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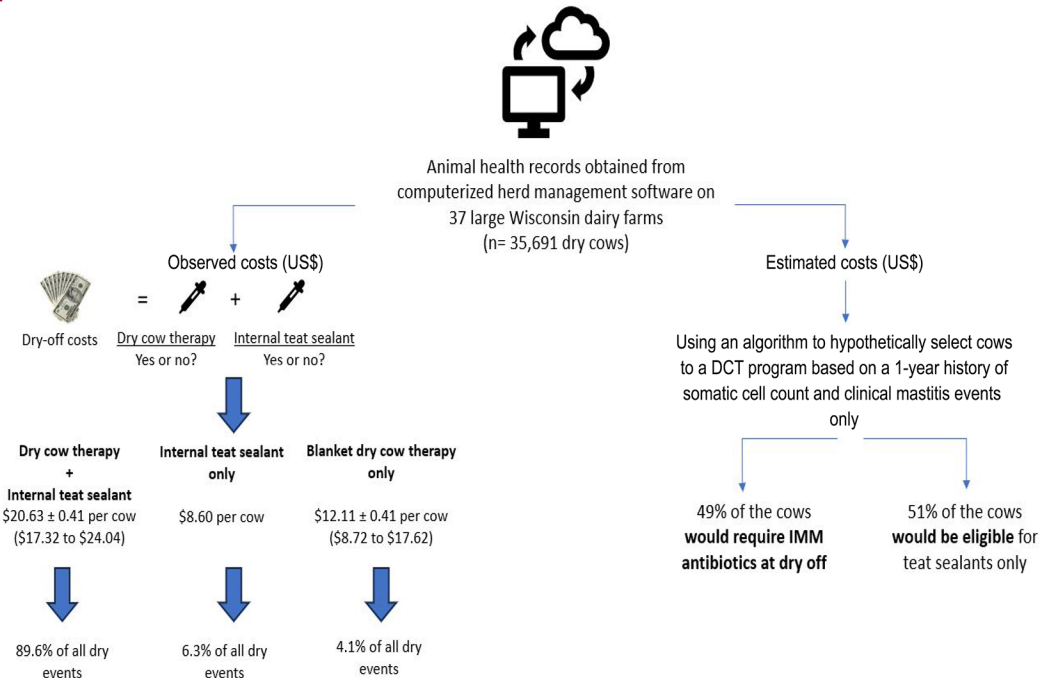
Short Communication
Health, Welfare, and Behavior

Variation in partial direct costs of dry cow therapy on 37 large dairy herds

J. Leite de Campos,[1] A. Kates,[2] A. Steinberger,[3,4] A. Sethi,[5] G. Suen,[3] John Shutske,[6] N. Safdar,[2] Tony Goldberg,[7] and P. L. Ruegg[8]*

Graphical Abstract



Summary

Blanket administration of antibiotics to cows at dry-off continues to be one of the most common udder health management practices used for mastitis control, but selective administration of antibiotics at dry-off is encouraged to reduce overall usage of antibiotics. In 37 herds in this observational study, blanket antibiotic therapy combined with an internal teat sealant was the most common protocol used at dry-off. The average cost of dry cow treatments ranged from $9 to $24 per cow. Based on an algorithm using individual cow somatic cell count and clinical mastitis history before dry-off, about half of the cows would have been eligible to receive nonantibiotic teat sealants only (no antibiotics) at dry-off, resulting in reduced antibiotic usage and an average savings of about $5.37 per dry cow (~27% of the partial direct costs).

Highlights

- The average partial direct cost of treatments given at dry-off was $19.57 per dry cow.
- Our algorithm was based on clinical mastitis history and somatic cell count during lactation before dry-off.
- Of the cows in the herds, 23% to 93% would have been eligible to receive only teat sealants at dry-off.
- Using a hypothetical selective dry cow therapy program, savings were estimated to be $5.37/cow.
- With selective dry cow therapy, antimicrobial use at dry-off would have been reduced by 51%.

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The list of standard abbreviations for JDSC is available at adsa.org/jdsc-abbreviations-24. Nonstandard abbreviations are available in the Notes.

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Abstract: The objective of this observational study was to estimate partial direct costs of dry cow antibiotic therapy (DCT) protocols used on 37 large dairy herds in Wisconsin and to estimate the potential monetary savings and reduction in antimicrobial usage (AMU) if selective DCT was used. Partial direct costs of DCT were calculated using costs of intramammary (IMM) antimicrobials and teat sealants. Data were retrospectively collected on 37 large dairy farms for a period of 1 yr and included the total number of cows dried off, types of IMM antimicrobial used, and product prices (obtained from farm invoices). A single farm visit was performed to verify data. Clinical mastitis (CM) and SCC history across lactation were used as the criteria to identify cows eligible to receive only teat sealants (no antibiotic DCT) based on adoption of a hypothetical selective DCT program. Descriptive statistics were performed using PROC MEANS to summarize continuous herd and cow characteristics. Differences in costs among IMM antibiotic products and eligibility to not receive antibiotics at dry-off by parity were analyzed using ANOVA. Differences in milk yield at the last test-day and DIM at dry-off based on eligibility for selective DCT were analyzed using PROC MIXED. A total of 35,691 cows were dried off across all herds (n = 37) and most of the herds used IMM antibiotic DCT at dry-off in most of the cows. Teat sealant was used as part of the dry-off protocol in all but 3 herds. Of the enrolled farms, 30 used blanket antibiotic DCT in all quarters of all cows and 7 herds used selective DCT with no administration of antibiotics given to 0.8% to 58% of the dry cows within the herd. Across all farms, the average cost of products given per dried cow was $19.57 ± 0.64 (mean ± SE) and ranged from $8.72 to $24.04. As expected, the cost per dried cow was greater ($23.45 ± $0.38) in herds that used higher cost IMM antibiotics as compared with herds that used lower cost IMM antibiotics ($16.64 ± $0.40). When using an algorithm based on udder health records to hypothetically select cows that would be eligible to receive teat sealants only (no antibiotic DCT), eligibility ranged from 27.3% to 93.3% within-herds and varied by parity, milk yield at last test-day, and DIM at dry-off. If a selective DCT program based on udder health records was used, an overall reduction of $5.37 (27% of total costs) per dry cow would be expected. Likewise, adoption of selective DCT based on udder health records would reduce AMU at dry-off by approximately 51%. However, neither of these estimates included potential adverse health complications (such as increased CM) that can occur if selective DCT programs are not effectively performed. Variations in partial direct costs at dry-off were observed among herds based on treatment protocols. In herds that have good udder health management and contagious mastitis pathogens controlled, adoption of selective DCT based on SCC and history of CM can reduce AMU and partial direct costs of dry cow management.

Blanket dry cow therapy (**DCT**) is an udder health management practice adopted by most farms in the United States and consists of administration of longer duration intramammary (**IMM**) antimicrobials in all quarters of all cows that dry off. This practice has been used to treat and prevent subclinical IMM infections during the early dry period. However, the necessity of using blanket DCT has been widely debated due to the emphasis on reducing antimicrobial usage (**AMU**) to avoid accelerating development of antimicrobial resistance (CDC, 2017). Blanket DCT began decades ago due to the high prevalence of IMI and the lack of accurate screening tests to identify cows that would benefit from selective use of antibiotics (Natzke, 1971). With reductions in the prevalence of cows with subclinical IMI and improvements in udder health management practices, selective DCT has been promoted with the overall objective of promoting judicious usage of antimicrobials. Selective DCT programs are based on use of IMM antibiotics to treat cows suspected of having existing IMI while using nonantimicrobial teat sealants to prevent new infections.

Recent clinical trials evaluating the effect of selective DCT on AMU and IMI incidence across the dry period and subsequent lactation have demonstrated promising outcomes (Rowe et al., 2020; McDougall et al., 2022). For example, Rowe et al. (2020) used an algorithm to identify cows that required antibiotic DCT at dry-off based on their history of clinical mastitis (**CM**) and SCC and reported a reduction of 55% in AMU at dry-off without negatively affecting udder health in subsequent lactations. Economic benefits from reducing AMU were estimated to be $7.85 per dry cow (Rowe et al., 2021).

In the United States, most dairy farmers continue to use blanket DCT, but with improvements in udder health management, blanket

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DCT adds unnecessary costs in herds that have good udder health management practices implemented. The purpose of this retrospective observational study was to estimate partial direct costs of DCT using data from 37 dairy herds in Wisconsin and to estimate the potential monetary savings and reductions in AMU in these herds based on adoption of an algorithm-driven selective dry cow program. We hypothesized that in this population of dairy herds, considerable reductions in AMU at dry-off and monetary savings could be achieved by implementing a selective DCT program.

Partial direct costs of blanket DCT and selective DCT were estimated at the cow level using previously collected data from a retrospective, observational study that used animal health records collected from large dairy farms in Wisconsin (Leite de Campos et al., 2021, 2023; Gonçalves et al., 2022). Herd eligibility criteria and descriptive characteristics have been previously described (Leite de Campos et al., 2021). In brief, 40 herds were originally selected based on size (≥250 lactating cows) and availability of animal health records. For this study, data from 37 of the original 40 herds were used based on usage of a common dairy management program (Dairy Comp 305; Valley Agricultural Software, Tulare, CA). Farms were visited once from September 2017 to December 2017 when animal health managers were surveyed about herd characteristics and treatment protocols used at dry-off. Data exported from Dairy Comp 305 included the number of cows dried off, treatment records, monthly milk yield and SCC, and CM history for 1 yr before the herd visit. Items were created in Dairy Comp 305 to obtain SCC and milk yield results from test-days and exported using the following command: EVENTS\2S365I ID BDAT LACT ITEM1 ITEM2 ITEM3 FOR LACT > 0. When records did not specify the dry-off protocol, that information was imputed from responses collected in the survey. Partial direct costs of DCT were estimated using animal health records obtained from a computerized herd management software (Dairy Comp 305; Valley Agricultural Software, Tulare, CA) using the following formula: observed cost per farm = cost per antibiotic tube (if used) × 4 treated quarters + cost per internal sealant (if used) × 4 quarters. We assumed 4 quarters were treated in all cows and did not include labor costs.

Among herds, 6 different IMM antibiotic DCT products, 1 lactating-IMM antibiotic product, and 1 nonantibiotic internal teat sealant were used at dry-off. No injectable antibiotics were administered at dry-off. Sales receipts from all herds were used to calculate a standard price per product. A single price per IMM tube per drug was established using the average price across all herds for each product. The average standard price per IMM tube among all herds was $3.86 for IMM ceftiofur, $2.18 for IMM cephapirin, $2.18 for IMM cloxacillin, $2.50 for an IMM product containing a combination of penicillin G and dihydrostreptomycin, $3.19 for an IMM product containing a combination of penicillin G and novobiocin, $2.78 for IMM cephapirin labeled for lactating cows, and $2.15 for the internal teat sealant. Costs of using IMM drugs were calculated based on the number of tubes used per cow.

Potential monetary savings and differences in AMU among farms were estimated based on the hypothetical adoption of a selective DCT program. Cows were classified as eligible to receive only an internal sealant (no antibiotic DCT) if they had no history of CM and all monthly SCC were <200,000 cells/mL during the lactation that was completed. Cows that did not meet those criteria were assumed to receive both IMM antibiotics and an internal teat sealant (if used on the farm). Antimicrobial usage was calculated using animal daily doses (**ADD**), and a detailed description can be found in Leite de Campos et al. (2021). In brief, a standard ADD was calculated for each IMM antimicrobial product and each DCT tube was defined as 1 ADD (Stevens et al., 2016).

Statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC). PROC MEANS was used to summarize characteristics of cows at dry-off (number of cows, DIM, SCC, and milk yield), dry-off costs, and IMM products, and to describe differences in AMU based on use of a hypothetical selective DCT program. PROC FREQ was used to summarize the distribution of parities (1, 2, and ≥3).

Normality of outcome variables was assessed using PROC UNIVARIATE. Differences in the proportion of cows eligible for selective DCT based on parity were analyzed using an ANOVA. Differences in DIM at dry-off based on eligibility (yes or no) to not receive IMM antibiotics at dry-off were analyzed using PROC MIXED. Differences in milk yield at the last test-day before dry-off based on eligibility for selective DCT were analyzed using PROC MIXED and included parity as a covariate. Differences in partial direct costs per dried cow were compared among IMM drugs and for herds that used blanket DCT or herds that used selective DCT programs using an ANOVA. Farm was included as a random effect in all analyses and differences in the least squares means were adjusted by Tukey's test (SAS, 2013). Statistical analyses were performed only for drugs that were used on ≥5 herds.

Selective DCT programs have been adopted as an option to reduce AMU in farms by identifying eligible cows based on herd records, SCC, or IMI status (Østerås et al., 1999). Herds enrolled in this study had similar characteristics to herds enrolled in previous studies with respect to the use of selective DCT (Rowe et al., 2020) and are representative of large conventional dairy herds in the Midwestern United States. Detailed characteristics of these farms have been previously described (Leite de Campos et al., 2021; Gonçalves et al., 2022). Enrolled farms (n = 37 herds) contained approximately 50,000 lactating cows (Leite de Campos et al., 2023) and dried off 35,691 cows (mean of 965 ± 131 cows per herd) at an average of 338 ± 2 DIM. Daily milk yield and SCC on the last test-day before dry-off were 31.5 ± 0.71 kg of milk per day and 226,110 ± 14,640 cells/mL, respectively (Table 1). Blanket DCT is commonly used on large US dairy farms (USDA–APHIS–VS–CEAH–NAHMS, 2014), and in the herds enrolled in our study, IMM antimicrobial DCT was used on all farms for the treatment of at least one cow (Table 1). The most common treatment protocol used at dry-off was administration of IMM antibiotic DCT and teat sealant in all quarters of all cows (n = 27 herds), followed by usage of a selective DCT program that included use of IMM antibiotics in some cows as well as teat sealant in all dried cows (n = 7 herds) and use of IMM antibiotic DCT only (no sealants) for treatment of all quarters of all cows (n = 3 herds). Among all farms, 89.6% of all cows were dried off using IMM antibiotic DCT combined with teat sealant, 6.3% of cows were dried off using teat sealant only, and 4.1% of the cows were dried off using only IMM antibiotic DCT.

The average partial direct costs per dried cow for cases treated with antibiotic DCT and teat sealant was $20.47 ± 0.02 and ranged from $12.46 to $24.04 per cow. The average partial direct cost per dried cow for cases treated only with IMM antibiotic DCT was $11.54 ± $0.12 and ranged from $8.72 to $15.44. As only one internal teat sealant was reported by all herds, the average stan-

Table 1. Description of the average SCC (cells/mL), milk yield (kg), DIM at dry-off, percent of cows receiving antibiotics with or without internal teat sealant, and partial direct costs of dry cow protocols for 35,691 cows on 37 Wisconsin dairy herds in 1 yr

			Average test-day value before dry-off per farm			Did not receive antibiotics		Partial direct cost per dry cow (US$)[1]		
Farm	Cows dried (n)	Internal teat sealant (yes or no)	SCC (cells/mL)	Milk yield (kg)	DIM	% of dry cows observed	% of dry cows eligible[2]	Observed value[3]	Hypothetical value	Savings per cow per herd[4]
F01	1,836	Yes	166,647	28.7	337	25.3	52.6	19.60	15.19	4.41
F02	329	Yes	118,477	35.6	347	0.0	60.5	23.79	14.63	9.16
F03	431	Yes	464,476	27.3	361	0.0	36.0	17.32	14.18	3.14
F04	1,053	Yes	194,613	32.0	351	2.2	46.3	17.13	13.14	3.99
F05	249	No	131,418	36.7	331	0.0	55.4	10.00	9.22	0.78
F06	556	Yes	194,216	31.4	338	0.0	53.1	18.60	13.29	5.31
F07	323	Yes	104,771	32.0	312	0.0	71.8	24.04	12.95	11.09
F08	1,663	Yes	340,672	28.5	338	0.0	40.3	17.32	13.80	3.52
F09	1,650	Yes	376,065	20.7	341	7.8	31.1	23.46	18.78	4.68
F10	407	Yes	294,489	36.2	340	0.0	49.6	21.69	15.23	6.46
F11	832	Yes	305,299	31.2	346	0.0	44.4	24.00	17.17	6.83
F12	366	Yes	186,260	34.1	329	0.0	61.2	18.52	12.43	6.09
F13	1,353	Yes	329,024	33.7	341	3.7	40.9	23.47	17.34	6.13
F14	292	Yes	213,469	32.5	360	0.0	52.1	17.32	12.78	4.54
F15	533	Yes	181,835	35.3	339	0.0	58.2	23.38	14.78	8.60
F16	450	No	210,933	32.3	354	0.0	58.9	17.16	12.23	4.93
F17	1,441	Yes	169,715	29.1	322	0.0	47.6	17.32	13.17	4.15
F18	782	No	170,829	44.5	327	0.0	72.0	8.72	8.63	0.09
F19	550	Yes	168,580	34.6	351	20.0	59.8	20.89	13.52	7.37
F20	431	Yes	160,508	33.4	322	0.0	49.4	17.57	13.10	4.47
F21	2,407	Yes	155,853	28.5	308	0.0	50.8	24.04	16.20	7.84
F22	3,722	Yes	224,833	25.6	338	0.0	47.3	18.40	13.78	4.62
F23	892	Yes	284,942	29.8	336	0.0	47.8	18.26	13.97	4.29
F24	668	Yes	195,743	30.4	346	1.5	55.2	23.00	15.04	7.96
F25	502	Yes	328,956	24.9	322	0.0	40.4	17.29	13.76	3.53
F26	420	Yes	125,745	31.0	355	0.0	55.2	21.00	14.57	6.43
F27	363	Yes	292,653	32.1	336	0.0	38.8	17.32	13.93	3.39
F28	688	Yes	343,615	28.6	343	0.0	27.3	24.04	19.82	4.22
F29	412	Yes	215,087	38.0	336	0.0	47.6	24.04	16.69	7.35
F30	294	Yes	291,684	32.1	363	0.0	46.6	19.84	14.66	5.18
F31	988	Yes	299,056	34.2	335	0.0	36.0	24.04	18.48	5.56
F32	670	Yes	202,928	28.3	331	0.0	39.1	17.34	13.93	3.41
F33	997	Yes	222,675	37.4	341	0.0	66.7	21.20	12.79	8.41
F34	2,628	Yes	46,375	29.0	323	58.0	93.3	12.27	8.85	3.42
F35	949	Yes	332,555	28.1	347	0.0	45.2	19.53	14.81	4.72
F36	1,055	Yes	127,027	29.0	325	0.0	55.6	24.01	15.43	8.58
F37	2,509	Yes	194,198	27.8	337	0.0	46.7	17.32	13.25	4.07
Mean	965		226,114	31.5	338	15.9	50.8	19.57	14.20	5.37

[1]Partial direct costs per farm divided by the number of cows dried off.

[2]Percentage of dry cows without a history of clinical mastitis or SCC >200,000 cells/mL in the lactation before dry-off.

[3]Observed costs were calculated as the sum of the costs of antibiotics, teat sealant, or both. Hypothetical costs were based on an algorithm using individual cow SCC and clinical mastitis history to select cows eligible to receive nonantibiotic teat sealants (no antibiotics) and were calculated as the sum of the total costs with antibiotics, teat sealant, or both at dry-off.

[4]Difference between the observed minus the hypothetical value.

dard price per IMM tube among all herds was used to estimate the fixed cost of $8.60 per cow ($2.15 per quarter). Although we used sales invoices from farms to estimate product costs, the costs per dried cow for cases treated with blanket DCT and teat sealant were similar to previous studies that estimated costs of DCT using fixed prices for IMM products (Rowe et al., 2020; Hommels et al., 2021).

The overall observed cost per dry cow among all herds was $19.57 ± $0.64 and ranged from $8.72 to $24.04 (Table 1). The average cost per dry cow was $19.48 ± $0.72 for herds that used blanket antibiotic DCT to treat all quarters of all cows versus $19.98 ± $1.56 for herds that used selective DCT ($P = 0.76$). As expected, costs per dry cow varied based on selection of IMM DCT product ($P < 0.001$) and were greater for cows that were treated with IMM ceftiofur hydrochloride ($23.45 ± $0.38) as compared with cows treated with IMM products containing a combination of penicillin G and novobiocin ($20.70 ± $0.42), combination of penicillin G and dihydrostreptomycin ($17.54 ± $0.41), cloxacillin ($16.78 ± $0.48), or cephapirin ($16.64 ± $0.40). The observed costs for herds using selective DCT were numerically slightly greater than costs for herds that used blanket DCT, because those herds tended to use the higher cost product ($P = 0.76$). Herds using selective DCT used higher cost IMM DCT antibiotics, therefore influencing the average partial costs

Table 2. Characteristics of 35,691 dry cows on 37 Wisconsin dairy farms based on eligibility to receive teat sealant only or intramammary antibiotics at dry-off

Variable	LSM	Minimum	Percentile			Maximum	*P*-value
			25th	50th	75th		
DIM at dry-off							<0.001
Eligible for teat sealant only[1]	333.5	304.4	325.3	331.6	338.7	366.5	
Required antibiotics[2]	342.7	310.7	335.2	342.7	353.1	365.8	
Milk yield at last test-day (kg/d)							<0.001
Eligible for teat sealant only[1]	33.7	24.8	31.4	33.3	35.7	44.4	
Required antibiotics[2]	29.6	18.9	26.7	29.1	32.5	44.8	
SCC at last test-day (cells/mL)							<0.001
Eligible for teat sealant only[1]	59,400	22,600	53,900	58,700	65,000	79,200	
Required antibiotics[2]	383,600	86,000	292,500	365,300	498,500	681,800	

[1]No history of clinical mastitis or SCC >200,000 cells/mL in lactation before dry-off.

[2]Had history of clinical mastitis or SCC >200,000 cells/mL in lactation prior to dry-off.

of dry cow treatments per farm. The average price per IMM tube for blanket antibiotic DCT herds was $2.92 ± $0.13, in contrast to $3.33 ± $0.30 for herds that used selective DCT programs. The actual price paid by farmers for each product was used in this study as our objective was to report the observed cost at dry-off at the herd level and to identify factors associated with variation in costs among herds. However, using a standard price for all IMM products ($2.72 per IMM tube and $2.15 per IMM teat sealant), the cost per dry cow would have been $17.69 ± $0.88 for herds that used a selective DCT program versus $18.68 ± $0.44 for herds that used blanket DCT. Variation in partial direct costs was associated with differences in prices paid for IMM DCT antibiotics and use of internal teat sealants. For example, a herd that dried off 1,000 cows per year using the highest cost IMM antibiotic ($3.86 per tube; $15.44 per cow) would pay $6,720 more per year as compared with use of the lowest cost IMM antibiotic ($2.18 per tube; $8.72 per cow). The usage of an internal teat sealant was associated with differences in costs per dry cow and represented approximately 36% of partial direct costs for farmers that used blanket DCT and internal sealants.

Based on use of a hypothetical selective DCT program, the proportion of cows eligible to receive only internal teat sealants was similar to that reported by Rowe et al. (2020). Based on CM and SCC history of the completed lactations, 51% (n = 18,318) of the enrolled cows would have been eligible to receive internal sealants only. The remaining 49% (n = 17,373) either had a CM event (n = 2,211 cows), at least 1 monthly SCC value ≥200,000 cells/mL (n = 9,929 cows), or both (n = 5,233 cows). Using the hypothetical selective DCT program, the proportion of cows eligible to receive only internal teat sealant varied by parity and included more cows in their first lactation as compared with cows in their second and ≥third lactation ($P < 0.001$). Among parity groups, 56.7%, 26.1%, and 17.9% of the first-, second-, and ≥third-lactation cows, respectively, would be eligible to dry off using a nonantibiotic teat sealant. The low proportion of eligible cows in later parities suggests that farmers may consider applying selective DCT algorithms specifically to younger cows.

Cows that were eligible to receive internal teat sealant only produced more milk per day and had lower SCC at the last test as compared with cows that required antibiotic therapy ($P < 0.001$, Table 2). Moreover, cows eligible for internal sealants only were dried off earlier in lactation as compared with cows that required antibiotic therapy ($P < 0.001$, Table 2), which may have been a result of better reproductive performance resulting in conception earlier in lactation. Previous studies have reported that cows in ≥third lactation often represent the greater proportion of cows affected with CM (Oliveira et al., 2013; Green et al., 2002). Occurrence of clinical or subclinical mastitis has been associated with losses in pregnancy (Fuenzalida et al., 2015), potentially increasing DIM. Likewise, lower milk yield should be expected from cows in the "not eligible" group, as they include animals that either had CM or subclinical mastitis (Huijps et al., 2008), both of which are known to reduce productivity.

The data used in this study originated from larger herds in a single state, but characteristics of these herds and treatments are representative of larger herds in the upper Midwest and results should be applicable to herds in this region. Antimicrobials are given to dairy cows for treatment or prevention of bacterial diseases and studies quantifying AMU have reported similar amounts of antimicrobials used to treat lactating cows in small and large herds across a gap of almost 15 yr (Pol and Ruegg, 2007; Leite de Campos et al., 2021). When using a dose-based metric to quantify AMU, the largest share of doses was related to mastitis treatment or prevention. Across all 37 herds, the combined ADD used for IMM treatment at dry-off totaled 280.02 ADD/1,000 cows (mean = 7.6 ± 0.16 ADD per 1,000-cow-d), but if selective DCT programs were used, usage could be reduced to 139.44 ADD/1,000 cows (mean = 3.8 ± 0.16 ADD per 1,000-cow-d), a 51% reduction. Similarly, use of selective DCT programs would reduce average costs at dry-off from $19.57 ± $0.64 to $14.20 ± $0.40, for a savings of $5.37 per dry cow or about $5,550 for the average herd enrolled in our study. One important limitation of this study is that we assumed all herds would be successful in implementing selective DCT and would not experience adverse outcomes such as increased clinical or subclinical mastitis. The decision to use selective DCT should be made in consultation with the herd veterinarian and include training of farm workers in hygienic administration of all IMM products including teat sealants. While the financial savings are relatively small, use of selective DCT programs in appropriate herds would result in considerable reductions in AMU and demonstrate commitment to enhancing antimicrobial stewardship.

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Nonstandard abbreviations used: ADD = animal daily doses; AMU = antimicrobial usage; CM = clinical mastitis; DCT = dry cow antibiotic therapy; IMM = intramammary.