95% CI	N	OR	95% CI
Access to pasture									
No				21	Referent				
Yes				81	3.09*	1.23–7.80			
Current use of bacteriological culturing					***				
Always/often				18	13.08***	3.08–55.60	10	1.59	0.48–5.32
Sometimes				23	8.89***	2.63–30.04	14	2.11	0.72–6.15
Sporadic				42	7.07***	2.59–19.34	26	2.45	0.96–6.23
Never				19	Referent		12[2]	Referent	
Average growth in herd size during last 2 yr				100	1.11*	1.03–1.20			
Perceiving mastitis problems									
No	45	Referent		63[2]	Referent		33	Referent	
Yes	26	2.72*	1.12–6.60	39	2.11	0.79–5.63	29	2.91**	1.30–6.52
ADD[2]	68	1.41*	1.06–1.88				61[2]	1.22	0.93–1.59
Bulk milk SCC				102	1.01**	1.00–1.02			

[1]OR = odds ratio.

[2]Confounder.

[3]ADD = animal daily dose; antibiotic usage based on national monitoring program.

$*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Table 7. Time-to-result as a desired test characteristic of microbiological mastitis diagnostics for clinical mastitis (CM) according to dairy farmers subdivided by different farm characteristics

	Veterinary clinic (explained variability = 13%)			On-farm (explained variability = 4%)		
Item	N	OR[1]	95% CI	N	OR	95% CI
Average growth in herd size during last 2 yr	76	1.15***	1.07–1.24	64	1.10**	1.03–1.18
Currently submitting milk samples for bacteriological culture in case of CM[2]		*				
Always/often	11	2.36	0.87–6.87			
Sometimes	21	4.57**	1.64–12.77			
Sporadic	27	1.99	0.86–4.57			
Never	18	Referent				
Farmers' age[2]	76	0.96*	0.92–0.99			

[1]OR = odds ratio.

[2]Year of birth.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

a time-to-result of 12 h, the indicated desired time-to-result differed from the predefined tests for the 3 indications. The current available on-farm microbiological tests could be of interest for the farmers, because these tests have a time-to-result of 18 to 24 h. These on-farm tests, however, are rarely used in the Netherlands. This may be because farmers are not aware of those tests, that herd sizes are too small for the farmers to collect enough milk samples and gain experience with the tests, or that they need the encouragement of other farmers or veterinarians who are enthusiastic about such diagnostic tests. The importance of social pressure was found in an earlier study on preventive measures regarding mastitis management (Jansen et al., 2009). Furthermore, a time-to-result <24 h may not be necessary for SCM and DCT diagnostics. Although we could assume that farmers are aware of this, they indicated that they appreciated a shorter time-to-result. This is likely based on emotions rather than on rational considerations because these cows have been infected for some time. Earlier studies showed that good stockmanship is important to farmers, which is not always based on rational considerations (Jansen et al., 2009; Swinkels et al., 2015).

Regarding CM and DCT, farmers were most interested in advice on which antibiotic to use rather than identification of the causative agent as a test outcome. In addition to farmers who already submit milk samples for bacteriological culture, this need is specifically indicated by farmers who pasture their cows. This may be because farmers pasturing their cows have a different attitude toward management than other farmers. With respect to SCM, however, farmers were most interested in the causative bacterium. This may be due to use of diagnostic results in management decisions at the herd level, such as focusing on contagious or environmental mastitis pathogens (De Vliegher et al., 2012) or at the cow level, such as culling or segregation. A continuous strategy of early detection of SCC with microbiological diagnosis directly followed by treatment based on the obtained results could improve cure rates of SCM (Barkema et al., 2006). Currently, however, this type of diagnostic approach is not used much: only 22% of the farmers indicated that they submitted milk samples for SCM. If farmers were willing to increase the use of microbiological mastitis diagnostics, as indicated in this study, this continuous strategy could result in a lower incidence of high-SCC animals in the herd and eventually in lower CM incidence. Furthermore, the use of on-farm mastitis diagnostics may result in informed treatment decisions and thus in limited usage of antimicrobial agents (McCarron et al., 2009).

The percentage of farmers currently submitting CM and SCM milk samples to laboratories is comparable with that reported in earlier studies (Hoe and Ruegg, 2006). In the Nordic countries, however, CM milk samples are submitted for microbiological diagnosis more often, although some between-country variation exists (Espetvedt et al., 2013). Our finding that farmers with larger herds submitted milk samples more frequently is in line with previous findings (Hoe and Ruegg, 2006). Furthermore, farmers with increasing herd sizes seem to have a greater need for a test resulting in advice on which antibiotic to use. With increasing herd sizes worldwide (Barkema et al., 2015), the need for microbiological mastitis diagnostics may increase.

Farmers reporting higher antibiotic usage more often indicated their need for a CM test indicating whether an antibiotic treatment was necessary (Table 6). This may suggest that these farmers consider microbiological mastitis diagnostics a potential way to reduce their antibiotic usage. Furthermore, one-third of the farmers were interested in a test resulting in whether or not to extend treatment of CM. Currently, the length of the treatment is generally based on the treatment protocol from the veterinarian, the label instructions of the antibiotic used, or the recovery of the cow. Although cure rates of CM may increase by extending treatment (Pinzón-Sánchez et al., 2011), and many farmers extend treatment (Swinkels et al., 2015), it is not always advisable to do so (Swinkels et al., 2013). The fact that one-third of the farmers were interested in a test to decide on extending treatment seems to indicate they are aware of the urgency of prudent antibiotic usage.

Worldwide, there is increasing public attention on antibiotic usage, which may lead to expanded requirements for applying antibiotic treatments in animal husbandry. Because reducing antibiotic resistance is one of the challenges of today's dairy industry (Barkema et al., 2015), microbiological mastitis diagnostics may be a useful tool in mastitis treatment decisions and may lead to more prudent antibiotic usage (Pinzón-Sánchez et al., 2011). Farmers expressed their need for reliable mastitis diagnostics, preferably on-farm, with a short time-to-result, and with an advice on which antibiotic to use as the outcome.

CONCLUSIONS

Dutch dairy farmers need microbiological mastitis diagnostics, and they expressed their willingness to use that type of test for CM, SCM, and DCT more frequently than they currently do. Specifically for CM, farmers currently submitting milk samples for bacteriological culture and farmers perceiving mastitis problems expressed their need for a test resulting in advice on the antibiotic to use. The farmers expressed their need for a reliable, affordable diagnostic microbiological mastitis test that is preferably executed on-farm, does not have many false results, and has a time-to-result $\leq$8 h.

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