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The Effect of Selective Dry Cow Treatment on New Intramammary Infections

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ABSTRACT

Dry cow therapy, or antibiotic treatment at end of lactation, is used to eliminate intramammary infections and prevent new infections during the dry period. It is one part of a total management system recommended in controlling intramammary infections in the dairy cow. Public health concerns advise prudent use of antibiotics, as their use may promote bacterial antibiotic resistance and leave antibiotic residues in the food chain. The effects of dry cow treatment and no treatment were compared, on new intramammary infections and clinical mastitis within two low cell count herds and two herds undergoing conversion to organic farming. The results will inform those restricting their use of dry cow therapy on the additional risk of new intramammary infection and aid in development of alternative management strategies. No cases of clinical mastitis in the dry period were observed in treated cows, whereas in the untreated groups a significant number were observed. Significantly more new infections at calving were found in the untreated group in all herds. In those quarters where infections were first detected at calving, the incidence of clinical mastitis was significantly greater in the untreated group in all herds. Clinical mastitis detection was significantly lower in organic herds. Untreated quarters infected at drying with *Corynebacterium* spp. or coagulase-negative staphylococci were found to have an increased risk of new infection by *Streptococcus uberis* or coliform bacteria. It can be concluded that dry cow therapy continues to lower significantly the rate of new dry period intramammary infection in herds with elevated somatic cell counts and a high prevalence of infection.
(**Key words:** selective dry cow therapy, intramammary infection, mastitis)

Abbreviation key: CNS = coagulase-negative staphylococci, **IAH** = Institute for Animal Health.

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INTRODUCTION

One of the first applications of the use of antibiotics in the dry or freshening period of the dairy cow was to reduce the incidence of summer mastitis (Pearson, 1950). More persistent formulations of antibiotic, to be used at drying, were developed to give efficacy of several weeks (Smith et al., 1967a,b). Now, dry cow therapy is one part of a total management system recommended to reduce the level of intramammary infection, both by eliminating infections present at drying and by preventing new infections during the dry period (Neave et al., 1966). In the United Kingdom, and elsewhere, this has been adopted within the umbrella of a Five-Point Mastitis Control Plan and dry cow therapy is routinely used on 99% of dairy farms in the United Kingdom. Somatic cell count of farm milk and the incidence of clinical mastitis have been significantly reduced in the United Kingdom and other progressive dairy countries, after the adoption of such management techniques (International Dairy Federation, 1993). A near eradication of mastitis caused by *Streptococcus agalactiae* and a large reduction in mastitis caused by *Staphylococcus aureus* occurs when the program is applied properly (Hillerton et al., 1995). However, concerns have been raised that blanket administration of dry cow therapy is indiscriminate and resulted in an overuse of antibiotics, as a proportion of the cows will be uninfected at drying. Possible major consequences include the development of antibiotic resistance in the bacterial flora of both animal and human populations and an increased risk of antibiotic residues in meat and milk products. Some countries have, therefore, adopted selective use of dry cow therapy on certain cows or quarters only (Bratlie, 1972). The World Health Organization has issued recommendations on reducing the use of antibiotics, and organic or biological farming prohibits the routine use of dry cow therapy (World Health Organization, 1998). Given these concerns and the significant changes in the incidence and etiology of mastitis since the 1960s, it is timely to review the use of dry cow therapy.

This study has evaluated the possible effects of selective dry cow therapy applied to uninfected cows in two low cell count herds and to all cows in two herds undergoing conversion to organic farming, on the new intramammary infection rate and on clinical mastitis postpartum.

MATERIALS AND METHODS

Trial Design

Four herds were recruited, two herds at the Institute for Animal Health (**IAH**) and two herds undergoing conversion to organic status. Cows were assigned, using a random number allocation table, within each herd to a treated or an untreated group. To detect a difference in effect significant at the 5% level with 80% power required 132 cows in each sample group. However, sample size in the organic herds was limited by the period available before conversion to organic status. Treatment was intramammary infusion of Cepravin Dry Cow (Schering Plough, Welvyn Garden City, UK) for both IAH herds and one organic herd and Orbenin Extra (Pfizer Animal Health, Sandwich, UK) for the other organic herd. All cows were dried abruptly at the end of the designated milking. Any cow that had a dry period longer than 16 wk or required medical or surgical intervention within 14 d after calving was excluded from the trial.

Two hundred thirty-six cows were recruited from the IAH herds from January 1999 to March 2000. These herds had an annual rolling bulk milk scc of approximately 150,000 cells per ml. The cows used were either free of IMI or infected only with *Corynebacterium* spp. or coagulase-negative staphylococci (**CNS**) at drying. Fifty-four cows were recruited from the two organic herds from February 1999 to November 1999. Both herds had an annual rolling bulk milk cell count of approximately 250,000 cells per ml. These cows had a variety of infections at drying. All cows had a winter housing period on straw bedding and a summer grazing period on grass. All cows were monitored for at least 100 d after calving and were under natural exposure to infection. Untreated and treated cows were managed as one husbandry group on each farm.

Sampling Procedure

When necessary, the teats of all cows were sampled aseptically by scrubbing using cotton-wool pledgelets in 70% ethanol solution until the pledgelets were no longer visibly dirty. A single 15-ml foremilk sample from each teat was collected according to IDF recommendations (International Dairy Federation, 1981). Samples were taken 1 wk before drying, at drying, within 24-h of calving where possible, and 7 to 14 d after calving. Extra samples were taken if any of the previous samples were not suitable, or for confirmation of infection. Sampling at predrying, drying and postcalving was usually on the same day each week and samples were assayed within 24 h of collection. Samples taken at calving were stored at 3 to 8°C for no more than 3 d until assay. Any samples from external farms were frozen if there was going to be a delay of more than 3 d between sampling and assaying.

Laboratory Examination

Cell counting was carried out on all suitable samples using a Fossomatic 360 machine according to the IDF method (International Dairy Federation (IDF), 1981).

Microbiological examination was performed according to IDF recommendations (International Dairy Federation, 1981). For routine samples 0.05-ml of milk was inoculated onto esculin blood (0.1% esculin, 5% sheep blood) agar. Plates were incubated for 48 h at 35 to 37°C and examined after 24 and 48 h incubation. Bacterial colonies were tentatively identified on gross morphology, and the number and type of colonies were recorded. Appropriate tests were performed on the colonies isolated, where necessary, to identify the pathogens. These included Gram staining, a catalase test to differentiate between streptococci and staphylococci and a tube coagulase test using rabbit plasma to differentiate between coagulase-positive staphylococci, and CNS. All streptococci were further identified using an API 20 Strep (bioMerieux, Marcy, France). Enterobacteriaciae were grown on MacConkey agar (Oxoid, Basingstoke, UK) and were identified using an API E (bioMerieux). *Corynebacterium* spp. were presumptively identified on stimulated growth on 1% Tween 80 supplemented blood agar as *Corynebacterium bovis*. A sample of 20 isolates, provisionally identified as *C. bovis*, were further examined by API Coryne (bioMerieux), which confirmed identification as *C. bovis*. Further isolates of similar gross morphology were assumed to be *C. bovis*. When gross morphology appeared different a proportion of these were examined by API Coryne (bioMerieux) to determine strain type.

Samples from cows with infections showing clinical signs were assayed as above. In addition, 0.05-ml of secretion from the quarter suspected to be clinically infected was inoculated onto esculin blood agar, 5% sheep blood agar and MacConkey agar and incubated as above.

Definitions

When the same pathogen was isolated in two consecutive samples or two out of three samples, or a pathogen came from one milk sample with a scc elevated in comparison to the other quarter cell counts, this was defined as an infection (International Dairy Federation, 1981). An elevated scc was defined as two times greater than that of the other quarters and greater than 200,000 cells per ml.

Clinical mastitis occurred when visible changes in the milk were seen such as watery milk, clots, or flakes and changes in the udder such as swelling or heat. These were either detected by the herdsman or at one of the routine sampling times.

Statistical Analyses

The data were analyzed by using the Minitab statistical computer package (release 12.21, Minitab Inc., Pennsylvania, PA). Logistic regression and χ^2 tests were carried out to determine if there was an effect of treatment on the probability of infection.

RESULTS

Each quarter has been treated as an independent observation in the analyses, consistent with previous investigations on similar topics (Schukken et al., 1993). All trends and significance levels remained when the data were analyzed with the status of individual cows (infected or uninfected) as the unit of study. No differences were found between herds for infection status at calving using logistical regression. All herds were not combined to allow demonstration of any differences between those herds with few or no infected cows at drying and those with more infections at drying. Thus, the results are presented jointly for the two IAH herds and for the two organic herds. A small number of cows had nonfunctioning quarters, accounting for any disparity between cow and quarter numbers. There were no significant differences, for any herd or the two experimental groups, in the infection status at drying for those quarters subsequently uninfected or infected with CNS, *Corynebacterium* spp., or infected with a pathogen. Preliminary analysis by logistic regression of cows with very long dry periods (longer than 16 wk) indicated that they represented a separate subset within the data set and required separate analysis. The prevalence of infections at calving for these animals was significantly higher than for those with a 'normal' dry period of 6 to 10 wk. This was probably due to the longer period of increased exposure to pathogens. Hence they were not included in the analysis.

Quarters Infected During the Dry Period

No cases of clinical mastitis were detected during the dry period in the treated quarters in any of the herds. Significantly more quarters in the untreated groups were found to have clinical mastitis in the dry period in both the IAH and the organic herds (7 of 499 quarters, $P = 0.012$ and 7 out of 172 quarters, $P = 0.05$, respectively, Table 1). All clinical cases during the dry period were caused by *Streptococcus uberis*, although one quarter had a mixed infection of *S. uberis* and *Arcanobacterium pyogenes*. Two cows from the IAH herds were removed from the herd during the dry period, after having clinical mastitis. All infections during the dry period were treated with a short acting intramammary antimicrobial preparation. These quarters were still included in the data on infection status at calving.

Quarters Infected at Calving

There were significantly more new IMI at calving in the untreated versus treated groups, 58 versus 19 quarters, respectively, for the IAH herds ($P < 0.001$), and 38 versus no quarters, respectively, for the organic herds ($P < 0.0001$) (Table 2).

Of those quarters infected at drying in the organic herds, 16 were in the untreated group and 11 were in the treated group. None of the quarters infected at drying were observed as having clinical mastitis during the dry period. Ten infected (all Gram positive) quarters in the untreated group were still infected at calving with the same pathogen, including two that had also become additionally infected with *S. uberis* and one that had a coliform infection instead of the original infection. In the treated group, 25% of the *Staphylococcus aureus* infections had resolved and all the other infections (*S. uberis*) appeared cured by the dry cow treatment.

Pathogen Type in Quarters Infected at Calving

The predominant organism causing the new infections at calving, in both sets of herds, was *S. uberis* (Table 3). In the IAH herds, the second highest number of new infections at calving was caused by coliform bacteria. The number of new coliform infections did not differ significantly between the treated and untreated groups.

In the organic herds, 13 new *S. aureus* infections were observed at calving. This was significantly more both as a proportion of quarters infected at calving ($\chi^2 = 5.98$, $P = 0.015$) and as a proportion of total quarters in the untreated group ($\chi^2 = 14.96$, $P < 0.001$) than the IAH herds. Cows had been dried with *S. aureus* infections in both the treated and untreated groups in the organic herds.

Two cows in the IAH herds had mixed infections at calving, one with *S. uberis* and *A. pyogenes* and the

Table 1. Quarters detected with clinical mastitis during the dry period for untreated and treated groups in the Institute for Animal Health (IAH) and organic herds.

	IAH Herds			Organic herds		
	Clinical cases during the dry period			Clinical case during the dry period		
	No. of quarters					
	No	Yes	Total	No	Yes	Total
Treated group	443	0[a]	443	144	0[b]	144
Untreated group	492	7[a]	499	165	7[b]	172
Total	935	7	942	309	7	316

[a]$\chi^2 = 6.26$, $P = 0.012$.
[b]$\chi^2 = 5.99$, $P = 0.05$.

other with *S. aureus* and *Streptococcus dysgalactiae*. Similarly, two cows in the organic herds had mixed infections, one with *S. uberis* and *A. pyogenes* and the other with *S. aureus* and *S. uberis*. These infections have been included in both rows accounting for the discrepancy in percentage totals.

Prevalence of CNS and *Corynebacterium* spp. at Calving

The percentage of quarters infected with CNS at calving was not significantly different between the treated and untreated groups in the IAH and organic herds (Table 4).

There were statistically significant differences between the prevalence of infection by *Corynebacterium* spp. at calving for the treated and untreated quarters in both the IAH and organic herds ($P < 0.001$). The prevalence of *Corynebacterium* spp. at calving may have been underestimated as identification of *Corynebacterium* spp. was not always possible when there was a profuse growth of staphylococci, streptococci, or coliforms. Some quarters that were treated either during the dry period, or at calving, may also have eliminated *Corynebacterium* spp. infections present at drying. There was a low, natural cure rate for *Corynebacterium* spp. infections during the dry period (Tables 5 and 6).

In the untreated groups in the IAH herds, 70.1% of the quarters infected at drying with *Corynebacterium* spp. were still infected at calving, 1.2% became infected with CNS, and 23% were infected with *S. aureus*, streptococci, or coliforms or had been treated due to a clinical mastitis episode. In 5.7% of previously infected quarters, *Corynebacterium* spp. was not detected at calving. In the untreated groups in the organic herds, 46.2% of the quarters infected at drying with *Corynebacterium* spp. were still infected at calving, 5% were infected with CNS, and 35% of quarters were infected with *S. aureus*, streptococci, coliforms, or had been treated due to a clinical mastitis episode in the dry period. Some 13.8% of quarters were no longer infected with *Corynebacterium* spp. at calving. In the treated group 1.6% of quarters were still infected at calving with *Corynebacterium* spp. in the IAH herds and 11.8% of quarters were still infected at calving in the organic herds.

Risk Factors for Quarters with CNS and *Corynebacterium* spp.

Untreated quarters with a CNS infection present at drying had a 4.2 greater risk of a new *S. uberis* infection at calving ($P = 0.05$) and a 4.7 times greater risk of a new coliform infection at calving ($P = 0.05$) than untreated uninfected quarters in IAH herds (Table 7). Untreated quarters, that had a *Corynebacterium* spp. infection at drying had a 5.0 times greater risk of a new infection with *S. uberis* than uninfected quarters (not significant) and a 3.2 times greater risk of a new coliform infection

Table 2. Quarter infection status at calving for the Institute for Animal Health (IAH) and organic herds.

	IAH herds			Organic herds		
	No new infections	New infections	Total	No new infections	New infections	Total
	No. of quarters					
Treated group	424	19[a]	443	144	0[b]	144
Untreated group	433	58[a]	491	134	38[b]	172
Total	857	77	934	278	38	316

[a]$\chi^2 = 17.43$, $P < 0.001$.
[b]$\chi^2 = 36.16$, $P < 0.0001$.

Table 3. Prevalence by pathogen type for quarters with new infections at calving (percentage of total quarters) for the Institute for Animal Health (IAH) and organic herds.

	IAH herds				Organic herds			
Pathogen type	Treated group	%	Untreated group	%	Treated group	%	Untreated group	%
Staphylococcus aureus	1	0.2	7	1.4	0	0	12	7.0
Streptococcus uberis	6	1.3	32	6.5	0	0	16	9.3
Streptococcus dysglactiae	0	0	3	0.6	0	0	5	2.9
Coliforms	11	2.4	12	2.4	0	0	2	1.1
Arcanobacterium pyogenes	1	0.2	2	0.4	0	0	1	0.6
Mixed infections	0	0	2	0.4	0	0	2	1.1
Total	19	4.1	58	11.8	0	0	38	22

than uninfected quarters (not significant) at calving in the IAH herd. In the organic herd, the risks for those quarters infected with *Corynebacterium* spp. at drying off were 2.2 times greater for a new *S. uberis* (not significant), although for one herd this figure was 3.92 times greater and the other organic herd had a high incidence of *Corynebacterium* spp. at drying. The new coliform infections in the organic herds at calving were too few to calculate risk factors for either *Corynebacterium* spp. or CNS infected quarters at drying. For new *S. aureus* infections, an increased risk factor of 2 times was observed for quarters infected with CNS at drying in the untreated IAH group (not significant). No difference in risk factors for new *S. aureus* at calving was seen for quarters infected with *Corynebacterium* spp. at drying in either of the IAH or organic untreated groups. However, the number of new infections in both groups of herds was low.

Treated quarters in the IAH herds did not show the same risk factors. Quarters infected with *Corynebacterium* spp. at drying had a 1.8 times greater risk of an infection with a new *S. uberis* at calving and quarters infected with CNS at drying had a 1.2 times greater risk of an infection with a new *S. uberis* than uninfected quarters. The number of new coliform infections at calving was low and risk factors were near to one for both *Corynebacterium* spp. infected quarters and CNS infected quarters compared with uninfected quarters.

Clinical Incidence

In those quarters with infections detected at calving, the incidence of subsequent clinical mastitis in the 3 mo after calving was significantly different between untreated and treated quarters in both the IAH herds and the organic herds [33 cases in untreated quarters compared with 12 in treated quarters ($P = 0.004$) and 8 cases in untreated quarters compared with 0 in treated quarters ($P = 0.009$) respectively, Table 8]. There was no significant difference in detection rates of clinical mastitis in the treated and untreated groups at IAH for those quarters infected at calving. Detection of clinical mastitis varied according to pathogen type and between herds. However, there was a significant difference between the detection rates for the IAH herds and the organic herds ($\chi^2 = 13.62$, $P < 0.001$). For *S. aureus* infections, 85.7% were detected as clinical mastitis by IAH farm staff, compared with 8.9% in the organic herds. The organic herds also had a higher prevalence of *S. aureus* infections at drying that had not been detected as clinical mastitis in the previous lactation. For *S. uberis* infections, all those in the treated group were detected as clinical mastitis for IAH herds, 46.8% detected in the untreated group for the IAH herds, and 25% in the organic herds. Some 66.7% of the *S. dysgalactiae* infections in the IAH herds were detected as clinical mastitis but only 20% in the organic herds. The rate of detection of the coliform infections becoming

Table 4. Prevalence of *Corynebacterium* spp. and coagulase-negative staphylococci (CNS) in quarters at calving for the Institute for Animal Health (IAH) and organic herds (percentage of total quarters).

	IAH herds				Organic herds			
Pathogen type	Treated group	%	Untreated group	%	Treated group	%	Untreated group	%
Corynebacterium spp.	1[a]	0.2	61[a]	12.4	9[b]	6.2	49[b]	28.5
CNS	38	8.5	36	7.3	5	3.4	7	4.1

[a]$\chi^2 = 49.40$, $P = < 0.001$.
[b]$\chi^2 = 18.31$, $P = < 0.0001$.

Table 5. Prevalence of *Corynebacterium* spp. at drying off and subsequent infection status of these quarters at calving for the Institute for Animal Health (IAH) herds.

	Treated quarters	% of treated quarters	Untreated quarters	% of untreated quarters
Total infected at drying off	63	14.2	87	17.4
No. not infected at calving	52	82.5	5	5.7
No. infected with CNS[1]	9	14.3	1	1.2
No. infected with other pathogen or treated	1	1.6	20	23
No. infected at calving	1	1.6	61	70.1

[1]Coagulase-negative staphylococci.

clinical mastitis ranged from 50% in the organic herds to 54.5% in the treated IAH group, and 58.3% in the untreated IAH group.

DISCUSSION

There was a significant difference between the incidence of clinical mastitis during the dry period for the untreated and the treated groups, with all cases caused by *S. uberis*. Previous work has also found high levels of infection due to *S. uberis* during the dry period but have rarely differentiated between infected quarters and those also showing clinical signs (Eberhart and Buckalew, 1972; Hassan et al., 1999; Neave et al., 1950; Oliver and Mitchell, 1983; Pearson, 1948; Smith et al., 1966; Woolford et al., 1998).

The incidence of clinical mastitis in the dry period for the IAH herds was 1.5% of untreated quarters and for the two organic herds averaged 4% of untreated quarters. For the IAH herds and one organic herd, this quarter incidence was lower than the 4% of quarters in the Dutch studies and the 6% of quarters in the Australian studies (Hassan et al., 1999; Schukken et al., 1993). However one organic herd, the smallest on trial, accounted for more than 70% of the dry period clinical cases. This herd had had problems with mastitis during the dry period previously and diligently checked the dry cows, perhaps accounting for the higher detection rate. Clinical mastitis in the IAH herds was only detected in the initial 4 mo of the study period perhaps because IAH farm staff had concerns over the impact of untreated cows during the initial phases. A study on selective dry treatment in a large dairy herd in California reported that clinical signs of mastitis were not detected during the dry period or at calving (Berry et al., 1997), but observation of dry cows was infrequent. In the UK, observation of dry cows in large dairies is often limited to a daily inspection and cows are rarely examined, especially in the early dry period. Only in those farms where and when there is a high incidence of summer mastitis are cows examined more often. This may explain the variation in clinical mastitis levels for the dry period between the four herds studied in this trial and those in previous work. With relatively little effort in three herds to detect clinical mastitis, there was still a significant difference between treated and untreated quarters, emphasizing the protective effect of dry cow therapy against clinical mastitis during the dry period.

There were significantly more new infections at calving in the untreated group compared with the treated group, in both the IAH herds and the organic herds, with more than 50% of the new infections caused by *S. uberis*. This is similar to previous reports on the incidence of new infections and prevalence of *S. uberis* in the dry period (Eberhart and Buckalew, 1972; Neave et al., 1950; Oliver and Mitchell, 1983; Pearson, 1948; Smith et al., 1966; Woolford et al., 1998). It is also not surprising as cows were housed on straw over the winter with a summer grazing period. The nonlactating

Table 6. Prevalence of *Corynebacterium* spp. at drying off and subsequent infection status of these quarters at calving for the organic herds.

	Treated quarters	% of treated quarters	Untreated quarters	% of untreated quarters
Total infected at drying off	76	55.4	80	51.4
No. not infected	61	80.3	11	13.8
No. infected with CNS[1]	6	7.9	4	5
No. infected with other pathogen or treated	0	0	28	35
No. infected at calving	9	11.8	37	46.2

[1]Coagulase-negative staphylocci.

Table 7. Infection status at drying for those quarters infected with *Streptococcus uberis*, *Staphylococcus aureus*, or coliforms at calving.

	Treated quarters				Untreated quarters			
Dry status	Not infected at calving	Infected with *S. uberis* at calving	Infected with coliforms at calving	Infected with *S. aureus* at calving	Not infected at calving	Infected with *S. uberis* at calving	Infected with coliforms at calving	Infected with *S. aureus* at calving
IAH herds								
Not infected	318	4	8	0	341	14	5	5
CNS[1]	62	2[a]	1	1	29	5[c]	2[e]	1[g]
Corynebacterium bovis	44	2[b]	1	0	63	13[d]	3[f]	1
Organic herds								
Not infected	54	0	0	0	58	4	0	6
CNS	2	0	0	0	5	1	0	0
C. bovis	76	0	0	0	60	9[h]	1	6

[a]1.8 times greater risk, [b]1.2 times greater risk, [c]4.2 times greater risk, [d]5 times greater risk, [e]4.7 times greater risk, [f]3.2 times greater risk, [g]2 times greater risk, [h]2.2 times greater risk.

[1]Coagulase-negative staphylococci.

udder is highly susceptible to certain infections and 50% of IMI acquired during the dry period will persist into the next lactation if not eradicated by appropriate treatment (Cousins et al., 1979). During the dry period new infection rates are highest in the early dry period, lowest when involution is complete, and increase again as parturition approaches (Cousins et al., 1979; Oliver and Mitchell, 1983; Smith et al., 1985). The significantly lower rate of infection, both at calving and due to *S. uberis* in the treated quarters, highlights the importance of dry cow therapy for preventing new infections during the early dry period. This applies both to herds with a low cell count and a low prevalence of infection, and those with a higher cell count and more cows infected at drying.

There were significantly more new infections at calving caused by *S. aureus* in the untreated organic group than in the untreated IAH group. There were no new infections due to *S. aureus* in the treated organic group and only 0.2% of quarters in the treated IAH group had new infections. This highlights the efficacy of dry cow therapy in preventing new *S. aureus* infections in the dry period. Both organic herds had a higher number of cows dried with one or more quarters infected with *S. aureus*, so there was a high exposure to this organism both from the cow and from other cows in the herd. Previous work had assumed that the primary challenge from *S. aureus* came from cross contamination at milking preceding drying (Browning et al., 1990). It is still not completely clear whether this is the main cause or whether the challenge is during the dry period from the cow herself and other cows within the herd. Studies on the prevalence of *S. aureus* in heifers have demonstrated higher levels in heifers at calving in herds where there is a higher prevalence of *S. aureus* in the cows (Fox et al., 1995; Hillerton et al., 1995; Nickerson et al., 1995). These heifers had not been milked and it indicated that the challenge was from within the herd. This study confirms previous work that indicated that contagious bacteria, especially *S. aureus*, are likely to establish more new infections in those herds where they

Table 8. Incidence of clinical mastitis in those quarters infected at calving (as percentage of infections present at calving).

	IAH[1] herds				Organic herds			
Pathogen	Treated group	As % of infections at calving	Untreated group	As % of infections at calving	Treated group	As % of infections at calving	Untreated group	As % of infections at calving)
Staphylococcus aureus	0	0	6	85.7	0	0	1	7.7
Streptococcus uberis	6	100	15	46.8	0	0	4	25
Streptoccus dysgalactiae	0	0	2	66.7	0	0	1	20
Coliforms	6	54.5	7	58.3	0	0	1	50
Arcanobacterium pyogenes	0	0	1	50	0	0	0	0
Mixed infections	0	0	2	100	0	0	1	50
Total	12	63.1	33[a]	56.8	0	0	8[b]	21.6

[a]χ^2 = 8.18, P = 0.004.

[b]χ^2 = 6.91, P = 0.009.

[1]Institute for Animal Health.

are prevalent (Eberhart and Buckalew, 1972; Neave et al., 1950; Postle and Natzke, 1974).

With an increasing interest in organic farming and many new control measures concentrating on prevention of environmental pathogens, control of *S. aureus* in the dry period is important. The poor cure rate in older cows has led to the suggestion of culling infected cows especially those older than parity 5 at drying, if this was economically acceptable (Browning et al., 1994; Österås et al., 1999; Sol et al., 1997b). The situation is more complicated and a decision to cull has to take into account the genetic merit of the cow and the potential gain in milk value in relation to quality milk payment bands (Stott et al., 2000).

In the organic herds, there was no spontaneous cure of *S. aureus* in the untreated group and a 25% cure in the treated group. Many of the infections present at drying in the organic herds were in older cows with high cell counts, accounting for the low cure rate. Infections by *S. aureus* are known to be difficult to cure, especially in older cows, those with a higher cell count and multiple quarters infected (Sol et al., 1994, 1997a). Although there is a lower efficacy of dry cow therapy in curing *S. aureus* infections compared with other pathogens, it is still generally accepted as more effective than lactation therapy (Schultze, 1983).

There was a significant difference between the treated and untreated groups in the clinical incidence of mastitis in early lactation, in those quarters infected at calving. Significant differences in clinical incidence between treated and untreated quarters have been recorded in previous studies but the length of the postcalving period has varied making comparisons difficult (Hogan et al., 1994; Williamson et al., 1995; Österås and Sandvik, 1996). In contrast, no difference in clinical incidence was observed between treated and untreated cows in a California study (Berry et al., 1997). This study compared clinical incidence over the first 120 d of lactation, clinical signs of mastitis were not detected during the dry period or at calving and no attempt was made to identify when the initial infection occurred.

There was no significant difference in the detection rate for clinical mastitis between the groups in the IAH herds but there was a significant difference between the organic and IAH herds. On one organic farm, the herdsman detected no infections and any infections were observed only at routine sampling times. This herd also reported little clinical mastitis during the dry period. Reasons for the lower detection in lactation, may include that routine foremilking was not carried out and more stringent withhold periods after antibiotic treatment for organic milk are applied.

No statistically significant differences were found in the prevalence of *Corynebacterium* spp. or CNS at drying between the treatment groups. There was no statistically significant difference in the prevalence of CNS postcalving between the treated and untreated groups. This is not unexpected as CNS are part of the normal flora of the skin and are commonly isolated from milk.

In the untreated group for all herds, significantly more *Corynebacterium* spp. infections persisted through the dry period than in the treated group. It is possible that new infections of *Corynebacterium* spp. may have occurred between the two postcalving sampling points; however, sampling routines for all groups were similar making comparisons valid.

Of the quarters infected by *Corynebacterium* spp. at drying, 98.4% of quarters in the IAH herds and 88.2% of quarters in the organic herds were cured by dry cow therapy. Dry cow therapy has been shown previously to be highly effective against these infections and a high incidence of *C. bovis* at calving is taken as an indication that dry cow therapy has not been properly applied (Bramley et al., 1976; Harmon et al., 1984; Hogan et al., 1994).

Spontaneous cure rates of these infections appear low in this study. Of quarters in the IAH untreated group previously infected by *Corynebacterium* spp., some 23% were infected with another pathogen, 70.1% were still infected with *Corynebacterium* spp. group, 35% became infected with another pathogen, and 46.2% were still infected with *Corynebacterium* spp. in the organic group at calving. Natural cure rates reported for *Corynebacteria* spp. during the dry period in untreated quarters have varied from 52.4 to 63.9% (Hogan et al., 1994; Harmon et al., 1984). More than 40% of *C. bovis* infections are associated with the streak canal (Honkanen-Buzalski and Bramley, 1984). This may be associated with the apparent low rate of growth of these bacteria in dry cow secretions attributed to a high rate of spontaneous elimination during the dry period (Oliver and Juneja, 1990).

Previously, the effect on the rate of new and additional infections, for quarters with existing infections by *Corynebacterium* spp. or CNS, has only been considered for infections occurring during lactation (Bramley and Neave, 1975; Hogan et al., 1988; Honkanen-Buzalski et al., 1984; Lam et al., 1997; Matthews et al., 1991; Rainard and Poutrel, 1988). In one selective dry cow trial, the prevalence of *C. bovis* at drying had no effect on the new rate of infection determined at calving but it was unclear whether this was in treated or untreated quarters (Rindsig et al., 1978).

In this study, no protective effect by *Corynebacterium* spp. or CNS was seen against new coliform or *S. uberis* infections during the dry period. Untreated quarters infected with *Corynebacterium* spp. or CNS at drying had a 2.2 to 5.0 times greater risk of acquiring a new coliform or *S. uberis* infection during the dry period. While the number of new *S. aureus* infections in the dry period was low, an increased risk factor of 2.0 times for CNS infected quarters was observed but there was no difference for quarters infected with *Corynebacterium* spp. The effect against *S. aureus* agrees with Australian work (Hassan et al., 1999). It may be that the presence of *Corynebacterium* spp. or CNS infections during the dry period interferes with the formation of a teat seal or aids in the acquisition of essential nutrients for the establishment of infection. Cows that received dry cow therapy had earlier closure of the teat canal by a keratin seal. Possibly bacterial enzymes from any existing bacterial colonization may impede occlusion of the teat canal lumen by keratin (Williamson et al., 1995). Dry cow therapy may resolve any teat canal or teat sinus infections thus increasing the rate of teat closure.

This study showed that dry cow therapy reduced the rate of new infection by approximately 80% and eliminated more existing infections than by spontaneous cure. This is similar to the original work on dry cow therapy (Smith et al., 1967a,b). The difference is that here new infections by *S. uberis* were prevented in herds with a low prevalence of *S. aureus*. In the 1980s, the main effect was in preventing new infections by *S. aureus* in herds with a high prevalence of *S. aureus*. Whatever the main pathogen, dry cow therapy reduces the new infection rate by approximately 80%.

CONCLUSIONS

Application of dry cow therapy compared with an untreated control significantly reduced the incidence of new intramammary infections both during the dry period and at calving. This was apparent in the two low cell count, broadly uninfected, herds and the two organic herds that had a higher prevalence of infections at drying and a higher cell count. The clinical incidence in those quarters infected at calving was also significantly lower for the treated groups in the subsequent lactation. The predominant pathogen isolated from infections was *S. uberis* although the prevalence of *S aureus* on the organic farms was also significantly higher.

There appeared to be no protective effect of infections by *Corynebacterium* spp. or CNS in untreated quarters against *S. aureus* and for infection by *S. uberis* or coliforms and increased susceptibility was observed.

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