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Intramammary infections in heifers during early lactation following intramammary infusion of pirlimycin hydrochloride or penicillin-novobiocin at the first milking after parturition

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A study was conducted to determine whether intramammary antibiotic treatment of heifer mammary glands following the first milking after calving was effective for reducing the percentage of mammary quarters infected during early lactation. Jersey and Holstein heifers from two research herds were assigned to one of three treatment groups: (1) no intramammary infusion following the first milking after parturition, (2) intramammary infusion of all quarters with pirlimycin hydrochloride following the first milking after parturition and (3) intramammary infusion of all quarters with novobiocin sodium plus penicillin G procaine following the first milking after parturition. Almost 93% of Jersey heifers (40/43) and 73·1% of quarters (125/171) were infected at the first milking. Almost 77% of quarters (33/43) were cured following treatment with pirlimycin, 61·8% (21/34) were cured following treatment with penicillin-novobiocin and 39·6% (19/48) of infections were eliminated spontaneously in the untreated control group. Significantly fewer infections were observed in pirlimycin or penicillin-novobiocin treated mammary glands of Jersey heifers during early lactation than in untreated control mammary glands. Almost 89% of Holstein heifers (32/36) and 52·8% of quarters (76/144) were infected at the first milking. About 57% (12/21) of quarters were cured following treatment with pirlimycin, 41·4% (12/29) were cured following treatment with penicillin-novobiocin and 23·1% (6/26) of infections were eliminated spontaneously in the untreated negative control group. Significantly fewer infections were observed in pirlimycin treated mammary glands of Holstein heifers during early lactation than in untreated control mammary glands. However, no significant differences were observed following penicillin-novobiocin treatment of Holstein heifers after the first milking of lactation compared with untreated control quarters. Coagulase-negative staphylococci, *Streptococcus uberis* and *Streptococcus dysgalactiae* subsp *dysgalactiae* were isolated most frequently in heifers from both herds.

Keywords: Heifer, mastitis, intramammary infection, calving, parturition.

Numerous studies (Oliver & Mitchell, 1983; Oliver et al. 1992; Smith et al. 1994; Fox et al. 1995; Nickerson et al. 1995; Oliver et al. 1997) have shown that intramammary infections (IMI) in pregnant heifers during the periparturient period occur frequently. Some of these infections persist for long periods of time, are associated with elevated somatic cell counts (SCC), and may impair mammary gland development and affect lactational performance (Trinidad et al. 1990a; Hallberg et al. 1995; Oliver et al. 2003). Research on methods for controlling mastitis in heifers has shown that *prepartum* treatment of heifer mammary glands is an effective method of reducing the percentage of heifers and mammary quarters infected with mastitis pathogens during early lactation. Trinidad et al. (1990b) demonstrated that intramammary infusion of a nonlactating antibiotic preparation containing penicillin and dihydrostreptomycin into breeding-age and

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primigravid heifers during different trimesters of pregnancy was effective in reducing the prevalence of mastitis and SCC at parturition. Oliver et al. (1992, 1997, 2004) demonstrated that *prepartum* intramammary infusion of heifer mammary glands with cephapirin sodium, sodium cloxacillin, pirlimycin hydrochloride, or novobiocin sodium plus penicillin G procaine 1–2 weeks before expected calving was an effective procedure for eliminating many infections in heifers during late gestation. Another study (Oliver et al. 2003) showed that *prepartum* intramammary infusion of heifer mammary glands reduced the prevalence of mastitis in heifers both during early lactation and throughout lactation. Oliver et al. (2003) also reported that *prepartum* antibiotic-treated heifers produced significantly more milk and had significantly lower SCC scores than untreated control heifers. These observations are probably associated with or due to the lower prevalence of mastitis pathogen isolation in *prepartum* antibiotic-treated heifers throughout lactation.

This strategy, however, involves treatment of heifers during the *prepartum* period at a time when animals usually do not receive dairy worker attention. Thus, *prepartum* therapy would be an additional step in the management of heifers, and also might require restraining facilities for safe treatment that may not be readily available. A more 'user friendly' approach would probably benefit the majority of dairy producers that are interested in controlling mastitis in heifers, and this might enhance adoption of techniques shown to be effective for controlling mastitis in heifers. The objective of this study was to determine the efficacy of intramammary antibiotic therapy of heifer mammary glands following the first milking after parturition on intramammary infections during early lactation.

Materials and Methods

Pregnant Jersey heifers (n=43) from The University of Tennessee Dairy Research and Education Center dairy research herd, Lewisburg TN, USA and pregnant Holstein heifers (n=36) from the East Tennessee Research and Education Center dairy research herd, Knoxville TN, USA were used. Heifers on each dairy were assigned to blocks with each block containing 3 heifers. Heifers were blocked by expected date of calving. Treatment groups were: (1) no intramammary infusion following the first milking after parturition, (2) intramammary infusion of all mammary quarters with a lactating cow antibiotic preparation containing 50 mg pirlimycin hydrochloride (Pirsue™, Pfizer Animal Health, Kalamazoo MI, USA) following the first milking after parturition and (3) intramammary infusion of all mammary quarters with a lactating cow antibiotic preparation containing 150 mg novobiocin sodium plus 100 000 i.u. penicillin G procaine (Albacillin™, Pfizer Animal Health) following the first milking after parturition. Milk withhold times for pirlimycin hydrochloride and penicillin-novobiocin are 36 h and 72 h after last treatment, respectively. Milk from antibiotic-treated heifers was discarded for 72 h after treatment.

Duplicate samples of mammary secretion were collected aseptically at the first milking after calving. Single foremilk samples were collected aseptically at 7, 14 and 30 d after calving. All samples were collected immediately before regular milking using standard procedures described by the National Mastitis Council (Hogan et al. 1999). Before sample collection, teats were dipped in a premilking teat disinfectant, cleaned thoroughly, dried with individual disposable paper towels, and teat ends were sanitized with swabs containing 70% isopropyl alcohol.

Milk samples were examined following procedures described by the National Mastitis Council (Hogan et al. 1999). Samples of mammary secretion (10 µl) from each mammary gland were plated onto one quadrant of a trypticase soy agar plate supplemented with 5% defibrinated sheep blood (Becton Dickinson and Company, Franklin Lakes NJ, USA). Plates were incubated at 37 °C, and bacterial growth was observed and recorded at 24-h intervals for 3 d. Bacteria on primary culture medium were identified tentatively according to colony morphologic features, haemolytic characteristics, Gram stain reaction and catalase test. Isolates identified presumptively as staphylococci were tested for coagulase production by the tube coagulase method. Isolates identified presumptively as streptococci were evaluated initially for growth in 6·5% NaCl, hydrolysis of aesculin and sodium hippurate and CAMP reaction. Streptococcal organisms were identified to the species level using the API 20 Strep system (bioMerieux Inc., Durham NC, USA) and a streptococcal agglutination system (Streptex, Remel, Lenexa KS, USA). Gram-negative isolates were identified to the species level using the following biochemical tests: triple sugar iron, urea, oxidase, motility, indole and ornithine decarboxylase and by the API 20 E identification system (bioMerieux Inc.).

A quarter was considered infected at the first milking after calving if the same pathogen was isolated from duplicate samples. If one of the duplicate samples contained a mastitis pathogen and the other duplicate sample did not, that mammary quarter was considered uninfected. A quarter was considered infected during early lactation if the same organism isolated at the first milking after calving was obtained at 7, 14 or 30 d after calving. A previously uninfected mammary gland was considered newly infected if the same pathogen was isolated from two consecutive samples during the experimental period. A bacteriological cure was defined as an infection observed at the first milking after calving that was negative for the presence of previously identified bacteria at 7, 14 and 30 d after calving. Treatment comparisons within herd were done using Pearson's chi square test (SAS release 8.02, SAS Institute Inc., Cary NC, USA).

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Table 1. Influence of antibiotic treatment of Jersey heifer mammary glands after the first milking of lactation with pirlimycin hydrochloride or penicillin/novobiocin on intramammary infections during early lactation

Parameter	Control	Pirlimycin	Penicillin/novobiocin
Number of heifers treated	15	15	13
Number of quarters treated	60	59	52
Calving			
Number (%) of heifers infected	15 (100)	15 (100)	10 (77)
Number (%) of quarters infected	48 (80)	43 (73)	34 (65)
Number of mixed quarter IMI†	13	7	7
Total number of IMI‡	61	50	41
Early lactation			
Number (%) of heifers infected	14 (93)	7 (47)	7 (54)
Number (%) of quarters infected	29 (48)	10 (17)	13 (25)
Quarters newly infected	5§	0	2
IMI calving – early lactation	25§	10	11
Total number of IMI	31	10	13
Number of mixed quarter IMI	2	0	0
Percentage cure rate	39·6[a]	76·7[b]	61·8[b]

† More than one mastitis pathogen isolated from milk sample
‡ Total number of infections = number of mammary quarters infected plus the number of mixed quarter IMI
§ Quarters newly infected and persistent IMI from calving to early lactation do not equal the number of quarters infected (29) because one quarter was persistently infected from calving and also developed a new infection
[a,b] Cure rates for treatments that share the same superscript are not significantly different at the 5% significance level

Results

Almost 93% of Jersey heifers (40/43) and 73·1% of quarters (125/171) were infected at the first milking after parturition. Of the mammary quarters infected at parturition, 76·7% (33/43) were cured following treatment with pirlimycin, 61·8% (21/34) were cured following treatment with penicillin-novobiocin and 39·6% (19/48) were eliminated spontaneously in the untreated negative control group (Table 1). Significantly fewer infections were observed in pirlimycin or penicillin-novobiocin treated mammary glands of Jersey heifers during early lactation than in untreated control mammary glands.

Almost 89% of Holstein heifers (32/36) and 52·8% of quarters (76/144) were infected at the first milking after parturition. Of the mammary quarters infected at parturition, 57·1% (12/21) were cured following treatment with pirlimycin, 41·4% (12/29) were cured following treatment with penicillin-novobiocin and 23·1% (6/26) were eliminated spontaneously in the untreated negative control group (Table 2). Significantly fewer infections were observed in pirlimycin treated mammary glands of Holstein heifers during early lactation than in untreated control mammary glands. However, no significant differences in infections during early lactation were observed following penicillin-novobiocin treatment of Holstein heifers after the first milking of lactation compared with untreated control quarters.

Mastitis pathogens causing IMI in heifers are presented in Tables 3 and 4. Coagulase-negative staphylococci (CNS) and Streptococcus species, primarily *Str. uberis* and *Str. dysgalactiae* subsp *dysgalactiae*, were isolated most frequently in heifers from both herds. Of the IMI observed in Jersey heifers at the first milking after calving, CNS accounted for 60·5%, *Streptococcus* species 32·2%, *Escherichia coli* 3·9%, and *Staphylococcus aureus* 3·3% (Table 3). Of the IMI observed in Holstein heifers at the first milking after calving, CNS accounted for 65·4%, *Streptococcus* species 14·8%, Gram-negative mastitis pathogens 11·1%, *Bacillus* species 4·9% and *Staph. aureus* 3·7% (Table 4). Percentage of samples with CNS throughout the experimental period was consistently lower in antibiotic-treated heifer mammary glands than in untreated controls in both Jersey and Holstein heifers. *Str. uberis* was isolated frequently from the herd with Jersey heifers while Gram-negative mastitis pathogens were isolated more frequently in the herd with Holstein heifers (Tables 3 and 4).

Discussion

Intramammary infections in heifers during the periparturient period are much higher than previously thought. In the present study, 93% of Jersey heifers and 73% of mammary quarters, and 89% of Holstein heifers and 53% of mammary quarters were infected at calving. Some of these infections can persist for long periods of time (Oliver et al. 2003), are associated with elevated SCC (Trinidad et al. 1990b; Hallberg et al. 1995), may impair mammary development (Trinidad et al. 1990b) and affect milk production after calving (Owens et al. 1991; Oliver et al. 2003; Bryan & Friton, 2005; Sol & Sampimon, 2005).

Differences in the incidence of IMI and types of bacteria causing IMI in pregnant Jersey and Holstein heifers were observed in the present study. One common denominator

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Table 2. Influence of antibiotic treatment of Holstein heifer mammary glands after the first milking of lactation with pirlimycin hydrochloride or penicillin/novobiocin on intramammary infections during early lactation

Parameter	Control	Pirlimycin	Penicillin/novobiocin
Number of heifers treated	13	11	12
Number of quarters treated	52	44	48
Calving			
Number (%) of heifers infected	12 (92)	9 (82)	11 (92)
Number (%) of quarters infected	26 (50)	21 (48)	29 (60)
Number of mixed quarter IMI†	4	0	1
Total number of IMI‡	30	21	30
Early lactation			
Number (%) of heifers infected	11 (85)	6 (55)	9 (75)
Number (%) of quarters infected	20 (39)	9 (20)	17 (35)
Quarters newly infected	10§	2	6¶
IMI calving – early lactation	12§	7	13¶
Total number of IMI	23	9	19
Number of mixed quarter IMI	3	0	2
Percentage cure rate	23·1[a]	57·1[b]	41·4[a]

† More than one mastitis pathogen isolated from milk sample
‡ Total number of infections = number of mammary quarters infected plus the number of mixed quarter IMI
§ Quarters newly infected and persistent IMI from calving to early lactation do not equal the number of quarters infected (20) because two quarters were persistently infected from calving and these quarters also developed a new infection
¶ Quarters newly infected and persistent IMI from calving to early lactation do not equal the number of quarters infected (17) because two quarters were persistently infected from calving and these quarters also developed a new infection
[a,b] Cure rates for treatments that share the same superscript are not significantly different at the 5% significance level

Table 3. Pathogens causing intramammary infections in Jersey heifers at calving and during early lactation

Mastitis pathogen	Treatment group	Calving†	Early lactation‡
Coagulase-negative *Staphylococcus* species	Control	39	22
	Pirlimycin	31	7
	Penicillin/novobiocin	22	6
Staphylococcus aureus	Control	2	1
	Pirlimycin	2	1
	Penicillin/novobiocin	1	1
Streptococcus species§	Control	19	8
	Pirlimycin	14	1
	Penicillin/novobiocin	16	6
Gram-negative¶	Control	1	0
	Pirlimycin	3	1
	Penicillin/novobiocin	2	0
Total	Control	61	31
	Pirlimycin	50	10
	Penicillin/novobiocin	41	13

† Same pathogen isolated in duplicate samples obtained at the first milking after calving
‡ Same pathogen isolated 7, 14 or 30 d after calving
§ Primarily *Streptococcus uberis* (31/49) at calving. During early lactation, 8 intramammary infections were due to *Str. uberis* and 7 were due to *Str. dysgalactiae*
¶ All *Escherichia coli*

in both herds evaluated was that CNS caused the majority of IMI in pregnant heifers during the periparturient period. This is consistent with other published reports on the prevalence of mastitis in heifers (Oliver, 1987; Oliver & Sordillo, 1988; Trinidad et al. 1990a; Pankey et al. 1991; Matthews et al. 1992; Smith et al. 1994; Fox et al. 1995; Nickerson et al. 1995). Collectively, results published thus far suggest that marked herd variation in the rate and types of pathogens causing IMI is common, that IMI in heifers during the *prepartum* period occur

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Table 4. Pathogens causing intramammary infections in Holstein heifers at calving and during early lactation

Mastitis pathogen	Treatment group	Calving†	Early lactation‡
Coagulase-negative *Staphylococcus* species	Control	18	15
	Pirlimycin	13	5
	Penicillin/novobiocin	22	10
Staphylococcus aureus	Control	1	1
	Pirlimycin	0	0
	Penicillin/novobiocin	2	2
Streptococcus species§	Control	6	3
	Pirlimycin	4	2
	Penicillin/novobiocin	2	1
Gram-negative¶	Control	5	0
	Pirlimycin	0	1
	Penicillin/novobiocin	4	3
Bacillus species	Control	0	4
	Pirlimycin	4	1
	Penicillin/novobiocin	0	3
Total	Control	30	23
	Pirlimycin	21	9
	Penicillin/novobiocin	30	19

† Same pathogen isolated in duplicate samples obtained at the first milking after calving
‡ Same pathogen isolated 7, 14 or 30 d after calving
§ Primarily *Str. dysgalactiae* (7 of 12) at calving and during early lactation (4 of 6)
¶ *Escherichia coli* (n = 6), *Klebsiella oxytoca* (n = 2), *Serratia marcesens* (n = 2), *Proteus vulgaris* (n = 2) and *Enterobacter cloaceae* (n = 1)

frequently, that CNS will probably cause the majority of IMI in pregnant heifers, and that variation in the prevalence of IMI in heifers should be expected among herds.

Studies by Oliver et al. (1992, 1997) demonstrated that *prepartum* intramammary infusion of heifer mammary glands with cephapirin sodium or sodium cloxacillin 1–2 weeks before expected calving was an effective procedure for eliminating many infections in heifers during late gestation. Another study (Oliver et al. 2003) showed that *prepartum* intramammary infusion of heifer mammary glands reduced the prevalence of mastitis in heifers both during early lactation and throughout lactation. A more recent study (Oliver et al. 2004) reported that *prepartum* therapy of heifer mammary glands a few weeks before expected calving with antibiotics used in the present study was an effective procedure for reducing the percentage of heifers and mammary quarters infected with mastitis pathogens during early lactation. Middleton et al. (2005) also demonstrated that *prepartum* intramammary infusion of pirlimycin hydrochloride reduced the prevalence of IMI during early lactation and no antibiotic residues in milk were detected.

To our knowledge, this is the first report describing intramammary treatment of heifer mammary glands following the first milking after calving as a means of controlling heifer mastitis. Antibiotic treatment of heifer mammary glands following the first milking after calving had varied results in the two herds evaluated. The bacteriological cure rate was significantly higher in Jersey heifer mammary glands treated with penicillin-novobiocin or pirlimycin than in untreated controls. Significantly fewer infections during early lactation were observed in mammary glands of Holstein heifers treated with pirlimycin than in untreated control quarters. However, no significant differences in infections during early lactation were observed following penicillin-novobiocin treatment of Holstein heifers after the first milking of lactation compared with untreated control quarters. The lack of a significant treatment effect in cure rates between penicillin-novobiocin and untreated controls in Holstein heifers may be due to the relatively small sample size. Thus, this more 'user friendly' approach for controlling mastitis in heifers did not appear to be as effective as *prepartum* antibiotic-treatment of heifer mammary glands with antibiotics used in the present study (Oliver et al. 2004).

Owing to the limited number of heifers per treatment group, milk production and SCC data were not evaluated in this study. Consequently, the economic benefit of treating heifers at the first milking after calving cannot be determined from the present study. The number of heifers per treatment group was sufficient to determine efficacy of antibiotic treatment at the first milking after calving. However, care should be taken when conducting studies using relatively few animals per treatment group to evaluate the influence of treatment on milk production and milk composition. One of the difficulties in working with heifers before calving is how to allocate heifers to treatment groups based on milk production. Blocking of heifers based on potential milk production can be done using the

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heifer parent average, which is based on the sire and dam predicted transmitting ability.

Data are equivocal regarding the influence of antibiotic treatment of heifers before or near calving on milk production in the subsequent lactation. Some studies reported that *prepartum* antibiotic-treated heifers produced significantly more milk than control heifers (Owens et al. 1991; Oliver et al. 2003; Bryan & Friton, 2005; Sampimon & Sol, 2005). A recent prospective cohort study by Bryan & Friton (2005) demonstrated that heifers treated parenterally near calving had a significant reduction in the incidence of mastitis after calving, and treatment was associated with increased milk production at first herd test after calving. Cost benefit and sensitivity analysis using a deterministic model showed an overall return on investment of $186 New Zealand per heifer, or >6 times the investment based on $30 treatment cost. Authors suggested that therapy shortly before calving with penethamate hydriodide in heifers with a high risk of mastitis during the periparturient period would probably be of significant preventative and economic benefit.

Conversely, other studies have shown that antibiotic treatment of heifers before or near calving reduced IMI but did not increase milk production or lower SCC in the subsequent lactation (Borm et al. 2005; Middleton et al. 2005). Reasons for this are unclear and need to be delineated. One potential explanation for differences or lack thereof in milk production following *prepartum* antibiotic therapy could be due to the prevalence of infection in the herds evaluated. In support of this contention, a recent trial by Sampimon & Sol (2005) indicated that *prepartum* antibiotic treatment of heifers was beneficial on high-prevalence farms but not on low-prevalence farms. This study was conducted in 13 Dutch dairy farms where 196 heifers were treated with cloxacillin 8–10 weeks before expected calving and another 196 heifers served as untreated controls. Farms with <15% of heifers with a cow SCC >150 000 cells/ml at the start of the trial were considered low prevalence (LP) while farms with >15% were considered as high prevalence farms (HP). Expected 305-d milk production was significantly higher (496 l) in antibiotic-treated heifers from HP farms in comparison with untreated animals but this difference was only 77 l (not significant) in heifers from LP farms. In both groups of farms, cow SCC was significantly lower in antibiotic-treated heifers than in untreated controls. An IMI had a significant influence on milk production and cow SCC in the treated and also in the untreated group in comparison with animals without an IMI. The authors concluded that treatment of heifers is beneficial on HP but not on LP farms. Thus, treatment of heifers in a high-prevalence herd may be more advantageous from a milk production perspective than in lower prevalence herds. However, high- and low-prevalence herds still need to be defined.

Another potential explanation for differences or lack thereof in milk production following *prepartum* antibiotic therapy could be due to the types of pathogens causing infection and the incidence of clinical mastitis in heifers in the herds evaluated. Some IMI in heifers result in clinical mastitis during the *prepartum* period and during early lactation. Nickerson et al. (1995) indicated that 29% of heifers and 15% of mammary quarters exhibited clinical mastitis at breeding age as evidenced by clots or flakes in mammary secretions. In another study, *Str. dysgalactiae* and *Str. uberis* were isolated from 34·4% and 19·5%, respectively, of heifers with clinical mastitis occurring from puberty up to 14 d after calving involving bacterial analyses of 2069 udder secretions isolated from 1481 heifers with clinical mastitis in Sweden (Jonnson et al. 1991). Waage et al. (1999) reported results of a 1-year field investigation of clinical mastitis in heifers in Norway. The study included 1361 cases of clinical mastitis in 1040 heifers that occurred *prepartum* or within 14 d after calving. Mastitis pathogens isolated most frequently from mammary quarters with clinical mastitis were *Staph. aureus* (44·3%), *Str. dysgalactiae* (18·2%), *Staph. aureus* together with *Str. dysgalactiae* (1·2%), CNS (12·8%), *Actinomyces pyogenes* (3·5%), *Act. pyogenes* together with *Str. dysgalactiae* (0·5%) or *Staph. aureus* (0·4%), and *Escherichia coli* (6·4%). Of the CNS isolated, *Staph. simulans* (53·7%), *Staph. hyicus* (14·8%) and *Staph. chromogenes* (14·8%) were the most prevalent species.

Other research has shown that presence of IMI before calving increased the risk of infection during lactation (Aaerstrup & Jensen, 1997); IMI at calving increased the risk of clinical mastitis within the first week after calving, and mastitis prior to parturition and mastitis within the first week after calving increased the risk of further cases of mastitis and culling during the first 45 d of lactation (Edinger et al. 1999). Thus, the preponderance of data from several studies conducted in different parts of the world suggests that it is highly advantageous to eliminate as many IMI in primiparous heifers as possible to minimize their potential impact in the subsequent lactation.

An advantage of antibiotic treatment of heifer mammary glands within a few weeks of parturition is that this is a time when mammary glands are highly susceptible to new IMI (Oliver & Sordillo, 1988). Antibiotic treatment at this time eliminates many infections present at the time of treatment and may also prevent new IMI from occurring at a time when mammary glands are highly susceptible to new IMI. In support of this contention, Trinidad et al. (1990c) demonstrated that intramammary infusion of an antibiotic formulation for nonlactating cows into pregnant heifers during different trimesters of pregnancy was effective in reducing the prevalence of mastitis at parturition. However, efficacy of *prepartum* antibiotic therapy at 7 or 14 d prior to expected calving in our studies (Oliver et al. 1992; 1997; 2003, 2004) was higher than that reported by Trinidad et al. (1990c). Furthermore, in an extensive survey involving heifers from many herds located in different regions of the country, Fox et al. (1995) indicated that the prevalence of heifer IMI was highest during the last trimester of pregnancy. Thus, methods of controlling mastitis

in heifers would probably be more effective if administered at some point during the last trimester of pregnancy when rates of IMI are highest as opposed to early gestation or at parturition when damage associated with IMI has already occurred.

While much has been learned about mastitis in heifers, many issues remain unanswered such as: (1) identification of herds where this strategy would be most advantageous and cost effective, (2) should all heifers in the herd be treated or only certain heifers? (3) are there certain CNS species that are more problematic than others? and (4) identification of key risk factors that could have a significant impact on prevention of heifer mastitis so that antibiotic treatment could be minimized. Additional studies are needed to address these fundamentally important questions.

In conclusion, a more 'user friendly' approach for controlling mastitis in heifers based on intramammary treatment following the first milking after parturition did not appear to be as effective as *prepartum* antibiotic-treatment of heifer mammary glands. Differences are probably due to the timing of antibiotic treatment, persistence of antibiotics in mammary tissue and secretions, and the time when new IMI occur in heifers during the periparturient period.

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