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The effect of antibiotic versus no treatment at dry-off on udder health and milk yield in subsequent lactation: A retrospective analysis of Austrian health recording data from dairy herds

M. Sigmund,[1]* C. Egger-Danner,[2] C. L. Firth,[3] W. Obritzhauser,[4] F. F. Roch,[3,5] B. Conrady,[3,6,7] and T. Wittek[1]

[1]University Clinic for Ruminants, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine Vienna, 1210 Vienna, Austria
[2]ZuchtData-EDV-Dienstleistungen GmbH, 1200 Vienna, Austria
[3]Unit of Veterinary Public Health and Epidemiology, Institute of Food Safety, Food Technology and Veterinary Public Health, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine Vienna, 1210 Vienna, Austria
[4]Veterinary practice, 8605 Kapfenberg, Austria
[5]Unit of Food Microbiology, Institute of Food Safety, Food Technology and Veterinary Public Health, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine Vienna, 1210 Vienna, Austria
[6]Department of Veterinary and Animal Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, 1870 Frederiksberg C, Denmark
[7]Complexity Science Hub Vienna, 1080 Vienna, Austria

ABSTRACT

Bovine mastitis is the most commonly diagnosed disease of dairy cows worldwide and causes extensive economic losses to milk producers. Intramammary infection status before dry-off plays a decisive role with respect to udder health and milk yield in the subsequent lactation. The aim of this study was to compare the effect of antibiotic dry cow therapy (DCT) versus no treatment at dry-off on milk yield, somatic cell count (SCC), inflammation of the mammary gland (IMG), and the incidence of clinical mastitis in the subsequent lactation. Dairy herd data from 251 Austrian dairy farms were recorded over an observation period of 12 mo and subsequently analyzed. The data set included 5,018 dairy cows: 2,078 were treated with antibiotics (abDCT group) and 2,940 were not treated (noDCT group) at dry-off. The abDCT group was subdivided, based on the antimicrobial active substances used for drying off, into 4 different groups (penicillins, cloxacillin, cephalosporins and rifaximin). Based on bacteriological culture results, infections were grouped into those caused by major, minor, and other pathogens. Additionally, the IMG was defined via SCC from milk recording data using a cutoff of 200,000 cells/mL before drying off and after calving. The incidence of clinical mastitis cases within 30 and 90 d in milk was calculated using veterinary diagnosis data. To investigate the effect of different dry cow therapies on the following parameters: milk yield, SCC, and diagnosed clinical mastitis cases, different linear mixed models were constructed. Overall, the abDCT group was determined to have a significantly higher milk yield over 305 d in milk in the subsequent lactation (increase of 6.18%), compared with the noDCT group (increase of 4.29%). Both groups (abDCT and noDCT) demonstrated a decrease in the first SCC after calving compared with the SCC before dry-off, although the treated cows had a significantly higher reduction. Regarding the different antibiotic groups, with exception of the rifaximin treated cows, all antibiotic groups showed a significant difference from not treated cows with respect to SCC. Additionally, we were able to demonstrate that cows with IMG before dry-off had a 2.073 times higher chance of an increased SCC (>200,000 cells/mL) after calving. With respect to the veterinary diagnosis data, neither the IMG before drying off nor the type of DCT had a significant influence on the probability of developing clinical mastitis within 30 or 90 d in milk. Only a small number of treatments was accompanied with a bacteriological examination before drying off. However, the existing data in this study indicates that the intramammary infection status before dry-off in combination with different dry cow treatments influences udder health and milk yield after calving. Nevertheless, further studies with larger data sets of bacteriological examinations are necessary to enable a more in-depth investigation into the effects of different antibiotic substances used for DCT.

Key words: dry cow therapy, intramammary infection, somatic cell count, antibiotics

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*Corresponding author: michael.sigmund@vetmeduni.ac.at

INTRODUCTION

Bovine mastitis is the most commonly diagnosed disease in dairy herds worldwide and causes serious economic losses due to therapy costs and a reduction in saleable milk (Seegers et al., 2003; Hogeveen et al., 2011; Raboisson et al., 2020). Focusing on udder health, the dry period plays a decisive role in mastitis control (Bradley and Green, 2004). Many influencing factors have been studied and found to have effects on udder health in the subsequent lactation, such as milking cessation method (Vilar and Rajala-Schultz, 2020), dry period length (Berry and Hillerton, 2007; Kok et al., 2017; Pattamanont et al., 2021), feeding strategies (Singh et al., 2020), milk yield at dry-off (Newman et al., 2010), milk leakage (De Prado-Taranilla et al., 2020) and general dry cow management (McDougall, 2003; Green et al., 2007; McMullen et al., 2021). Nevertheless, determining the IMI status at drying off remains one of the most crucial points for optimal dry-off management. Intramammary infection status can be determined directly by detection of the causative pathogen via bacteriological culture or indirectly based on the measurement of the inflammatory response induced by the IMI (e.g., using a proxy such as the SCC; Torres et al., 2009; Adkins and Middleton, 2018). The evaluation and interpretation of the influence of bacteria detected in milk samples remains challenging. However, Green et al. (2002) found that a positive bacteriological culture at drying off increases the risk of acquiring a new IMI in the subsequent lactation. Bradley et al. (2015) found substantial differences in prevalence and pathogen distribution in milk samples at drying off in 12 dairy herds from 6 different European countries. All dairy cows in these herds received blanket dry cow therapy (**DCT**), and therefore, it was not possible to compare treated with untreated control cows with respect to infection dynamics in the subsequent lactation. Numerous comparative studies between antibiotic and nonantibiotic dry-off methods have reported heterogeneous results in terms of their effect on udder health after calving. For example, Winder et al. (2019) found in their systematic review with a meta-analysis of 45 studies, a lower risk of acquiring a new IMI when dry cows received cephalosporins, penicillins with aminoglycosides or cloxacillin compared with no antibiotic DCT. To the authors' knowledge, only one retrospective study has previously been published in Austria describing the influence of antibiotic dry-off treatment on udder health on small-structured Austrian dairy farms (Wittek et al., 2018). The results of that study showed that dairy cows, treated with antibiotic dry cow tubes before dry-off, achieved higher milk yields and lower SCC in the subsequent lactation. However, the authors did not subdivide the antibiotic group into different antibiotic classes, nor were milk samples bacteriologically cultured. The prophylactic use of antibiotic DCT regardless of the udder infection status is no longer acceptable and cannot be justified in terms of increasing antimicrobial resistance and international requirements for prudent use of antimicrobials. The aim of the present study was to compare the effects of antibiotic dry-off treatment versus no treatment of Austrian dairy cows, by means of analyzing milk recording data, veterinary diagnoses and treatment data, as well as bacteriological culture results at the end of lactation. We hypothesized that the various antibiotics used for DCT would have different effects on the parameters SCC, milk yield, clinically diagnosed mastitis cases after calving and the inflammation status of the mammary gland.

MATERIALS AND METHODS

Because no human or animal subjects were used, no ethical approval was required for the preparation of the manuscript.

From October 1, 2015, to September 30, 2016, dairy herd data (breed and lactation number, milk recording data, veterinary mastitis diagnosis, and dry cow treatment data) were collected from 251 Austrian dairy farms as part of the multidisciplinary Austria-wide project "ADDA Advancement of Dairying in Austria." Seventeen veterinary practices agreed to provide their data on standardized diagnoses (Egger-Danner et al., 2012) and treatments for participating dairy farms, as previously described (Firth et al., 2017). Only farmers who were members of the national milk recording service and the Austrian Animal Health Service, and who agreed to the use of their herd data, were eligible for inclusion in this study. The Austrian Animal Health Service is an independent association with the aim of improving animal health through various voluntary programs (i.e., combating parasites, improving reproduction and udder health) with intensified diagnostics. The milk recording data and dairy herd data (breed and lactation number) were supplied by ZuchtData EDV-Dienstleistungen GmbH (Vienna, Austria). Based on veterinary treatment data, dairy cows were divided into those that received long-acting antibiotic dry-off treatment (**abDCT** group), and cows that were dried off without treatment (**noDCT** group). It is important to note that 99 of these dairy cows received an internal teat sealant. Of these 99 animals, 24 belonged to the abDCT group (0.82% of samples) and 75 to the noDCT group (3.61% of samples). Due to these small number of samples, no separate group was created for the use of nonantibiotic teat sealants. The decision on the dry-

Table 1. Classification of the different antibiotic dry cow tubes according to their compositions and appropriate number of treated dairy cows in the present study

Product number	Composition[1]	n[2]	Antibiotic group
1	Penethamatehydriodide 100 mg, benethamine penicillin 280 mg, and framycetin sulfate 100 mg	247	Penicillins
2	Procaine benzylpenicillin 1,000 mg, benzylpenicillin potassium 314 mg, and neomycin sulfate 500,000 IU	121	Penicillins
3	Cloxacillin (benzathine salt) 1,000 mg	477	Cloxacillin
4	Cloxacillin (benzathine salt) 1,280 mg	684	Cloxacillin
5	Cloxacillin (benzathine salt) 500 mg and ampicillin (as the trihydrate) 250 mg	354	Cloxacillin
6	Cephalonium (as cephalonium dehydrate) 250 mg	52	Cephalosporins
7	Cephalexin 200 mg	1	Cephalosporins
8	Cefquinome sulfate 150 mg	99	Cephalosporins
9	Rifaximin 100 mg	43	Rifaximin

[1]Antimicrobial active substances per dry cow tube.

[2]Total number of dairy cows treated.

off treatment was taken by the farmers in consultation with their veterinarians.

At the time of data collection, 9 different antibiotic products were used as intramammary dry cow formulations in the 17 participating veterinary practices. The abDCT group was subdivided into 4 different antibiotic groups: penicillins, cloxacillin, cephalosporins, and rifaximin (Table 1). All antibiotic dry-off tubes were dispensed to the farmers by their herd veterinarians (NB: by law, according to the Control of Veterinary Medicinal Products Act, veterinary antibiotics in Austria are only available from veterinarians, never over-the-counter, and may only be dispensed to farmers who are members of the Animal Health Service; TAKG, 2021). Antibiotic tube application was carried out by the farmers according to their usual management practices. Data on diagnosed mastitis cases after calving were obtained from the veterinary diagnosis and treatment data. As all farms were members of the national milk recording service, updated data were available for every animal approximately every 4 to 6 wk on SCC, milk fat, milk protein, and milk yield. In this study, SCC and milk yield in 305 DIM were considered. Furthermore, the inflammation status of the mammary gland was classified based on the SCC from milk recording data before dry-off and after calving. During the project, quarter milk samples were collected aseptically from dairy cows by farmers or herd veterinarians. The samples were sent to one of the 5 participating Austrian veterinary laboratories for culturing and bacteriological examination, as previously reported (Schabauer et al., 2018). The data set of bacteriological examinations consisted of 7,180 quarter milk samples from 1,424 dairy cows, including information from the medical history form on the sampled cow (i.e., pretreatment, affected quarter, as well as the reason for bacteriological culture, such as control before dry-off, abnormal milk, increased SCC, udder swelling, dairy herd monitoring). Samples, which were submitted with the specification "control before dry-off" and "high SCC plus control before dry-off," were included in this analysis. In the case of dairy cows with several samples submitted, only the last examination before dry-off was taken into account. Cows with the bacteriological culture result "yeast," "mixed culture," "dirt," "mold" or "algae" in one or more quarters were considered as nonevaluable for the statistical approach and were excluded (n = 68). Due to these selection criteria, a total of 1,305 quarter milk samples from 334 dairy cows were included in the analysis. Laboratory findings were classified into major pathogens (*Staphylococcus aureus*, *Streptococcus uberis*, *Streptococcus dysgalactiae*, coliforms), minor pathogens (NAS, *Corynebacterium bovis*), other pathogens (miscellaneous gram-positive bacteria) and negative test results (negative and no growth). Depending on the quarter milk sample results, each cow was assigned to one of the 4 groups. Cows with more than one detected bacterium in the bacteriological examination were assigned to the most important group. The prioritization within the 4 groups was in descending order: major pathogens, minor pathogens, other pathogens, and negative test results. Therefore, if a cow was found to be infected with both *Staph. aureus* and *Escherichia coli*, then she was assigned to the major pathogens group, no hierarchy of bacterial species within major or minor groups was required.

Data from a pool of 5,018 cows were used to investigate the effect of different dry cow therapies on the following parameters: milk yield, SCC and veterinary-diagnosed clinical mastitis cases. For this purpose, 10 different linear mixed models were constructed. Nonsignificant predictors were removed stepwise in the models, whereas the reduced models were compared with corresponding full models with ANOVA. If ANOVA was not significant, the reduced model was kept. Due to missing data and records, the number of cows differ between the used models, depending of the considered variables. The syntaxes of the models and corresponding sample sizes are listed in Supplemental Table S1 (https://phaidra.vetmeduni.ac.at/o:1159). For comparisons of milk yield (defined as the total milk production in 305 DIM) and the SCC before and after calving, DCT log10 milk yield ratios (**MYR**) and log10 cell count ratios (**CCR**) were calculated as follows:

$$MYR = \log 10\left(\frac{305 \text{ DIM milk yield after DCT}}{305 \text{ DIM milk yield before DCT}}\right) \text{ and}$$

$$CCR = \log 10\left(\frac{\text{first recorded cell count after at least 5 d postcalving}}{\text{last recorded cell count before DCT}}\right).$$

Data were visually checked for normal distribution with histograms and Q-Q plots. Homogeneity of variances was analyzed with Levene's test. To explain the effect of DCT on MYR and CCR, the linear mixed model 1 (full) and model 2 (full) were constructed (Supplemental File S1, https://phaidra.vetmeduni.ac.at/o:1083). Due to the stepwise removing of nonsignificant predictors, for the model 1 (final) parity and log10 cell count after DCT were kept as predictors and herd as random factor. Regarding the model 2 (final), parity and 305 d milk yield before DCT were kept as predictors and herd and animal as random factors. For Model 1a and 2a, the different antibiotic groups were used instead of the binary predictor [abDCT(yes-no)]. For Model 1b and 2b, the pathogen groups were added as additional predictors to the models. Given the small number of bacterial data, these models were only described, but not used for any valid statement (Supplemental File S1). Furthermore, the parameters clinical mastitis (diagnosed by veterinarians within 30 and 90 DIM, respectively) and inflammation of the mammary gland (**IMG**; defined via SCC and a cutoff of 200,000 cells/mL) before (**IMGb**) and after (**IMGa**) dry-off were analyzed in the models 3 to 5. To explain the effect of DCT and the different antibiotic DCT groups on IMGa, binomial generalized linear mixed models 3 and 3a were used, respectively. In the binomial generalized linear mixed models 4 and 5, the clinical mastitis within 30 and 90 DIM were defined as outcome variables, IMGb and abDCT(yes-no) included as fixed effects and the herd as random effect. The percentage of diagnosed clinically mastitis cases, grouped by bacteriological test results before dry-off and DCT were analyzed descriptively. In a second step, the inflammation status of the mammary gland of the dairy cows were classified into 4 categories (healthy, newly infected, cured, chronically infected), based on their SCC before dry-off and after calving. Dairy cows which had an SCC of <200,000 cells/mL in the last milk recording in combination with an SCC of <200,000 cells/mL in the first after calving, were defined as healthy and those animals with both values above the cutoff as chronically infected. The category newly infected described the circumstance when a dairy cow only had a higher SCC than the cutoff in the first milk recording after calving and cured cows only had an SCC above the cutoff before dry-off. All statistics and graphics were done in the R statistical environment, R 4.0.5 using the packages "lme4," "MASS," "car," "stats," and "ggplot2" (R Core Team, 2021).

RESULTS

In total 2,078 dairy cows were treated with antibiotics before drying off, and 2,940 were not treated at that time. Not all of the 5,018 dairy cows had a complete data set. Supplemental Table S1 shows the respective number of dairy cows included for every model calculated.

Milk Production

Dairy cows in the abDCT group had a higher mean 305 DIM lactation milk yield before dry-off, than those of the noDCT group (8,618 vs. 8,514 kg). Among the 1,380 cows considered in model 1, the 747 animals without antibiotic dry-off had a mean log10 MYR of 0.018 (corresponding to an increase of 4.29% of milk yield in the following lactation period) and the 633 abDCT cows had a mean log10 MYR of 0.026 (increase of 6.18%). According to model 1, abDCT has a very small but statistically significant ($P = 0.018$) positive effect on the milk yield ratio (Table 2). Investigating the different antibiotic groups separately in model 1a, none of them had a significant influence on the milk yield ratio (Supplemental Table S2, https://phaidra.vetmeduni.ac.at/o:1160). Parity and SCC after calving significantly affected the MYR ($P < 0.01$) in both models (1 and 1a). Regarding the log10 MYR, there seems to be a huge variation among animals independently from the IMI status and independently from the chosen antibiotic (Supplemental Figure S1, https://phaidra.vetmeduni.ac.at/o:1155).

Somatic Cell Count

Among the 1,380 animals used in model 2, the median value of the SCC in the last milk recording before dry-off was 98,000 cells/mL (40,000 cells/mL after calving) in the noDCT group and 112,000 cells/mL (26,000 cells/mL after calving) in the abDCT group. The first milk recording after calving took place on average on d 25 postpartum (for both groups), the time period for

Table 2. Model 1 final: Results from general linear mixed model testing the association between milk yield ratio and antibiotic dry cow therapy in 1,380 cows from 237 dairy farms

	Model 1 (final) – output		
Item	Estimate	SE	P-value[1]
Fixed effects			
Intercept[2]	7.408×10^{-2}	5.241×10^{-3}	<0.001
abDCT (yes-no)[3]	7.547×10^{-3}	3.187×10^{-3}	0.018
Parity	-1.269×10^{-2}	8.251×10^{-4}	<0.001
log10(SCCa)[4]	-1.378×10^{-2}	2.597×10^{-3}	<0.001
Random effects	Variance	SD	
Herd	3.634×10^{-4}	1.906×10^{-2}	
Residuals	2.708×10^{-3}	5.204×10^{-2}	

[1]Significance was declared at $P < 0.05$.

[2]Intercept = milk yield ratio was the reference category, calculated using the milk yield in 305 DIM from the milk recording data before and after dry cow therapy.

[3]abDCT(yes-no) = antibiotic or nonantibiotic dry cow therapy.

[4]log10(SCCa) = SCC from the first milk recording data after calving.

Table 3. Model 2 final: Results from general linear mixed model testing the association between cell count ratio and antibiotic dry cow therapy in 1,380 cows from 237 dairy farms

	Model 2 (final) – output		
Item	Estimate	SE	P-value[1]
Fixed effects			
Intercept[2]	-4.898×10^{-1}	1.583×10^{-1}	0.002
abDCT (yes-no)[3]	-2.254×10^{-1}	3.518×10^{-2}	<0.001
Parity	-2.982×10^{-2}	1.322×10^{3}	0.002
sqrt (milk yield before)[4]	-3.093×10^{-3}	1.765×10^{-3}	0.08
Random effects	Variance	SD	
Animal	2.307×10^{-1}	4.803×10^{-1}	
Herd	1.199×10^{-2}	1.095×10^{-1}	
Residuals	1.575×10^{-1}	3.968×10^{-1}	

[1]Significance was declared at P-values <0.05.

[2]Intercept = cell count ratio was the reference category, calculated using the SCC from the last milk recording data before dry cow therapy and the first SCC after calving.

[3]abDCT(yes-no) = antibiotic or nonantibiotic dry cow therapy.

[4]sqrt (milk yield before) = square root from the milk yield in 305 DIM from the milk recording data before dry cow therapy.

the last SCC from milk recording data before dry-off was on average 70 d (71 d for the abDCT group and 69 d for the noDCT group, on average). The mean log10 CCR of the noDCT group was −0.284 (corresponding to a decrease of 48.04%), whereas it was −0.518 (decrease of 69.68%) in the abDCT group. According to model 2, abDCT cows had a significantly ($P < 0.001$) higher reduction of the SCC compared with noDCT cows (Table 3). Analyzing antibiotic groups separately showed that each of the antibiotic groups (in addition to rifaximin) led to a significantly higher reduction in SCC than among noDCT cows (Supplemental Table S3, https://phaidra.vetmeduni.ac.at/o:1161). Comparing bacteriological results, there were only slight differences in the CCR between noDCT and abDCT (Supplemental Figure S2, https://phaidra.vetmeduni.ac.at/o:1156).

Udder Health

According to model 3 (Table 4) and model 3a (Supplemental Table S4, https://phaidra.vetmeduni.ac.at/o:1162) only the IMGb status had a significant influence on the IMGa status, whereas antibiotic or DCT (model 3) or the different antibiotic groups (model 3a) showed no significant influence on the chance of having an increased SCC after calving. When only the IMG status is accounted for (model 3 reduced), dairy cows with IMGb had a 2.073 (95% CI: 1.651–2.603) times higher chance to keep on having an increased SCC (>200,000 cells/mL) after calving compared with cows with a SCC value lower than 200,000 cells/mL in the last milk recording data before dry-off (Supplemental Table S5, https://phaidra.vetmeduni.ac.at/o:1163). Based on the results of models 4 and 5, neither the IMGb nor the type of DCT had a significant influence on the chance of developing clinical mastitis within 30 or 90 d after calving, respectively (Supplemental Tables S6 and S7, https://phaidra.vetmeduni.ac.at/o:1164).

Bacteriological Culture Results

Results of bacteriological cultures from quarter milk samples before drying off were available for 334 cows. Milk samples were submitted on average 87 d before calving. The most frequently detected udder pathogens

Table 4. Model 3: Results from binomial general linear mixed model testing the association between inflammation of the mammary gland after calving defined via SCC and antibiotic dry cow therapy in 3,462 cows from 251 dairy farms

	Model 3 output		
Item	Estimate	SE	P-value[1]
Fixed effects			
Intercept[2]	−2.248	0.097	<0.001
IMGb[3]	0.789	0.151	<0.001
abDCT(yes-no)[4]	−0.156	0.141	0.268
IMGb:abDCT	−0.103	0.235	0.661
Random effect	Variance	SD	
Herd	0.186	0.431	

[1]Significance was declared at $P < 0.05$.

[2]Intercept = inflammation of the mammary gland after calving was the reference category and defined via SCC threshold of >200,000 cells/mL in the first milk recording data after calving.

[3]IMGb = inflammation of the mammary gland before dry-off, defined via SCC threshold of >200,000 cells/mL in the last milk recording data before dry-off.

[4]abDCT(yes-no) = antibiotic or nonantibiotic dry cow therapy.

were NAS (n = 52, 33.55% of all positive samples) and *Staph. aureus* (n = 47, 30.32%, Figure 1). Veterinary diagnosis data on occurring mastitis cases were available from 232 (69.46%) cows, of which 12 were diagnosed with clinical mastitis within 30 DIM, and 22 within 90 DIM after calving (for proportions grouped by bacteriological result and treatment, see Supplemental Figures S3 and S4, https://phaidra.vetmeduni.ac.at/o:1157). Supplemental Figure S5 (https://phaidra.vetmeduni.ac.at/o:1158) demonstrates the IMG status (healthy, newly infected, cured, chronically infected), based on the SCC from milk recording data in combination with the bacteriological culture results and DCT strategy. Of 234 cows with both SCC data and bacteriological culture results before dry-off, 69 cows (32.91%) had an SCC value of more than 200,000 cells/mL in the last milk recording data before dry-off. In 31 dairy cows, the bacteriological analysis was negative before dry-off, in 26 a major pathogen was detected, in 12 a minor pathogen, and in 8 dairy cows an infection with other pathogens. The highest number of cases with an SCC of >200,000 cells/mL before and <200,000 cells/mL after calving (cured) including bacteriological findings before dry-off, had received cloxacillin DCT, with 12 cows in the group of the major pathogens (Supplemental Figure S5). Cloxacillin was the most commonly used antibiotic DCT formulation among animals where a bacteriological culture was also available.

DISCUSSION

The aim of the study was to compare the effects of antibiotic dry-off treatment versus no treatment in Austrian dairy cows. The group of cows treated with antibiotics before dry-off achieved a 1.062-fold increase of MYR in the subsequent lactation compared with a 1.043-fold increase in the noDCT group. This is in line with findings by Wittek et al. (2018), who reported that antibiotic-treated animals produced 91 kg more milk in the subsequent lactation. In contrast, Niemi et al. (2020) found no significant difference comparing various DCT strategies on milk production in their longitudinal study. Studies directly comparing the effect of antibiotic DCT alone with no treatment before dry-off on milk yield throughout subsequent lactation are sparse; however, a possible reason for the higher milk yield would be the improved cure rates of existing IMI by antibiotics during the dry period. With respect to the 4 antibiotic groups, a clear explanation to why no group showed a significant influence on the MYR, although the abDCT group alone was significant, could not be determined. It should be noted, however, that the individual antibiotic groups were relatively small and lacking statistical power. Parity and SCC after calving showed a significant influence on the MYR. The influence of a higher lactation number and SCC on milk yield, are well-known factors in dairy production (Lee and Kim, 2006; Hagnestam-Nielsen et al., 2009). The association between DCT and milk yield is most likely explainable due to the IMI status before dry-off. Although the small number of bacteriological examinations before dry-off in the current data set limited the statistical analysis, dairy cows with positive bacteriological cultures before drying off have been reported to have an increased risk to succumbing to clinical mastitis (Green et al., 2002) and a reduction in milk yield due to mastitis in dairy cows is a well-known phenomenon (Wilson et al., 2004; Heikkilä et al., 2018).

Regarding the SCC, both groups (abDCT and noDCT) demonstrated a decrease in the calculated CCR, although antibiotic-treated dairy cows had a significantly higher reduction in SCC. With the exception of rifaximin, this result was also determined for all antibiotic groups compared with no treatment. It should be noted, however, that rifaximin was the least frequently used antibiotic group with the highest variation in this investigation. A higher decrease in the SCC compared with no DCT due to the use of antibiotic dry cow tubes has also been shown in other studies (Rajala-Schultz et al., 2011; Wittek et al., 2018). However, the median of the SCC in the last milk recording was around 14,000 cells/mL higher in the cows dried off with antibiotics. It seems likely that the SCC was used as a decision criterion due to the fact that bacteriological examinations before dry-off were only carried out on a small number of dairy cows and the direct link between bacterial IMI and elevated SCC is undisputed (Djabri et al., 2002). With regard to the mastitis cases diagnosed by the herd veterinarians within the first 30 and 90 DIM, neither IMGb nor antibiotic treatment as a whole or when subdivided into different antibiotic groups showed a significant influence. In contrast to our findings, Winder et al. (2019) concluded, after a systematic review with meta-analysis of the literature, that cloxacillin, cephalosporins, and penicillin in combination with aminoglycosides are able to significantly reduce the risk of IMI at calving, compared with no dry cow treatment. Our insignificant results regarding the diagnosed mastitis cases are at least partly explainable with the most commonly detected udder pathogen (NAS) in this study before dry-off. Rowe et al. (2021) reported no substantially increased rate of clinical mastitis cases in the following lactation when NAS was detected before dry-off and Vasquez et al. (2018) reported high spontaneous cure rates of NAS IMI throughout the dry period.

Subclinical mastitis may have played another decisive role in this finding as these IMI are often able to remain

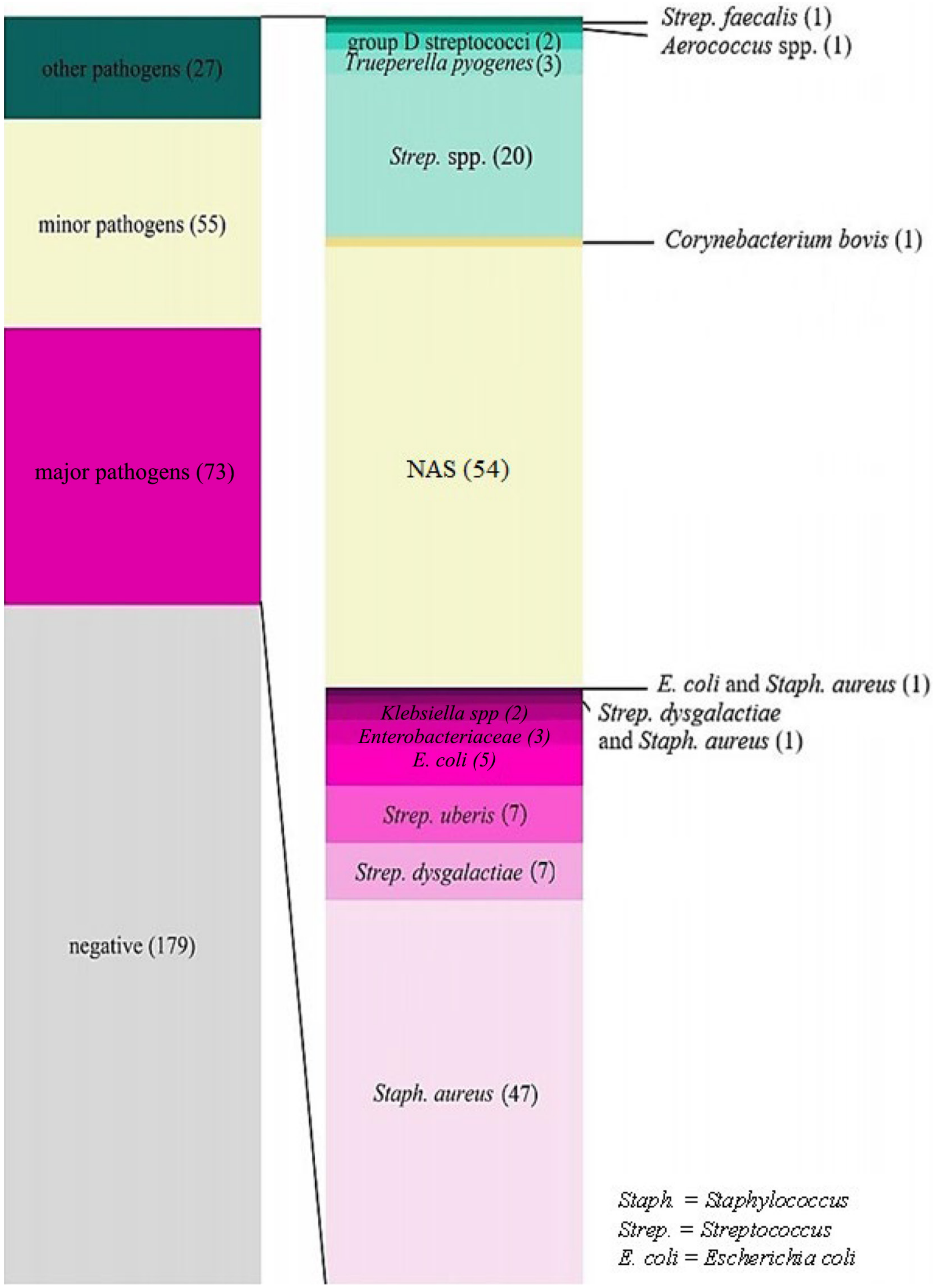

Figure 1. Distribution of the bacteriological test results before dry-off (n = 334) in the 4 main groups selected (i.e., major pathogens, minor pathogens, other pathogens, and negative) and number of cows with the specific udder pathogen detected.

unnoticed. Due to the small number of bacteriological examinations carried out before drying off in this study population, analyses were limited to descriptive statistics. For this reason, an SCC cutoff was used to define the infection dynamics across the dry period. The chosen SCC cutoff value of 200,000 cells/mL to distinguish between healthy and infected udders is internationally widely used (Rajala-Schultz et al., 2011; Henderson et al., 2016; Lipkens et al., 2019) and combining SCC from milk recording data before and after dry-off to describe the IMI status (i.e., healthy, cured, chronically infected, and newly infected) has already been done in a similar way by another research group (Lipkens et al., 2019). In addition, a link has been shown between an increased risk of SCC >200,000 cells/mL and a positive culture for major pathogens (Scherpenzeel et al., 2014). In the present study, inflammation status of the mammary gland across the dry period using SCC data showed that cows with SCC >200,000 cells/mL in the last milk recording before dry-off had a 2.073 higher probability to keep on having an increased SCC (>200,000 cells/mL) after calving. Contrary to our expectations, the administration of long-acting antibiotic dry-off tubes did not appear to influence these high SCC animals. Whereas, Niemi et al. (2022) found an association between antibiotic-treated cows before dry-off and a decreased SCC after 45 DIM. It could also be that antimicrobial resistance against the used long-acting antibiotics, not appropriate choice of long-acting antibiotics or a not hygienic insertion of internal teat sealants confounded the outcome of our study. Still, due to missing data, the latter could neither be confirmed nor denied.

In view of the different dry cow tube antibiotic formulations, it was not possible to identify a specific “all-rounder” regarding an improvement of the udder health. Although the literature describes a 1.51 to 2.10 times higher cure rate of infected quarters applying antibiotic dry cow tubes in contrast to no treatment (Halasa et al., 2009), the preventive use of antimicrobial products in the livestock sector must be critically questioned. The present study suggested that antimicrobial DCT on healthy cows could even lead to an overall lower milk yield, providing an economic as well as clinical reason to avoid blanket DCT. Nevertheless, the use of critically important antimicrobials in veterinary medicine should be avoided whenever possible (O’Neill, 2016). A total of 5,018 cows were included in the present study, of which 41.41% were treated with antibiotics at dry-off. A comparison to other studies with respect to the dry-off strategies from the 251 participating Austrian dairy farms in our retrospective study was not possible, primarily due to the fact that our data sets did not cover entire herds but rather individual cow data and bacteriological culture results. In contrast to other European countries, such as Denmark (Bennedsgaard et al., 2010), the use of dry cow tubes in Austria is not required to be linked to a mastitis diagnosis or a bacteriological culture of milk samples. Irrespective of this fact, the recorded quantities of antibiotic dry cow tubes prescribed and dispensed to dairy farmers in Austria have been declining continuously since mandatory reporting of antimicrobial dispensing began in 2015, which could indicate a more prudent use of antimicrobial substances (Fuchs and Fuchs, 2020).

The present study has several limitations: First, the retrospective-nature of the heterogeneous data set, which meant that for each parameter a different number of dairy cows was included in the calculations. Therefore, the results of the main investigations (MYR, CCR, and IMG) are only partially comparable with each other. The analyzed data set, based on a convenience sample of dairy farms, may only partially reflect the actual situation at drying off in the whole dairy cattle population in Austria. Second, the low total number of dairy cows in some groups (e.g., cows administered teat sealants), which allowed only a limited number of available variables to be included in the statistics. Regarding the heterogeneous number of treatments within the antibiotic dry-off formulations, the products were grouped into 4 antibiotic categories based on their active substances. The low number of bacteriological examinations performed at the end of lactation before dry-off resulted in the third limitation. The individual pathogens were grouped into 4 main categories (major pathogens, minor pathogens, other pathogens, and negative) for statistical analysis, which only partially served the hypothesis of a pathogen-specific effect.

CONCLUSIONS

Dairy cows dried off with antibiotics were found to have an improved MYR and CCR compared with the nontreated group, however the data also showed that only a small number of bacteriological examinations were performed before dry-off and a relatively large proportion of the dairy cows with negative bacteriological cultures or low SCC before dry-off were still dried off with antibiotics. This is neither in line with the Austrian government recommendations to reduce antibiotic treatment in livestock nor in line with a responsible and targeted use of antimicrobial agents. Nevertheless, the analyzed data in this survey, which was based on a convenience sample of farmers and veterinarians, are not necessarily representative of treatment and drying off practices nationwide. Due to the extremely large proportion of cows dried off with cloxacillin, no conclusions could be made with respect to the comparative efficacy of the 4 antibiotic groups. Further studies with larger data sets of bacteriological examinations are necessary to enable an in-depth investigation into the effects of different dry cow antibiotic formulations.

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ORCIDS

M. Sigmund https://orcid.org/0000-0002-9991-5176
C. Egger-Danner https://orcid.org/0000-0002-8879-6845
C. L. Firth https://orcid.org/0000-0002-4919-7786
W. Obritzhauser https://orcid.org/0000-0002-2041-5081
B. Conrady https://orcid.org/0000-0001-8554-5963
T. Wittek https://orcid.org/0000-0001-6113-8458