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Effect of selective dry cow treatment on udder health and antimicrobial usage on Dutch dairy farms

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ABSTRACT

Since 2013, selective dry cow treatment (SDCT) has been the standard approach in the Netherlands where farmers select cows for the use of antimicrobials at drying-off. Shortly after its introduction, antimicrobial usage decreased significantly, and no significant association was found between the level of SDCT and clinical mastitis (CM). Obviously, at that time long-term associations could not be evaluated. This study aimed to provide insight into the methods and level of implementation of SDCT on Dutch dairy farms with a conventional milking system (CMS) or an automatic milking system (AMS) in 2016 and 2017, several years after the implementation of SDCT. Udder health and antimicrobial use were also assessed. For this study, 262 farmers recorded dry cow treatments as well as all CM cases in the period from May 1, 2016, until April 30, 2017. Additionally, somatic cell count (SCC) data on cow and herd level, treatment data on herd level and questionnaire results on udder health management were collected. Data were analyzed using descriptive statistics with differences between milking systems being evaluated using nonparametric univariable statistics. In the study period, SDCT was applied on almost all (98.8%) of the participating dairy farms. The main reason for applying antimicrobials at drying-off was either the SCC history during the complete previous lactation or the SCC at the last milk recording before drying-off. The median percentage of cows treated with antimicrobials was 48.5%. The average incidence rate of CM was 27.3 cases per 100 cows per year. From all CM cases that were registered per herd, on average 32.8% were scored as mild, 42.2% as moderate, and 25.0% as severe CM. The mean bulk tank SCC of the herds was 168,989 cells/mL. A cow was considered to have subclinical mastitis (SCM) if individual SCC was ≥150,000 cells/mL for primiparous and ≥250,000 cells/mL for multiparous cows. Passing these threshold values after 2 earlier low SCC values was considered a new case of SCM. The mean incidence rate of SCM in these herds was 62.5 cases per 100 cows per year. Bulk tank SCC and the incidence rate of SCM on farms with a CMS were statistically lower than on farms with an AMS, whereas the incidence rate of CM did not significantly differ between both groups of farms. The AMS farms had more cows per herd treated with antimicrobials at drying-off and a larger proportion of severe CM cases than did CMS farms. It is unknown whether the differences are due to the milking system or to other differences between both types of farms. This study showed the level of adoption of SDCT, udder health, and antimicrobial usage parameters several years after the ban on the preventive use of antimicrobials in animal husbandry. It found that udder health parameters did not differ from those found in Dutch studies before and around the time of implementing SDCT, whereas SDCT was widely applied on Dutch dairy farms during the study period. Therefore, it was concluded that Dutch dairy farmers were able to handle the changed policy of antimicrobial use at drying-off while maintaining indicators of a good udder health.
Key words: antimicrobials, dairy, udder health, selective dry cow treatment, automatic milking system

INTRODUCTION

Intramammary infections cause mastitis, a common occurrence affecting animal welfare and economics in dairy cows worldwide (Huijps et al., 2008; Lam et al., 2013). New IMI occur frequently in the dry period, specifically shortly after drying-off and before calving (Bradley and Green, 2001). To reduce the prevalence of IMI, dry cow treatment with antimicrobials (**DCT**) aims to eliminate IMI already present at drying-off and prevent new IMI during the dry period (Bradley and Green, 2001). The use of blanket DCT (**BDCT**)

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in which all cows, irrespective of their IMI status, are treated intramammarily with dry cow antimicrobials, has been advocated for more than 50 years as part of a standard mastitis prevention program (Neave et al., 1969). Historically, BDCT was the main approach, including in the Dutch dairy industry (Sampimon et al., 2008). Roughly 90% of the Dutch dairy cows were dried off with antimicrobials in 2009 (Lam et al., 2013). Intramammary treatment accounted for over 60% of the total antimicrobial usage (**AMU**) in Dutch dairy herds, of which roughly two-thirds was related to DCT (Kuipers et al., 2016). In 2008, the Dutch government decided that AMU in the livestock industry had to be reduced (Covenant antibiotic resistance animal husbandry; Dutch Ministry of Agriculture, Nature and Food Quality, 2008). Part of the regulation on prudent antimicrobial use was a ban on the preventive use of antimicrobials in Dutch livestock (Vanhoudt et al., 2018). As a result, selective DCT (**SDCT**), rather than BDCT, has been used by Dutch dairy farmers. Although the preventive effect of internal teat sealants is well known (Rabiee and Lean, 2013; Rowe et al., 2020), the use of these sealants and of other measures to prevent the risk of new IMI was not part of the regulations, which only concerned the use of antimicrobials. Selective DCT was introduced, where farmers select cows for DCT based on criteria such as the cow-level SCC, IMI history, or both. The effect of DCT in low SCC cows on udder health, bacteriological status, and AMU in the Netherlands was assessed in 2011 and 2012 by Scherpenzeel et al. (2014). Dutch farmers progressively implemented SDCT in their herd health management program and by 2013, 75% of them applied SDCT (Scherpenzeel et al., 2016). Although implementing SDCT may have a negative effect on udder health in individual cows (Scherpenzeel et al., 2014), when judged at the herd level, no adverse effects were apparent, whereas AMU decreased significantly (Scherpenzeel et al., 2016). From November 2012, BDCT was no longer allowed in the Netherlands (Vanhoudt et al., 2018), although at that time it was not clear how to interpret and execute SDCT in practice and how to select cows for DCT. In January 2014, a guideline on the implementation of SDCT was provided by The Royal Dutch Veterinary Association, including cow-level selection criteria to decide whether to apply antimicrobials at drying-off. The guideline prescribes using DCT when the cow SCC on the last milk recording before drying-off was >50,000 c/mL for multiparous cows or >150,000 c/mL for primiparous cows. The last milk recording should occur ≤6 wk before dry-off (Vanhoudt et al., 2018). Although the effects of the SDCT approach were followed closely in early years, the extent to which SDCT is applied on Dutch dairy farms several years after the ban on BDCT, and the methods actually used commonly to select cows for DCT are unknown. The long-term association between SDCT and udder health and AMU is also unknown.

During the same period, the use of automatic milking systems (**AMS**) in the Netherlands has increased to approximately 20% of herds (unpublished data, 2016, National Cattle Health Surveillance System). Milking with an AMS may be associated with the level of implementing SDCT, because these farmers may apply different selection criteria than farmers using a conventional milking system (**CMS**), a difference already reported (Vilar et al., 2018). It is important to understand why farmers with an AMS differ from farmers with a CMS in their approach of SDCT to tailor DCT advice and to further reduce AMU in dairy herds.

In this study we aimed to gain insight into the method and level of implementation of SDCT on Dutch dairy farms several years after its implementation. Additionally, we assessed the incidence rates of clinical mastitis (**IRCM**) and subclinical mastitis (**IRSCM**) as well as AMU. Relevant differences between dairy farms with a CMS or an AMS regarding SDCT, udder health and AMU are also described.

MATERIALS AND METHODS

Study Populations

In March 2016, 3,000 of the nearly 17,000 Dutch dairy farmers were randomly selected and requested by letter to participate in this study. They were asked to return a form if they were interested to participate. Only conventional (nonorganic) farms that participated in a milk recording program including SCC measurement, at a 4- to 6-wk interval (Dutch Royal Cattle Syndicate CRV, Arnhem, the Netherlands), were eligible for inclusion. The drop-out percentage during the study period was expected to be 10 to 20% given previous experiences where farmers were requested to record cow-level data on CM and SDCT for a one-year period (Santman-Berends et al., 2016b). Based on a sample size of at least 240 farms (assuming 20% will drop out) the level of occurrence of methods applied for SDCT could be evaluated with a confidence interval of 95% and an accepted error of 6 to 7%, if we assumed that the method would be applied in 50% of the herds. Additionally, with the sample size we could estimate the IRCM and the IRSCM with 95% confidence and an accepted error of 2 to 3% given an expected median IRCM of 28.6 per 100 cows per year (IQR: 20–41, Santman-Berends et al., 2016b) and an IRSCM of 70 per 100 cows per year

(IQR: 54–86, Santman-Berends et al., 2016b). Based on these calculations, it was decided to include 300 dairy farms. Based on the CMS and AMS distribution in the Dutch dairy sector, at that time 20% of all dairy herds had an AMS (unpublished data, 2016, National Cattle Health Surveillance System), we expected approximately 240 of these farms to have a CMS and 60 farms to have an AMS. With this representative study population (study population 1) we would be able to answer our research questions on the implementation of SDCT and to assess udder health and AMU on Dutch dairy farms in the study period from May 1, 2016, until April 30, 2017. To be able to evaluate differences in SDCT approach, udder health and AMU between farms with a CMS and an AMS, additional AMS farms were added to study population 1, leading to study population 2. To determine detectable differences between CMS and AMS farms, the power two-way proportions function in Stata version 14.0 (StataCorp, 2015) was used. Adding 20 extra AMS farms enabled us to detect a difference of 18% in the outcome of interest (e.g., application of SDCT, assuming a 50% occurrence in one of the groups). In total, we aimed to include data from 300 herds in study population 1, and data from 240 herds with CMS and from 80 herds with AMS in study population 2.

Data Collection

Cow Data on Clinical Mastitis and Drying-Off. All enrolled farms were visited during the first month of the study by a technician trained in dairy farm management. During this visit, the objectives of the study and the definitions were explained. Farmers had to register all clinical mastitis (**CM**) cases on a standardized form, regardless of whether they had treated mastitis with antimicrobials or not and regardless of the lactation stage (including the dry period) of cows, from the study period. Additionally, all cows that started a dry period during this time had to be registered by the farmer. Information regarding dry cows included the date and treatment at drying-off, as well as, if applicable, the reason to apply antimicrobials at drying-off. Farmers were asked to register data on a daily basis and to deliver their data on a monthly basis by returning the forms by mail, email, or telephone. If the forms were not returned on time, farmers were reminded by email or telephone on a weekly basis. To ensure high data quality and to reduce bias, a quality check procedure was developed in Stata version 14.0 (StataCorp, 2015) for the timely detection of incomplete records and administrative errors. When abnormalities were detected, the farmer was immediately contacted and the submitted data were corrected. Abnormalities detected and corrected during the study period included typing errors in the unique herd number and animal identification numbers and in sporadic cases data fields that were left blank.

Routinely Collected Herd Data. Farmers were asked to provide their consent to use routinely collected data, which included data on AMU (MediRund, ZuivelNL, The Hague, the Netherlands), and cow movement data from the identification and registration database (provided by the Dutch Enterprise Agency RVO, Assen, the Netherlands) on a daily level. Additionally, bulk tank SCC data (**BTSCC**; Qlip Laboratories) was available bi-weekly, whereas cow-level SCC data were available every 4 to 6 wk (CRV, Arnhem, the Netherlands). All routinely collected data were available from May 1, 2016, until April 30, 2017. More information on the background of these databases can be found in Santman-Berends et al. (2016a).

Additional Herd Management Information. Data regarding herd management and implementation of SDCT was collected using a detailed questionnaire consisting of 2 parts. The first part was conducted during the farm visit in the first month of the study, whereas the second part was conducted by telephone between October 31, 2016, and December 16, 2016. The questionnaire contained open and multiple-choice questions on herd characteristics, udder health management, and the implementation of SDCT in the previous year. The questionnaire was pretested on completeness, wording, and duration by interviewing 2 farmers and incorporating their feedback into the final version. These 2 farmers did not participate in the study. Three telephone interviewers were trained to ask the questions in a similar way and used a protocol to approach the dairy farmers as uniformly as possible. The interviewee was the person who was responsible for dry cow management on the farm.

Definitions. In this study, cows with CM were defined as having abnormal milk or udder or both, with or without systemic symptoms. The severity of CM was scored by the farmers using a scoring system as described by Pinzón-Sánchez and Ruegg (2011). Mild mastitis (grade 1) was defined as abnormality of milk (including abnormal color, viscosity, or presence of clots), moderate mastitis (grade 2) as abnormality of milk and udder (including warm, painful, swollen, or red quarters) and severe mastitis (grade 3) as abnormality of milk and udder along with systemic clinical signs in cows (including apathy, no appetite, dehydration, or fever). This information was provided to the farmers in person and written down on a card to keep as a reference for them to check during the study period.

The CM cases occurring in the same quarter within 14 d of a previous case in that quarter were considered to be the same case (Lam et al., 2013). Identification and registration data were used to calculate the number of cow days at risk (Santman-Berends et al., 2015), which are necessary to calculate the IRCM and IRSCM. The IRCM for each herd was expressed as the number of quarter cases per 100 cows at risk per year and was calculated as the number of quarter cases of CM during the study divided by the number of cow days at risk and multiplied by 365 d and by 100 cows (Santman-Berends et al., 2015); cows were assumed to be always at risk for CM because if one quarter was affected by CM, cows are still at risk for developing CM in another quarter. Additionally, the percentage of CM cases within the first 30 and 100 DIM was calculated, was based on the date of calving combined with the date of CM. The IRSCM was expressed per 100 cows at risk per year and was calculated as the number of new subclinical mastitis (**SCM**) cases during the study divided by days at risk, multiplied by 365 d and by 100 cows; a new case of SCM was defined as a high cow SCC after 2 previous composite low cow SCC values in the milk recording program, irrespective of the dry period. In our study, the threshold values for a high SCC were 150,000 cells/mL for primiparous and 250,000 cells/mL for multiparous cows, analogous to the definitions commonly used in the Netherlands (Sampimon et al., 2010; Lam et al., 2013; CRV, 2020). Cows could have more than one case of SCM in the same lactation. During the dry period, the time before first calving, the first 4 d after calving and the time between successive recordings, whereas the cow is considered as infected based on SCC, the cow was not at risk for a new case of SCM, and these days were therefore not included in the days at risk. New high SCC cows in early lactation was quantified at herd level as the percentage of herds with >25% of multiparous cows with a new high SCC in early lactation (a binary parameter per herd). A cow was defined as having a new high SCC in early lactation when she had a low SCC (≤150,000/250,000 cells/mL) on the 2 last test day measures before drying-off and an SCC >250,000 cells/mL at the first test day after calving, during the first 60 DIM. Another indicator of udder health in early lactation was the percentage of herds with >25% of cows with persistently high SCC during the dry period (a binary parameter per herd). A cow having a persistently high SCC was defined as a cow with a high SCC (>150,000/250,000 cells/mL) on the last test day before drying-off, followed by a high SCC (>250,000 cells/mL) at the first test day after calving during the first 60 DIM.

Data on AMU originated from the national Dutch MediRund database (provided by the Dutch dairy association, ZuivelNL, The Hague, the Netherlands) through which all antimicrobials delivered by veterinarians to individual farms are monitored. Based on this, data on all relevant antimicrobials delivered by herd veterinarians for treatment in cows >2 yr, and for different methods of administration, were collected in each of the participating farms from April 2016 until March 2017 and were included in the analysis. The AMU was presented as the average animal defined daily dose per year (**ADDD/Y**; the average number of days per year a cow receives antimicrobial treatment) and was calculated for each of the herds, according to the definitions provided by the Netherlands Veterinary Medicines Authority (SDA, 2014) and as described by Santman-Berends et al. (2015). Antibiotic use for DCT was calculated as 1 ADDD/Y per quarter treated with antimicrobials at drying-off, as defined by the Netherlands Veterinary Medicines Authority (Scherpenzeel et al., 2014). This means that when cow-level DCT treatment was applied, the AMU for DCT was 4 ADDD/Y (Gonggrijp et al., 2016). From the AMU data, 4 relevant parameters were derived for this study: total AMU in cows >2 yr of age, AMU for DCT, AMU for intramammary treatment, and AMU for parental treatment in cows >2 yr.

For each study herd, the mean herd size (cows >2 yr) and the mean average BTSCC were available through the National Cattle Health Surveillance System (Santman-Berends et al., 2016a).

Statistical Analysis

For analyses, the data on quarter and cow level were aggregated to herd level. Descriptive statistics, such as means, medians, 25th percentile to 75th percentile (**P25-P75**) and percentages were used to describe the study population, the level of SDCT, udder health parameters (IRCM, IRSCM, herds with >25% of cows with new high SCC in early lactation, and persistently high SCC during the dry period and BTSCC), AMU and reasons used by farmers to select cows for DCT using Stata 14.0 (StataCorp, 2015). We used the univariable nonparametric Kruskal-Wallis test to evaluate differences in the application of SDCT, BTSCC, IRSCM, IRCM, CM cases within 30 and 100 DIM, severity of CM, and AMU between AMS farms and CMS farms, as the tested parameters are often not normally distributed. The proportion test was used to evaluate differences in percentage of herds with >25% of cows with new high SCC in early lactation and persistent high SCC during the dry period. Differences with $P \leq 0.05$ were considered significant between the 2 groups.

RESULTS

Farm Selection

Of the 3,000 dairy farmers that were approached to participate in the study, the first 320 farmers that responded to our letter were asked to show their interest and to indicate whether they met the inclusion criteria. In total 302 farmers agreed to participate and started the study. Data from 262 of these farms could be used for the analysis. Data from 40 farms were excluded during the study period because data were, despite very regular contact and reminders, not delivered on time (n = 14); farmers perceived the administrative work as too laborious (n = 8); farmers did not want to further participate without giving a reason (n = 14); farms had both AMS and CMS (n = 3); or farms did not apply a dry period (n = 1).

Data of 262 farmers who completed the study period was used in the analyses, of whom 189 used a CMS and 73 used an AMS on their farm. Study population 1 (245 farms; 189 CMS farms and 56 AMS farms) was used to evaluate the DCT strategy, udder health and AMU on Dutch dairy farms in the study period (Figure 1). The data of the 17 additional AMS farms with complete data were added to the same farms as population 1 and will be referred to as study population 2 in this paper.

Description of Dutch Dairy Farms (Study Population 1)

Descriptive Statistics. The mean herd size (cows >2 yr) was 106 and ranged between 23 and 344 (P25-P75: 74–129). During milking time, milking gloves were used on 81.1% of the CMS farms. Premilking udder preparation was performed on all CMS farms. Dry towels were used on 66.0% of these farms and moist disinfectant wipes on 14.0%. A combination of water and dry towels was used on 1.6% of the CMS farms, and on 7.5% of these farms premilking teat disinfection in combination with dry towels was used. Other methods for premilking udder preparation were used on the remaining CMS farms (10.8%). Foremilk stripping of each milked cow was applied on 33.0% of the CMS farms. Postmilking teat disinfection was applied on 94.6% of the CMS farms and on 96.2% of the AMS farms.

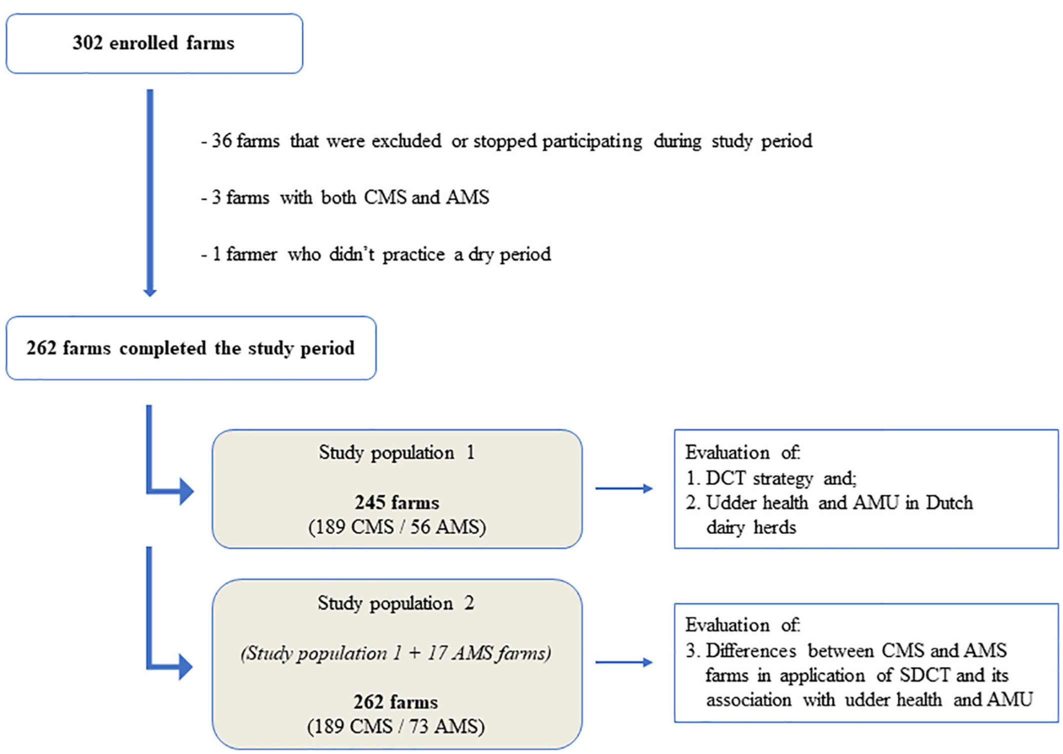

Figure 1. Schematic overview of the 302 initially enrolled farms and the number of farms included in the analysis. CMS = conventional milking system; AMS = automatic milking system; DCT = dry cow treatment; SDCT = selective dry cow treatment; AMU = antimicrobial usage.

Implementation of SDCT. The median number of cows dried off during the study was 64 per herd, ranging between 11 and 259. The mean dry period was 49 d, ranging between 28 and 72 (P25-P75: 45–54). Selective DCT was applied on almost all participating dairy farms (98.8%). The mean percentage of cows per herd treated with antimicrobials at drying-off was 46.7% (median 48.5%; P25-P75: 29.9–61.5%). Of the farmers that applied SDCT, 7 farmers (2.8%; 1 AMS farm and 6 CMS farms) never applied antimicrobials at drying-off during the study period. Three farmers (1.2%; 1 AMS and 2 CMS farms) applied BDCT during the study period.

Choices with Regard to Dry-Off Management. Based on survey data, the majority of the farmers lowered milk production before drying-off by reducing the cow's intake of concentrates (59.9%), by lowering the energy value of the basic roughage ration (26.6%), and by less frequent milking (38.0%).When farmers decided to use antimicrobials at drying-off, antimicrobials were applied in all quarters of a cow by 89.3% of farmers, whereas 10.7% (sometimes or always) decided to apply antimicrobials to a limited number of quarters per cow. Farmers who indicated that they applied DCT to all quarters of a cow provided various reasons for this decision, such as a lack of available techniques to differentiate between quarters (20.2%), they never considered another approach (18.8%), lack of time (12.5%), or they thought that deciding on DCT on quarter level was the wrong way of applying DCT (11.5%). In 76.0% of the farms, internal teat sealants were used during the study period. On 45.3% of these farms, internal teat sealants were used in all cows that were dried off; in the other herds, internal test sealants were used only in a selection of cows. During the actual drying-off process itself, most the farmers stated that they wore milking gloves (71.7%), milked out cows first (88.2%), cleaned the teats with disinfection wipes (87.3%), and used teat disinfection spray or dip (81.4%).

Reasons to Apply Antimicrobials at Drying-Off. Based on individual registrations at the cow level, the farmers gave multiple reasons (on average 1.4 reason per farmer) to apply antimicrobials at drying-off. For 59.4% of the cows in which DCT was applied, the SCC at the last milk recording before drying-off was used as a reason. For 41.5% of the cows, the SCC history during the complete previous lactation was used. The CM history in the previous lactation was used for 12.4% of the cows, and for 8.9%, milk yield at the day of dry-off was used.

Clinical Mastitis. The mean IRCM in study population 1 was 27.3 cases/100 cows per year (median 24.6 cases /100 cows per year; P25-P75: 16.7–36.6). The distribution of the IRCM in study population 1 is shown in Figure 2. Of all registered CM cases, 19.2% (P25-P75: 10.5–25.5) occurred within the first 30 DIM and 43.6% (P25-P75: 34.5–53.1) within the first 100 DIM. Of the registered CM cases, on average 32.8% of cases per herd were scored as mild and 42.2% as moderate. Hence, on average, 25.0% were scored as severe CM. Of all CM cases per herd, 81.0% were treated with antimicrobials (median 93.1%; P25-P75: 70.7–100%). Per herd, the cows with CM had on average 1.1 infected quarter during the study period. In an average 21.9% of cases per herd, the left front quarter was affected. The right front quarter was on average affected in 24.0% and the left rear and right rear quarter were affected in 29.3 and 31.2% of the cases per herd, respectively.

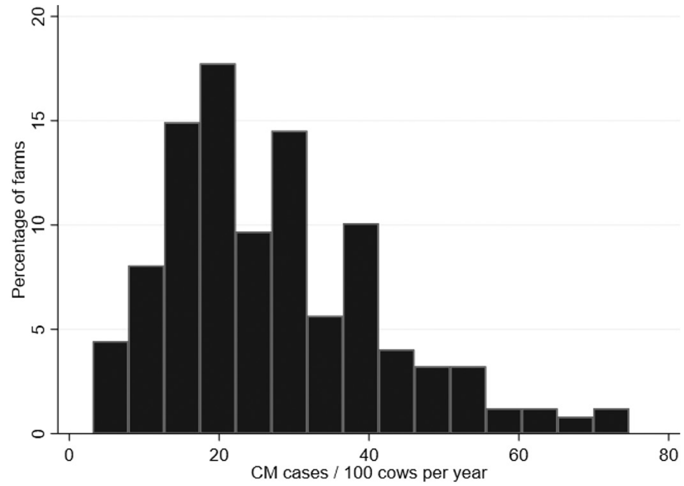

Figure 2. Histogram of the observed incidence rate of clinical mastitis (CM; quarter cases per 100 cows at risk per year) on 245 Dutch dairy farms from May 1, 2016, until April 30, 2017.

Subclinical Mastitis and Antimicrobial Usage. The mean BTSCC over the course of the entire study period was 168,989 cells/mL (median 162,063; P25-P75: 131,542–202,083). The mean IRSCM in these herds was 62.5 cases per 100 cows per year (median 60.9; P25-P75: 48.2–73.7). The percentage of herds with >25% of multiparous cows with a new high SCC in early lactation was 8.2% (95% CI: 6.5–10.1%). The percentage of herds with >25% of cows with persistently high SCC during the dry period was 0.7% (95% CI: 0.3–1.5%). The mean AMU during the study period was 2.94 ADDD/Y (median 2.86; P25-P75: 1.85–3.85) in cows (>2 yr old) of which on average 1.30 ADDD/Y was used for DCT (median 1.34; P25-P75: 0.71–1.80) per herd. The mean AMU for intramammary treatment was 0.73 ADDD/Y (median 0.6; P25-P75: 0.35–0.95) and for parenteral treatment 0.05 ADDD/Y per herd (median 0; P25-P75: 0–0).

Comparison Between AMS and CMS Farms (Study Population 2)

Udder Health and Antimicrobial Usage. The mean dry period length was shorter on AMS farms than on CMS farms. On AMS farms the mean dry period length was 48 d, and on CMS farms 50 d ($P = 0.05$). The percentage of cows per herd treated with antimicrobials at drying-off was significantly higher on AMS farms than on CMS farms ($P = 0.02$). On AMS farms 52.8% of the cows were treated with antimicrobials at drying-off, whereas on CMS farms 44.8% received antimicrobials at drying-off. As a result, ADDD/Y for DCT tended to be higher on AMS farms (Table 1). Of the 73 AMS farmers, one farmer never applied antimicrobials at drying-off during the study period, and one farmer applied BDCT throughout the study period. Of the 189 CMS farmers, 6 farmers never applied antimicrobials at drying-off during the study period, and 2 farmers applied BDCT throughout the study period. Electrical conductivity was more often used as a method to select cows for DCT on AMS farms (13.1%) than on CMS farms (1.9%, $P = < 0.001$). The proportions of farms using other criteria to select cows for DCT did not differ by farm type. On AMS farms, BTSCC and IRSCM were significantly higher than on CMS farms. The IRCM was not significantly different between AMS farms and CMS farms. Furthermore, the occurrence of CM within the first 30 and 100 DIM did not differ between farm types, nor did the percentage of herds with >25% of multiparous cows with a new high SCC in early lactation or the percentage of herds with >25% of cows with persistently high SCC during the dry period (Table 1).

The CM cases were more often classified as severe on AMS farms (32.6% of the CM cases) than on CMS farms (2–2.9% of the CM cases, $P = < 0.001$, Figure 3).

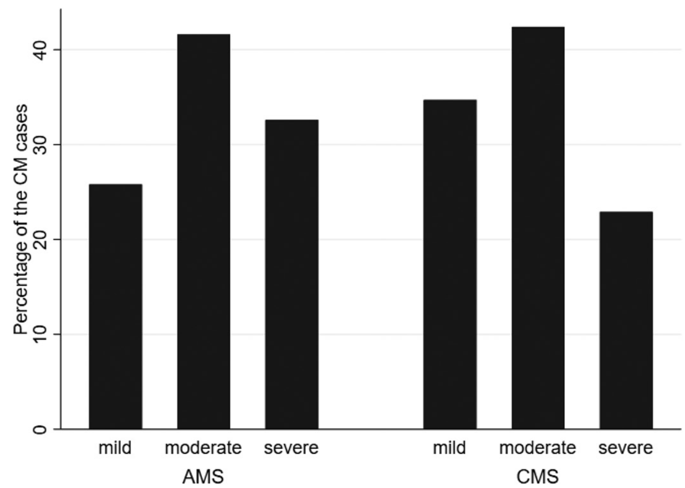

Figure 3. Severity of clinical mastitis (CM) on dairy farms with an automatic milking system (AMS; n = 73) and a conventional milking system (CMS; n = 189).

DISCUSSION

In this study we aimed to gain insight into the method and level of implementation of SDCT on Dutch dairy farms several years after implementation of SDCT. We also assessed IRCM and IRSCM, as well as AMU.

Table 1. Differences in udder health and antimicrobial usage between Dutch dairy farms with an automatic milking system (AMS) and a conventional milking system (CMS)

Variable	AMS farms (n = 73)	CMS farms (n = 189)	*P*-value
Udder health			
Incidence rate of clinical mastitis (CM)/100 cows per year[1]	27.0 (4.4–74.7)	27.6 (3.1–74.7)	0.44
CM cases within 30 DIM[1] (%)	19.0 (0–71.4)	19.2 (0–62.5)	0.49
CM cases within 100 DIM[1] (%)	42.9 (8.3–72.7)	43.8 (0–76.9)	0.53
Incidence rate of subclinical mastitis/100 cows per year[1]	75.2 (20.0–137.7)	58.3 (16.7–108.6)	<0.001
Herds with >25% of multiparous cows with a new high SCC in early lactation (%)	8.5	7.6	0.65[2]
Herds with >25% of cows with persistently high SCC during the dry period (%)	0.0	1.0	0.09[2]
Bulk tank SCC[1] (× 1,000 cells/mL)	189.9 (55.5–276.9)	162.5 (63.1–335.3)	<0.001
Antimicrobial usage			
Annual percentage of cows treated with antimicrobials at drying-off (%)	52.8	44.8	0.02
ADDD/Y total[1,3]	3.13 (0.14–7.71)	2.88 (0.06–8.59)	0.17
ADDD/Y dry cow treatment[1,3]	1.44 (−0.93 to 3.24)[4]	1.26 (0–3.12)	0.08
ADDD/Y intramammary treatment[1,3]	0.69 (0–2.57)	0.74 (0–2.52)	0.56
ADDD/Y parenteral applied antimicrobials[1,3]	0.01 (0–0.32)	0.06 (0–5.4)	0.62

[1]Values are means (minimum, maximum) per herd.

[2]*P*-value was determined using the Proportion test. For all other parameters in this table the Kruskal-Wallis test was used.

[3]Average animal defined daily dose per year (ADDD/Y) in cows >2 yr old.

[4]The negative minimum value is caused by returns of medicine to the veterinarians, which sporadically occur.

Relevant differences between dairy farms with a CMS or an AMS regarding SDCT, udder health and AMU were described.

Dutch Dairy Farms

In the study period, almost all (98.8%) Dutch dairy farms in our study applied SDCT. The level of implementation of SDCT had further increased since 2013 when BDCT was banned. In that year, SDCT was reportedly applied in 75% of the Dutch dairy farms (Scherpenzeel et al., 2016). Furthermore, our results show that in SDCT-herds, fewer cows per herd were treated with antimicrobials at drying-off (mean 46.7%) in the study period as compared with 2013 (mean 63.0%) (Scherpenzeel et al., 2016). The observations from the herds in the 2013 field study and those from the herds in our current study may not be fully comparable, because the 2013 study included only dairy farmers with a CMS (Santman-Berends et al., 2015), whereas in our study, both CMS and AMS farms participated. This should be kept in mind when comparing studies. Reasons for the decreased AMU for DCT in these years might be the launch of the guideline on the implementation of SDCT in 2014, which prescribes how to select cows for DCT (Vanhoudt et al., 2018). Additionally, it may be that farmers found they could do without DCT if they use internal teat sealants or other approaches to prevent IMI, giving them confidence to use lower amounts of antimicrobials at drying-off.

Farmers often had more than one reason to apply antimicrobials at drying-off. The most frequently used reason during the study period was SCC at the last milk recording before drying-off. In 2013, SCC history during the complete previous lactation was the main selection criterion (Scherpenzeel et al., 2016). One reason for this difference between studies might be that the guideline on the implementation of SDCT, which prescribes using the SCC at the last milk recording before drying-off (Vanhoudt et al., 2018) was not yet available in 2013 and farmers therefore chose their own criteria. Another reason could be experience obtained over time, where farmers had more confidence in SDCT and used SCC at the last milk recording for convenience reasons. A difference between these studies is that our current study registered reasons to apply antimicrobials at drying-off were for each cow individually, at the moment of drying-off, whereas in the study of Scherpenzeel et al. (2016) the selection criteria applied for DCT were drawn from a herd-level survey. Inventory of selection criteria for DCT on herd level reveals criteria that are used on the farm but does not give information on reasons for applying DCT on cow level. To study this in more detail, farmers were asked to register their reasons for applying DCT for each individual cow separately, based on which we experienced these reasons differed from cow to cow.

Different algorithm-guided methods to select cows for SDCT have been described in different countries, such as New Zealand (DairyNZ, 2012) the United Kingdom (Bradley et al., 2010) and the United States (Rowe et al., 2020). In those countries, methods used include cow-level SCC during the last 3 tests before drying-off (Bradley et al., 2010) or SCC during the whole previous lactation (DairyNZ, 2012; Rowe et al., 2020). Some of these algorithms also include CM history as a selection criterion. In our study we found that even though CM history was not a criterion in the Dutch national guideline on the implementation of SDCT, it was used for 12.4% of the cows as a reason to apply antimicrobials at drying-off. However, a recent study showed, that including CM in the algorithm has little effect on the risk classification of cows, indicating that algorithms based on SCC alone may be equally effective (Rowe et al., 2021).

Internal teat sealants were used by 76.0% of the herds during the study period, which is higher when compared with 2013, when 64% of the herds used internal teat sealants (Scherpenzeel et al., 2016). Internal teat sealants are more used presently instead of antimicrobials, to prevent new IMI during the dry period, indicating a shift over time. Based on literature, the use of internal teat sealants at drying-off is a valid approach to help prevent new IMI from occurring during the dry period (Rabiee and Lean, 2013).

Our study showed a lower IRCM than reported in previous studies on Dutch dairy farms in 2005 (van de Borne et al., 2010) and 2013 (Santman-Berends et al., 2015) and is comparable to a study in 2010 (Lam et al., 2013). Our study was a follow-up and very comparable to the 2013 study as reported by Santman-Berends et al. (2015, 2016b) and by Scherpenzeel et al. (2016) and uses the same definitions and calculations as those studies. In the study of Santman-Berends et al. (2016b), the mean IRCM, which was estimated solely on dairy farms with a CMS, was 32.2 cases per 100 cows per year, compared with 27.6 cases per 100 cows per year on the CMS farms in our current study population. Additionally, the mean IRSCM and the mean BTSCC in our current study were better than those described in the 2013 field study (Santman-Berends et al., 2016b).

In a recent Dutch study (Santman-Berends et al., 2021), a downward trend for BTSCC was observed over the period of 2013 until 2017. The BTSCC in 2017 as described in that study (170,000 cells/mL) was comparable to the average BTSCC found in our study (168,989 cells/mL). The percentage of herds with >25% of cows with persistently high SCC during the dry period (0.7%) and the percentage of herds with >25% of multiparous cows with a new high SCC in early lactation in our study (8.2%) were in line with the 2017 findings from the study of Santman-Berends et al. (2021) of 1.2 and 8.0%, respectively.

With regard to the udder health parameters, policy changes in the country may have had an influence on our results. From December 2016 onward, national legislation required dairy farmers to decrease herd size because of excess manure. Therefore, between December 2016 until the end of 2017, farmers moved more cattle to slaughter than in other years (Rijksoverheid, 2015). If, as is likely, repeated CM or (chronic) SCM was a selection criterion for culling, this may be a reason for finding a lower IRCM, IRSCM and BTSCC compared with earlier studies.

Of all CM cases, on average 81.0% were treated with antimicrobials in the study period compared with 72% of all cases in 2013 (Santman-Berends et al., 2015), which may be related to severity of mastitis cases involved. Generally, data that describe the severity of CM is sparse and studies are mainly done on large US dairy farms with CMS (Pinzón-Sánchez and Ruegg, 2011, Oliveira et al., 2013). Of the cases where severity was recorded in the US studies, the proportion of cases with severe symptoms was 8% (Pinzón-Sánchez and Ruegg, 2011) and 15.3% (Oliveira et al., 2013). In our study, 25.0% CM cases were scored as severe. This may partly be associated with the fact that in our study AMS farms were included, where CM diagnostics are based on deviations by sensors during milking, which may have an effect on CM detection. When milk is not checked by the famer during milking, mild CM cases may be missed, which can either result in self-clearance of the infection or in cases with more severe symptoms at the eventual time of detection. When fewer mild cases are detected, this will lead to an increase of the percentage of severe CM cases. This hypothesis was supported by the finding that the CM cases on AMS farms were generally classified as more severe than those on CMS farms. Apart from that, it seems that also in the CMS farms in our study the number of severe CM cases was relatively high. This may be due to that fact that on only 33.0% of the CMS farms in our study cows were stripped before milking, which is substantially lower than in the studies of Pinzón-Sánchez and Ruegg (2011) and Oliveira et al. (2013). This may lead to a lower number of cows with mild CM than in other studies. Further, as Oliveira et al. (2013) showed, the majority of severe CM cases were caused by gram-negative pathogens. Finally, it was found that DCT may have an effect on the type of pathogens associated with CM after calving (Bradley et al., 2010) and therefore possibly on severity of cases. Whether the distribution of pathogens was different in our study compared with the 2013 study or the other studies is unknown because we did not perform bacteriological diagnostics. It would, also from a perspective of animal welfare, be interesting to know more about the cause of the relatively high number of severe CM cases in our current study.

Dutch udder health parameters have shown a slow but steady improvement since 2009, which is hypothesized to be associated with the launch of a national udder health program in 2005 (Lam et al., 2013). This improved udder health status may have created favorable circumstances for implementing SDCT. After the introduction of SDCT, Dutch dairy farmers may have further improved the dry cow management, with a better udder health as a result. As appears from this study, the majority of farmers take several measures to prevent occurrence of new IMI during the dry period such as lowering milk production before drying-off and taking hygiene measures during the drying-off process itself. Decreasing milk production before drying-off has been previously reported to result in better udder health (Dingwell et al., 2004; Newman et al., 2010). All in all, BDCT is not absolutely necessary for a good udder health, with both clinical trials (Scherpenzeel et al., 2014; Rowe et al., 2020), as well as practical experience showing that preventive use of antimicrobials in dairy cows can be decreased.

For this study, a random group of Dutch dairy farmers was requested by letter to participate. Nevertheless, bias may have occurred because farmers that responded to our request may have had a more than average interest in udder health or may have a different view on SDCT compared with the total study population. Also, farmers had to be really dedicated to finish the whole study, recording a full year of CM cases and data on DCT. This is reflected in the drop-out percentage of our study which may mean that our results are not fully representative for the total population. On the other hand, the average herd size (cows >2 yr) of 106 in our study population seems comparable to that of the total Dutch dairy herd population, of 105 cows >2 yr in 2016. The same was true for BTSCC, which was 168,989 cells/mL and therefore fairly comparable to the Dutch average of 170,000 cells/mL in 2017, as published by Santman-Berends et al. (2021). In a theoretical ideal study without selection bias it may be so that udder health management is worse than in the herds of motivated farmers that voluntarily participated in our study, and that SDCT may have a different effect than we found. However, given the effects described on a national base by Santman-Berends et al. (2021) and the udder health parameters being comparable to national population, we believe our study population was a fair representation of the Dutch dairy farms in the Netherlands and that our findings are valid.

Comparison Between AMS and CMS Farms

The use of AMS is steadily increasing in the Dutch dairy industry. However, few studies have investigated differences between AMS and CMS farms in the relation between SDCT, udder health and AMU. Cows on AMS herds had a slightly shorter dry period than cows in CMS herds in our study. A finding considered more relevant was that on AMS farms, significantly more cows per herd were treated with antimicrobials at drying-off than on CMS farms. This is in line with findings in a study on Finnish farms in 2016, which showed that AMS farms were more likely to apply BDCT than were CMS farms (Vilar et al., 2018; Niemi et al., 2020). At the same time, another recent study on Dutch dairy farms showed that AMS farmers used equal amounts of antimicrobials during the lactation and at drying-off as CMS farmers (Deng et al., 2020).

Electrical conductivity was more often used as a method to select cows for DCT on AMS farms than on CMS farms. This is likely due to the fact that electrical conductivity is more commonly applied on AMS farms than on CMS farms, where it is the most common indicator used to detect SCM and CM as has been described by Hovinen and Pyörälä (2011). Electrical conductivity data are available on a real-time interval providing the most recent information whether or not to use DCT for farms with a AMS. Test characteristics of electrical conductivity to diagnose SCM are not of recent date, are limited and unconvincing (Maatje et al., 1992; Norberg et al., 2004). It remains uncertain what the effect of this is on SDCT and its consequences on udder health and therefore needs specific attention in future research.

In our study, BTSCC and IRSCM were statistically higher on AMS than on CMS farms. This is in line with findings of Hiitiö et al. (2017) and Niemi et al. (2020), who recorded that Finnish farms with AMS had higher SCC than CMS farms. In the Dutch national cattle health monitoring system, it was also found that herds with an AMS have a significantly higher BTSCC and higher percentages of cows with a high SCC (Santman-Berends et al., 2016a). Results from epidemiological studies indicate that udder health is negatively affected by a change from CMS to AMS (Hovinen and Pyörälä, 2011). A recent longitudinal study in the Netherlands showed that udder health worsens during the transition from CMS to AMS, but decreased in magnitude over the course of the study period (van den Borne et al., 2021). Although in our study IRCM did not differ between AMS farms and CMS farms, CM cases on AMS farms were more often classified as severe than those on CMS farms. Combining this finding with our results that significantly more cows per herd with an AMS were treated with antimicrobials at drying-off compared with herds with a CMS, indicates that udder health remains a point of attention on AMS farms. Based on small-scale studies, however, there definitely are indications that good udder health can be achieved in AMS farms, providing that proper management is maintained (Hovinen and Pyörälä, 2011). Based on our study it is unknown whether the differences between AMS farms and CMS farms are due to the difference in milking system or have to do with other differences between both types of farms.

Because the use of AMS has further increased in the dairy industry after the ban on BDCT, it is important to know in what sense AMS farmers differ from CMS farmers in their approach to SDCT to tailor advice and further reduce AMU on dairy farms. Our research was unable to determine the cause of the differences between AMS farms and CMS farms. It may be due to the difference in milking system or related to the application of SDCT. However, other possible differences between AMS farms and CMS farms, such as management factors or cow factors, may also play a role here. Based on our findings, we recommend further research into the differences between AMS farms and CMS farms in the field of implementing SDCT, particularly the association between the level of SDCT and udder health and AMU.

The findings of our study provide insight into the midterm developments of AMU and udder health after implementation of SDCT at national level. This information is of added value for other countries that are considering implementing an SDCT policy.

CONCLUSIONS

We conclude that the changed antimicrobial policy in the Netherlands led, after multiple years, to a decrease in AMU with no worsening of udder health observed. In the study period, SDCT was applied on almost all (98.8%) of the participating dairy farms. The main reason to apply antimicrobials at drying-off were the SCC history during the complete previous lactation or the SCC at the last milk recording before drying-off. The average IRSCM and BTSCC on CMS farms appeared to be better than on AMS farms, whereas no difference was found in IRCM. Additionally, a relatively larger proportion of severe CM cases were registered in farms with an AMS compared with farms with a CMS, which warrants further research.

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