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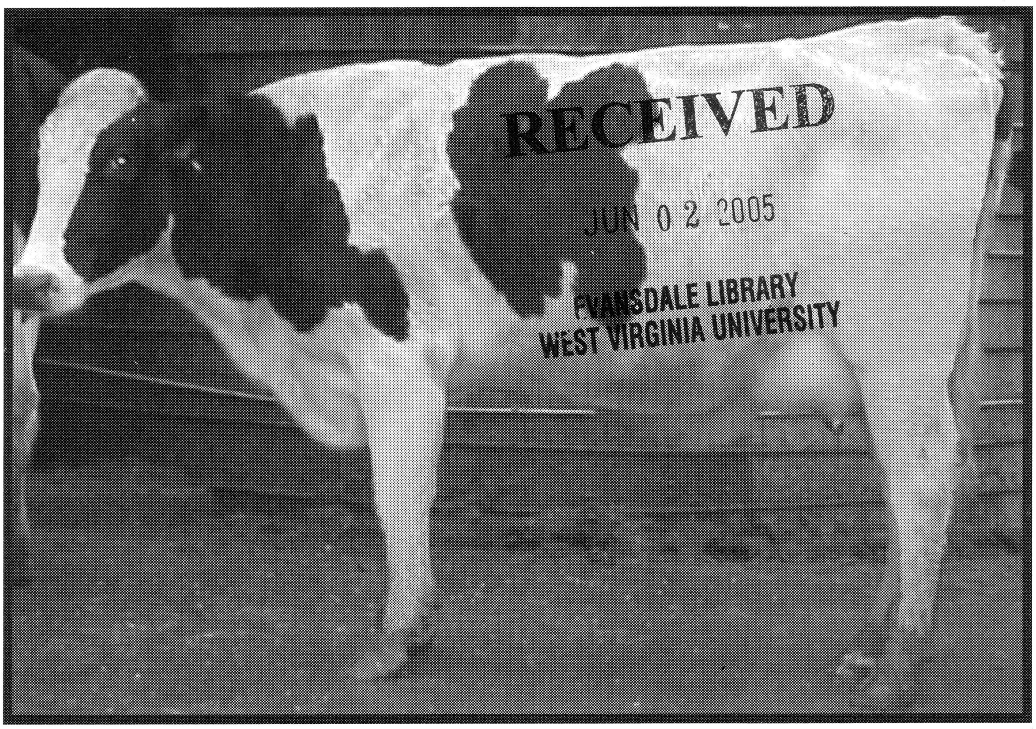

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- Nancy J. Kerr completed the studies in this bulletin in partial fulfillment of the requirements for the doctor of philosophy degree in animal and food science at the West Virginia University Davis College of Agriculture, Forestry, and Consumer Sciences. A native of Carmichaels, Pa., she also holds a master of science degree in animal and veterinary sciences from West Virginia University and a bachelor of science degree in animal and biological sciences from the Pennsylvania State University.
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Cover Photo. This prepartum heifer was milked for 22 days before the photograph was taken and calved two days later.

Keywords: Prepartum Milking, Prepartum Mastitis, Heifers, Milk Production, Mastitis Prevention

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A field study was conducted in two commercial dairy herds to determine effects of milking Holstein heifers prepartum on postpartum incidence of mastitis, reproduction, milk production, and overall health. Heifers were assigned to one of three groups: *Reference-*non-prepartum milked, postpartum milked (n=50), *Prepartum Milked* (n=77); or *Prepartum Milked with Mastitis* (n=34). Prepartum milking consisted of twice daily milk removal by machine milking. Number of days milked prepartum depended upon fullness of the teats, detection of milk leakage, or visual indications of mastitis. Incidence of prepartum mastitis averaged 21%. Heifers with clinical mastitis prepartum were treated with an intramammary antibiotic for lactating cows. Average daily milk production and number of days milked prepartum were greatest for heifers that initiated lactation in spring or summer compared to fall or winter. Heifers with flat teat ends had a greater incidence of mastitis prepartum compared to those with round-shaped teat ends and heifers with viscous secretions were more likely to contract mastitis. Postpartum first lactation milk production was greater for prepartum milked heifers compared to reference heifers. Postpartum linear somatic cell scores did not differ among groups but were affected by season. Number of days to first service was comparable among groups, however heifers that had mastitis prepartum required more services per conception, had more days open, and had longer calving intervals. Initiating milking when fullness of the teats appears sufficient to support a milking unit may improve udder health, reproduction, and overall health during first lactation.

Introduction

Chronic mastitis and poor reproduction are the most cited reasons for culling dairy cattle. Mastitis is costly due to decreased production, medical treatment, extra labor, increased rate of cow replacement, and negative effects on reproduction. Intramammary infections result from pathogens entering the udder, predominantly through the teat canal (29), thus the teat is an important first-line defense against mastitis (69). The keratin lipid plug that forms in the teat has bacteriostatic properties (4) that protect the mammary gland between milkings (11). Although the lipid plug seals the streak canal (25) during the dry period (81), often it is lost in the final 7 to 10 days prepartum (86), increasing susceptibility to environmental pathogens. Contagious mastitis pathogens were cultured from heifers at incidences of 8 to 97% (12, 18, 54, 61, 73) as early as 18 days of age (89) with the highest prevalence in the last trimester of pregnancy (30, 63), when the incidence of mastitis prepartum is greatest (71). Heifers infected with mastitis prepartum occasionally freshen with one or more nonfunctional quarters and might not reach full production potential in first lactation (61, 72, 97). Thelitis, a common complication of mastitis in heifers (97), causes the teat canal to narrow and become rigid, decreasing milk flow. Of dairy heifers treated for mastitis prepartum or within 14 days postpartum, 10.9% were culled within four weeks following initial treatment compared to 4.5 % for non-infected heifers, and 25% of the treated heifers that were not culled had at least one nonfunctional quarter (97). Only 40% of the treated quarters were cured and in milk 28 days after treatment. In addition, changes in pliability of teat tissue as a result of edema or congestion might alter resistance of the teat canal to bacterial invasion (69). Prevalence of mastitis was associated less with round teat ends (58) and more with inverted teat ends (50). Other authors have confirmed that somatic cell count (SCC) and incidence of mastitis are least for pointed and round teat ends and highest for flat and inverted teat ends (43, 83). Further, decreased reproductive performance (9), including early fetal mortality or abortion (78), was associated with mastitis during early lactation.

Most development of mammary tissue occurs in first gestation (92), and level of milk production is related to degree of development of the udder at calving (48). The alveolar lumen and total epithelium were more developed in prepartum-milked quarters than in postpartum-milked quarters (7) leading to the conclusion that prepartum milking stimulated epithelial development (6). Milking half of the udder of prepartum heifers did not result in a distortion of the udder (20), and, in all cases, the teats and udders were soft and pliable (94). Milking prepartum reduced incidence of mastitis during the first 30 days postpartum (32, 106). Further, prepartum-milked heifers were inseminated sooner postpartum and averaged fewer services per conception (39, 46) and days open (46). Amount of milk produced in response to prepartum milking varies considerably (2, 36, 37, 104), but milk from prepartum-milked heifers is suitable for marketing earlier than milk from heifers that are not milked until after parturition (103, 106). Earlier studies of prepartum milking were testing the ability of the practice to prevent milk fever (23, 87, 94), and the majority of studies were on multiparous cows (2, 32, 37, 106), used small numbers (39, 90), or milked only one or two quarters (5, 37, 47, 99). No adverse effects of prepartum milking have been reported, and prepartum milking has been a regular practice in some herds (19, 103, 106).

Udder edema is accumulation of lymph in the intercellular tissue between the secretory tissue and the skin (55) at the base of the udder, and in severe cases in the entire udder. Swelling can occur in front of the udder, umbilical area, the back of the udder toward the vulva, and hindquarters (79, 93). Typically udder edema, especially in heifers (79), begins shortly before calving, when blood flow to the udder increases, and edema steadily increases (26) until parturition. Edema can strain suspensory ligaments such that the udder becomes distended, less flexible, and susceptible to physical trauma. Swelling can cause shortening of the teats and make attachment of the milking machine difficult, as well as hinder milk flow. Use of a diuretic is the most effective treatment (79), but udder edema, an inconvenience, usually diminishes after parturition without special care. However, management problems and permanent damage are likely (96), as udders congested for a prolonged time seldom return to normal due to infiltration of fibrous connective tissue (28). Edema was more frequent and more pronounced in first-calf heifers than in older cows (26, 33, 104), but whether prepartum milking decreases edema has not been established (1, 23, 32, 46, 82, 95, 106). Prepartum heifers fed grain had higher body condition scores, more edema, and greater milk production (26) than heifers fed forage alone, but incidence and degree of udder edema were not related to plane of nutrition (40, 41). Udder edema was correlated with subsequent milk production but not with body condition at parturition (80). Prepartum edema in heifers increased as the age at calving increased, and as gestation length increased, but was not correlated with season, environmental temperature, or photoperiod (53). Other predisposing factors include concentrations of serum sodium (41, 77) and potassium (77), and genetic susceptibility(21).

The aim of this study was to identify factors that affect responses to prepartum milking in Holstein heifers. Preventing mastitis and reducing the severity of edema prepartum might be key to increased milk production, reproductive efficiency, and longevity in first lactation. More importantly, identifying infected quarters, implementing antibiotic therapy, and prepartum milking might reduce use of antibiotics and tissue damage to the mammary gland leading to improved health and performance of the animal and enhanced quality of milk produced. Effects of prepartum milking on udder health, production in first lactation, days to first estrus, and subsequent calving interval have not been assessed adequately for heifers. In addition, no studies have reported if prepartum and early postpartum mastitis in heifers are influenced by teat end shape, although that factor is known to influence mastitis later in lactation.

Procedures

Two Holstein herds that met criteria of a well managed herd (32) [1) DHI rolling herd milk average >20,000 lbs., 2) twice-a-day milking, 3) rolling herd SCC < 400,000 cells per ml of milk, 4) routine post milking teat dipping and dry cow therapy, 5) < 35 % annual culling rate, 6) calving interval < 13.5 months, 7) at least once monthly reproductive herd health visit, and 8) low incidence of metabolic disorders] were used from September 2000 to December 2002 (farm 1), and from September 2001 to January 2002 (farm 2). Heifers were housed on bedded pack with free access to grass paddocks until 30 days prior to expected parturition, when they were moved to free-stall barns with sawdust-bedded stalls and concrete alleys. Heifers and lactating cows had free access to a common concrete exercise paddock.

Heifers were assigned to groups based on teat size and development and/or indications of mastitis. Prepartum milking was initiated if leakage of milk or uneven udder and teat development were observed. Thus, three groups were formed: non-prepartum milked reference (farm 1, n = 31; farm 2, n = 19), prepartum milked (farm 1, n = 68; farm 2, n = 9), and prepartum milked with mastitis (farm 1, n = 27; farm 2, n = 7). Heifers were acclimated (8 to 10 minutes or until milking was completed for all cows in the respective row) to a double six herringbone parlor at least two days prior to initial milking. Heifers were scored for body condition (range of 1 to 5, 1 = thin, 5= obese (102)) and edema (range of 1 to 5, 1 = none, 5 = severe (21)) once weekly beginning 21 days before expected calving until 21 days postpartum and monitored daily through the first 30 days postpartum for left displaced abomasum (LDA), which was corrected by ventral paramedian abomasopexy, and ketosis (day and severity of occurrence were recorded). Incidence of retained placenta (not expelled within 12 hours of parturition) was recorded. Heifers with clinical mastitis prepartum were treated with an intramammary antibiotic for lactating cows (Today™, Franklin Laboratories, Inc., Fort Dodge, IA) for three to four treatments and milked twice daily. All heifers and lactating cows were milked at 13 and 11-hour intervals.

Two weeks prior to expected parturition, heifers were confined to sawdust-bedded box stalls from the evening milking until the morning milking. Approximately 15 to 23 kg of total mixed ration (TMR) and 50 L of water were offered in the evening. After morning milking, heifers had free access to the feed bunk, concrete exercise lot and free stall barn. Heifers showing signs of labor (vaginal discharge, elevated tail, appearance of chorion, abdominal straining while urinating) after morning milking were confined to a box stall. Heifers requiring assistance at parturition received 1ml of oxytocin (Butler, Dublin, OH) within 20 minutes of calving. Calves were removed from the dam between 15 minutes and 1 hour following parturition and fed 2 L of frozen colostrum from multiparous cows for the first feeding. Calves then were fed waste milk (discarded milk from fresh and/or treated cows), or commercial milk replacer if waste milk was not available, until weaning.

Statistics: Data were analyzed for effect of group (*reference* - postpartum milked only, *mastitis* mastitis and prepartum milked, *prepartum* - no mastitis and prepartum milked). Average daily prepartum milk production, number of days milked prepartum and total prepartum milk production, as well as postpartum milk production, linear somatic cell score, and subsequent reproductive performance were analyzed for effects of season and its interaction with group. Month of the initial milking was designated as: Spring – March 1st to May 31st; Summer – June 1st to August 31st; Fall – September 1st to November 30th; and Winter – December 1st to February 28th. Effects of season were determined using orthogonal contrasts. Incidence of retained placenta, ketosis, left displaced abomasum, postpartum mastitis and culling were analyzed by Chi-Square analysis. The effects of teat end shape and viscosity of initial milk secretion were examined using the CatMod Procedure of SAS (Cary, NC). Data for prepartum milk production, teat shape, linear somatic cell score, reproduction and culling rate were collected on farm 1 only. Differences in milk production among days within season were analyzed using a t-test of the Least Squares Means.

Results

Incidence of Mastitis and Edema. Thirty-four heifers (21.5%) developed mastitis prepartum, either before or within the first four days following initial milking. Another 74 heifers (46.8%) showed signs of edema (Figure 1) and were pre-milked. Edema tended to develop in the fore udder and predominantly in the navel area of the prepartum-milked heifers. At periparturition, edema occurred in the lower portion of the udder in reference heifers. Prepartum milking had no significant effect on reducing edema. However, the severity of edema in the prepartum milked heifers was not greater than that of the reference heifers at parturition and declined at a comparable rate after calving. Teats of heifers milked prepartum remained soft and pliable (Image 1). The incidence of mastits postpartum was 42.4%, twice the prepartum rate. Occurrence of mastitis postpartum was related ($p<0.001$) to prepartum condition of the udder (Chi square = 15.6, 2 df). More heifers that had mastitis prepartum had mastitis postpartum (61.5%, while heifers with prepartum edema were intermediate (42.4%), and those heifers not prepartum milked were least affected (28.1%).

Incidence of mastitis was associated with both teat end shape and viscosity of the initial milk secretion. In heifers with flat teat ends, the proportion (50%) that developed

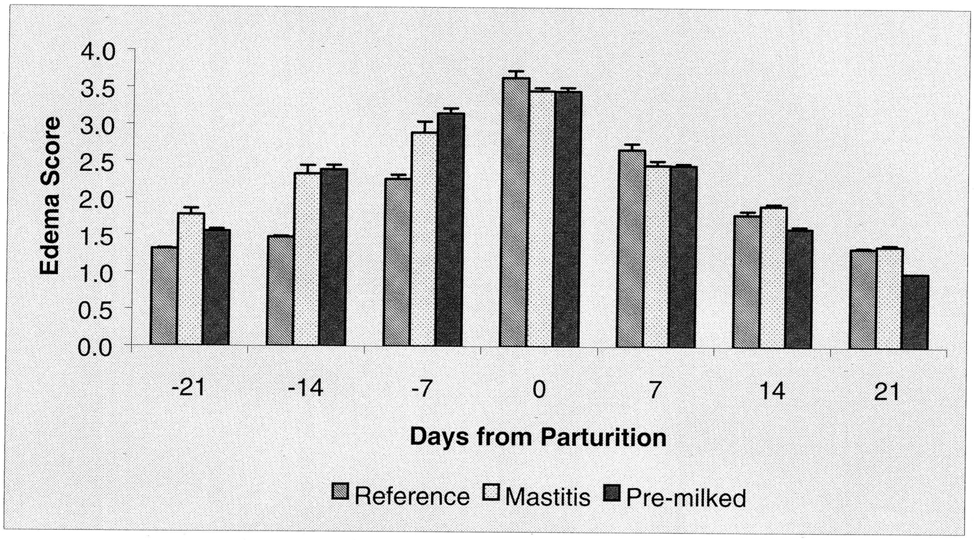

Figure 1. Mean edema score for Holstein heifers for the three weeks before and after parturition. Scores at and after parturition did not differ among treatment groups (p>.05).

mastitis prepartum was higher (p<0.01) than in heifers with other shaped teat ends (11%). Heifers that had secretions of low viscosity at initial milking had a higher incidence of postpartum mastitis (p<0.001). In addition, the interaction between teat end shape and viscosity was significant (p<0.0001). Thus, there was a greater likelihood of mastitis in heifers with flat teat ends and low viscosity initial secretions both prepartum and postpartum.

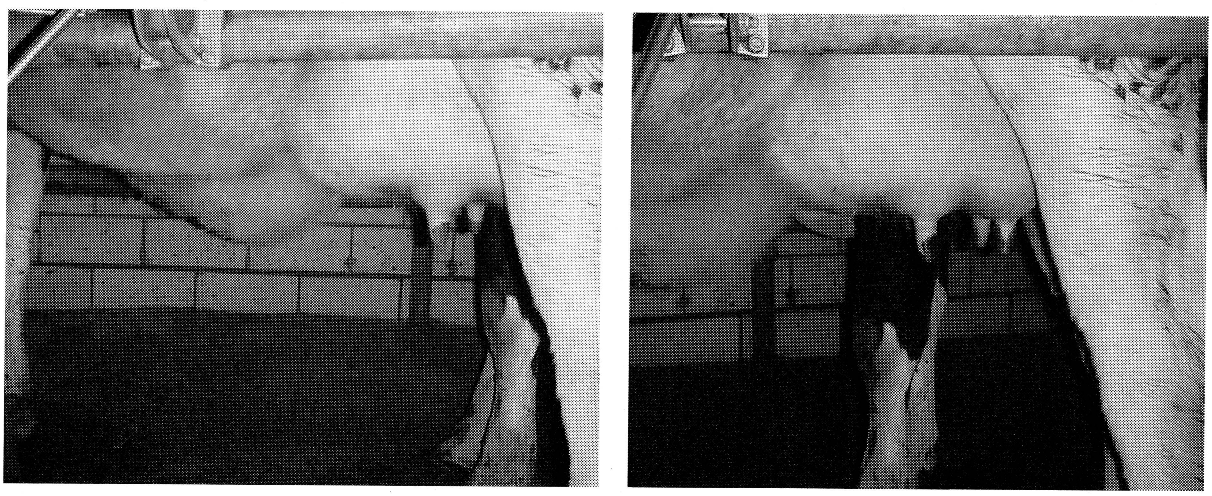

Image 1. *Left Panel.* Photograph taken on day 2 prepartum prior to milking unit attachment. Notice edema present at the navel and fore-udder areas. The heifer was milked for a total of 24 days prepartum. *Right Panel.* Photograph of same heifer immediately following milker unit detachment. Notice wrinkling of the teats with no "caking" present.

Body Condition Score. Body condition scores did not differ among the three groups over the prepartum or early postpartum period. On farm 1, body condition scores prepartum to day-7 postpartum differed among groups on day-14 prepartum ($p<0.01$) and tended to differ on day-21 prepartum and day-7 postpartum with the reference heifers having the least body condition and tending to lose more condition from day-21 prepartum to day-21 postpartum. In contrast, body condition scores differed on farm 2 from day-7, with reference heifers having the greatest condition and tending to lose more condition from parturition to day-21 postpartum than prepartum-milked heifers. One reference heifer lost a quarter of one body condition score from -7 days to parturition, but increased body condition by day-14 postpartum to that of the prepartum day-21 score. That heifer delivered a stillborn calf 10 days prior to expected calving. Five of the seven heifers with mastitis prepartum maintained body condition score prepartum, one heifer lost body condition (3.75 to 3.25) from -14 days to -7 days, and one increased body condition between day -7 and parturition.

Reproduction. Lengths of gestation did not differ significantly among groups (Table 1). Similar proportions, overall 8.3%, of heifers (5/50 reference, 5/34 mastitis, and 4/74 premilked) had retained placentas (RP). Two prepartum milked heifers with retained placenta required assistance at parturition. Number of days to first service did not differ significantly among groups. However, having mastitis prepartum compared to not having mastitis prepartum increased ($p<0.01$) number of services per conception, total days open, and subsequent calving interval.

Table 1. Mean ± Standard Error for Reproductive Characteristics of Holstein Heifers at First Parturition

Group	Age at Calving (Months)	Gestation Length (Days)	Days to First Service	Services per Conception	Days Open	Calving Interval (Months)
Reference	31.6 ± 0.9	279 ± 0.7	91.1±4.5	1.32 ± 0.94	108.6± 7.6	12.8±0.3
Premilked	34.8 ± 1.0	278 ± 0.9	90.8±5.2	1.67 ± 0.15	116.5± 7.8	13.0±0.3
Mastitis	36.5 ± 1.4	281 ± 1.3	104.1±8.3	2.70 ± 0.33	184.8±14.4	15.2±0.5

Ketosis. Thirty-one heifers (19.6%) developed ketosis. Incidence of ketosis occurred most frequently in heifers that had mastitis prepartum (5 of 50 reference, 12 of 74 prepartum milked, and 14 of 34 prepartum mastitis, Chi square = 13.5, $p<0.01$). Ten heifers (32.3%, 10/31) experienced moderate to severe ketosis within 21 days postpartum. Heifers that initiated lactation with mastitis (9/14) from May to September were most likely to develop ketosis. Eight heifers had primary ketosis. The following heifers were classified as having ketosis secondary to another afflication: seven with prepartum mastitis, four with prepartum mastitis and left displaced abomasum (LDA), one with prepartum mastitis and RP, one with LDA, one with RP, five with LDA, RP, and metritis, two with metritis, and two with RP and metritis.

Left Displaced Abomasum. Ten heifers (6.3%), two reference, five mastitis, and three prepartum milked, had LDA. One mastitis heifer required assistance at parturition (the uterine artery was severed and sutured) and developed severe ketosis and metritis. A second mastitis heifer had severe ketosis 11 days prepartum, LDA at parturition and surgical correction on day 3 postpartum. Another mastitis heifer had severe ketosis two days prepartum, LDA on parturition, and surgery on day 1 postpartum. That heifer had mastitis in all four quarters at initial milking and was milked for 13 days prepartum. A fourth mastitis heifer had clinical mastitis in one quarter prepartum, developed a small amount of ketosis prepartum, and LDA on day-4 postpartum. One prepartum milked heifer had assisted calving, a retained placenta, no ketosis and developed LDA. Another prepartum milked heifer had no clinical signs of mastitis, ketosis, or metritis and developed an LDA on day 20 postpartum. The two prepartum milked heifers that had a LDA at parturition had lost one-half to three-quarters of a BCS from day -7 to parturition.

Linear Somatic Cell Score. Linear somatic cell scores did not differ among groups. There was a season by test day linear somatic cell score interaction. Mean linear somatic cell scores at days 30, 60, 120, and 270 were greatest ($p<0.01$) for heifers that calved in winter. At day 120, linear somatic cell scores were greater ($p<0.01$) for heifers that calved in spring and summer compared to fall and winter.

Milk Production. Average daily prepartum milk production (Figure 2) was greater ($p<0.0001$) for heifers that initiated lactation in spring or summer than those in fall or winter (14.4 vs. 9.1 kg/d) and were milked longer (24.9 vs. 9.5 days) before parturition ($p<0.01$). Hence, total prepartum milk production was greater for spring and summer compared to fall and winter ($p<0.05$), but was not different between spring and summer or fall and winter. Mean milk production was greater on the day following parturition ($p<0.0001$) than either the day before or day of parturition, and these days differed among seasons ($p < 0.01$, Figure 2). Mean postpartum milk production differed among groups ($p<0.0001$), reference heifers produced 28.4 compared to 32.6 and 33.2 kg per day for mastitis and prepartum milked heifers, respectively. Prepartum-milked heifers that initiated lactation in spring produced more milk than mastitis and reference heifers that initiated lactation in the spring for the 305-day lactation, while prepartum milking initiated in fall and winter produced more milk than reference heifers during the entire first lactation. Production was greater for spring than winter ($p < 0.001$) and for summer than winter ($p < 0.01$).

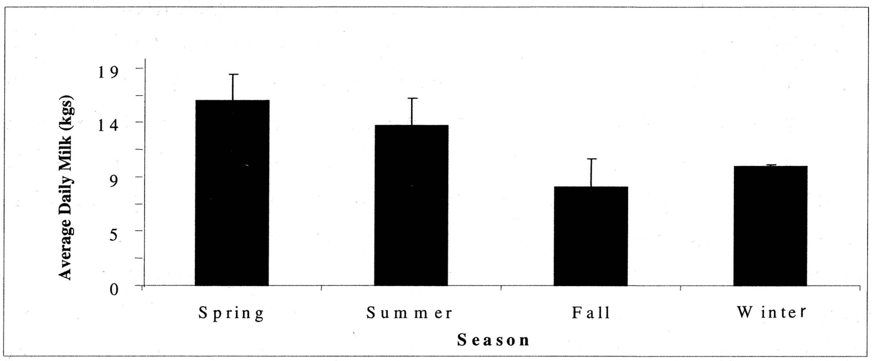

Figure 2. Least Squares Means for Average Daily Prepartum Milk Production by Season Daily prepartum milk production was greatest ($p < 0.001$) for heifers that initiated prepartum milking during spring and summer compared to fall and winter. Daily prepartum milk production was greater for spring versus fall ($p < 0.001$), spring versus winter ($p < 0.01$), and summer versus fall ($p < 0.01$).

Culling. Overall culling rate was 21.4%. Udder-related causes (19/27) were the most prevalent reason for culling and accounted for all of the cases in reference heifers, 55% in prepartum milked, and 69% in heifers that had prepartum mastitis. Reproduction was the second most prevalent basis for culling in prepartum-milked (11%) and heifers with mastitis prepartum (15%). Heifers in the reference group were culled (16%) for mastitis before day 45 postpartum (n=2), chronic inhibition of milk letdown (n=2), or teat injury (n=1). Heifers milked prepartum were culled (13%) for mastitis in late lactation (n=2), poor teat placement and udder structure (n=1), teat injuries (n=2), non-pregnancy (n=1), leg and hip abscesses (n=2), or chronic bladder infection (n=1). Heifers with mastitis prepartum were culled (48%) for chronic mastitis postpartum (n=3), high somatic cell count and an expected extended calving interval (n=2), a non-functional quarter (n=3), teat injury (n=1), non-pregnancy (n=2), or laminitis (n=2). One reference heifer died due to a ruptured milk vein, and three prepartum milked heifers died – one at parturition, one due to heat stress, and one from a gram-negative mastitis infection.

Discussion

In the present study, prepartum milking aided in identification and treatment of clinically infected quarters. Thus, 21% of heifers were treated with a lactating cow intramammary antibiotic prepartum, a selective, as opposed to blanket, therapy. In Australia and New Zealand, where incidence of mastitis is low in grazing herds, infusion of an intramammary antibiotic for non-lactating cows into uninfected quarters resulted in a 50% increase in incidence of mastitis compared to untreated controls (15, 52). In the current study, 78.9% were not infected with mastitis prepartum, at parturition, or during the first 30 days postpartum. If the recommended practice of administering intramammary antibiotic therapy to all prepartum heifers during the third trimester of gestation had been followed (62, 65, 67, 68, 71), then the majority of heifers would have received unnecessary antibiotic treatment and incurred additional treatment and labor costs, in addition to the risk of antibiotic residues in milk during the first 3 days postpartum (64). On farm 1, 16 of the 27 heifers that had mastitis prepartum had mastitis again postpartum. Oliver et al. (65) reported that only 11% of heifers that were infected and treated with a non-lactating cow intramammary antibiotic prepartum developed mastitis postpartum. Treatment with an intramammary antibiotic intended for a non-lactating cow as opposed to a lactating cow might have decreased the incidence of postpartum mastitis, but the milk produced prepartum could not have been marketed as soon.

Milking was initiated when the teat was wide enough to support a milking unit without slippage and before edema and congestion in the teats were evident. Heifers secreting watery, yellow, serum-like secretions (before lactogenesis occurred) or thick, yellow, colostrum-like secretions with keratin plugs at the initial prepartum milking did not develop mastitis prepartum or during the first thirty days postpartum. However, heifers having thin, white milk-like secretions in one or more quarters were at greater risk of developing mastitis prepartum, in agreement with Hallberg et al. (38), where 81% of quarters with mastitis prepartum had low viscosity secretions. A greater proportion of heifers with flat-shaped teat ends developed mastitis prepartum than of heifers with round- or pointed-shaped teat ends. Heifers with flat-shaped teat ends were more likely to have low viscosity secretions (18 of 29) and 14 of those developed mastitis prepartum, whereas those with round- and pointed-shaped teat ends were more likely to have high viscosity secretions (55 of 76). Only two of 76 heifers with round teat ends and 1 of 16 heifers with pointed teat ends that had high viscosity secretions developed mastitis prepartum, but an association between teat end shape and somatic cell count was not found in a recent study (16).

Methods for preventing mastitis involve labor, insecticides for fly control, systemic and intramammary antibiotic treatment, inorganic bedding materials, culling infected cows, and/or vaccination. Individual hygienic practices (i.e. use of sanitizers in wash water for udder preparation, single service towels, back flushing liners, and application of germicides on teats post milking) reduced number of bacteria but not incidence of new infections (22). Hygienic practices of wearing rubber gloves dipped in sanitizing solution between preparing cows, pasteurizing teat cup clusters between cows, washing udders with single service towels, and dipping teats with a germicide post-milking reduced new infections per year from two to one per cow (60). Although each procedure reduced number of organisms on the teat, the combination of procedures had little value in controlling herd infections. Culling is not economical (59), because the need for replacement heifers increases. Intramammary and/or systemic antibiotic therapy, an integral part of controlling mastitis since the late 1940s, is more effective in dry than lactating cows. Antibiotics are retained in the mammary gland for a longer period in dry cows, allowing for greater success in eliminating a broader range of mastitis pathogens, and there is no economic loss due to discarding milk.

Risk factors associated with prepartum mastitis in heifers include an increase in mean milk yield per cow in the herd and an increase in the overall herd incidence of clinical mastitis (56). Methods of preventing mastitis in prepartum heifers include vaccination, fly control, segregation of pregnant heifers from dry cows (42), use of organic material for bedding and maintenance of bedding (44), use of barrier teat dips (91), maintaining a clean, dry environment (74), administering an intramammary antibiotic product at various stages prepartum (62, 65, 70, 71), and selection for mastitis resistance (76). Vaccines have marginal efficacy (105). Treating heifers with intramammary antibiotics before parturition, particularly in the third trimester of gestation (71), has shown greater success in eliminating pathogens compared with treatment during lactation (68). However, this treatment can leave residues in milk during early lactation (68) and increases the risk of development of antibiotic resistance after prophylactic administration (66). No infusion product has been approved for treatment of mastitis in prepartum heifers. Furthermore, intramammary treatment of all prepartum heifers might be viewed as unnecessary, excessive, and a questionable sustainable agricultural practice.

Natzke (57) stated that three criteria needed to be met for an effective, national mastitis control program: 1) maximum dollar return to all dairy producers; 2) aimed at all herds, not only herds having a high incidence of infection; and 3) effective against all pathogens. Because the rate of eliminating clinical mastitis in lactating cows with antibiotic is only 29 to 40 percent effective, disease prevention is more cost effective than treatment (75). Researchers are investigating ways to reduce unnecessary use of antibiotics in dairy cows (8). Milking heifers prepartum might be an effective, sustainable practice to reduce incidences of clinical and subclinical mastitis during the postpartum period and most importantly, reduce the frequency of nonfunctional quarters in the early postpartum heifer with minimal use of intramammary antibiotics. Bowers et al. (13, 14) and Kearney et al. (46) initiated milking after teats and udder were susceptible to mastitis pathogens and included heifers that were infected before the initial prepartum milking. Thus, these researchers did not observe a decrease in somatic cell count and mastitis incidence, either prepartum or postpartum, in prepartum-milked heifers. Conversely, Greene et al. (32) reported that prepartum milked cows and heifers had a lower incidence of new mastitis cases than non-prepartum-milked controls. In the present study, heifers with prepartum mastitis were more likely to develop mastitis postpartum, while milking animals with edema in the prepartum period resulted in a lower proportion of postpartum cases of mastitis.

This study extends the conclusions based on cows (9, 78) that preventing mastitis improves reproductive performance. Prepartum-milked heifers with clinical mastitis did not have an increase in the number of days to first service, but had a greater number of services per conception and days open, as well as a longer calving interval than the other groups. Negative energy balance both prepartum and postpartum prolonged the interval to initial ovulation in association with reduced follicular development (51, 88). There was no effect of prepartum milking on incidence of retained placenta, confirming another study in which only Holstein cattle were used (32). Earlier studies (1, 2) had found that prepartum milking caused an increase in the incidence of retained placenta in animals that produced large quantities of milk prepartum, but that might have been because of selenium deficiency and three breeds of cattle, Jersey, Holstein, and Ayrshire, were used instead of just Holsteins as in the present study.

Dry matter intake (DMI) decreases approximately 30% during the final 10 days of gestation in heifers, thus contributing to the negative energy balance (34). Grummer et al. (35) reported that DMI increased in cows milked prepartum, but a decline in DMI still occurred. Prepartum-milked heifers that were not infected with mastitis produced more milk prepartum than infected heifers. Whereas heifers in this study consumed a ration balanced for early lactating, high producing cows, those in studies with much lower prepartum milk yields were fed rations balanced for non-lactating or close-up heifers (13, 32, 46). During the final 10 days of gestation, DMI decreases by 30% (10, 35), predisposing the animal to development of ketosis, the principal metabolic disorder associated with carbohydrate, fat, and protein metabolism. Ketosis and hypoglycemia occur most frequently in high-producing dairy cows in late gestation and within the first six weeks postpartum and cause a marked decrease in milk production and body weight resulting in an economic loss for the producer. Although prepartum-milking increased prepartum DMI (35), prepartum milking did not affect the incidence of ketosis (23). Approximately two-thirds of ketosis cases are considered primary, while one-third of cases occur secondary to retained placenta, metritis, displaced abomasum, nephritis, hardware, lameness, or other conditions that caused a greater decrease in DMI (31).

Incidence of prepartum mastitis was lower during summer and fall, in agreement with Waage et al. (98) in which heifers on pasture during summer and fall had a lower incidence of mastitis than heifers in confinement during the same period. In previous studies (67, 68), only 8 to 10% of prepartum heifers were infected with major (environmental) mastitis pathogens. Heifers that initiated lactation from May to September were most likely to develop ketosis. A total of 21 heifers (16.7%) developed ketosis either pre- or postpartum. Of the 21 affected heifers on farm 1, 12 belong to the prepartum-milked with mastitis group and 9 belonged to the prepartum-milked group. No reference heifers developed ketosis. However, on farm 2, 10 heifers (28.6%) experienced moderate to severe ketosis within 21 days postpartum, 5 in the reference group, 3 in the prepartum-milked with mastitis group, and 2 in the prepartum-milked group. The higher incidence of ketosis in reference heifers on farm 2 most likely was due to different nutrition and management of parturient animals between the two farms.

Completeness of milk removal is an important determinant of the rate of milk secretion, because residual milk contains feedback inhibitor of lactation (49, 100, 101). Some heifers produce as much as 20 to 35 kg of milk per day prepartum (104). Milking cows and heifers fewer than 14 days prepartum did not affect postpartum milk production or reproduction (2, 106). Season of the year affected number of days milked and total amount of milk produced prepartum. With the exception of a few reports (23, 24, 32), prepartum milking of cows and heifers was studied briefly and mainly during the fall and winter. Greene et al. (32) conducted a field study on prepartum milking over a 13-month period. Only 15% of the animals were heifers, and the mean number of days milked prepartum was 12.7 (range of 1 to 33 days). In the current study, the overall mean number of days milked prepartum was 14.9 days. Heifers in which prepartum lactation was initiated in the spring were milked for a greater number of days compared to those in which prepartum lactation was initiated in the summer, fall, and winter. Milk production was greatest for the seasons in which heifers were milked prepartum for the longest number of days. However, average daily milk production was greater in the spring and summer compared to fall and winter, independent of number of days milked. Greene et al. (32) reported that the number of days prepartum-milked had no effect on the amount of milk produced prepartum, which is in agreement with the current study, however number of days prepartum-milked and average daily prepartum milk production were influenced by season. Prepartum milk production and the number of days milked prepartum were influenced by season, both being greater for the spring and summer months compared to fall and winter months. The seasonal effect continued into the postpartum in agreement with literature reviewed by Dahl et al. (17) that heifers exposed to short-day photoperiods during the final two months of gestation and exposed to long-day photoperiods during lactation have improved milk yields.

Some researchers stated that prepartum milking is labor intensive (32). However, researchers who studied growth and health of calves born to prepartum milked dams reported no increase in labor intensity or involvement in rearing calves (2, 3, 45, 85). In contrast, intramammary antibiotic infusion therapy of heifers is labor intensive, requiring additional handling of animals, and requires adequate handling and restraint facilities (70, 75). Two concerns of infusion therapy of heifers are worker safety and the fact that prepartum infusion might disrupt the natural keratin plug or could lead to induced infections due to poor treatment procedure.

Milking heifers prepartum might be economically justified if reproductive performance, a reduction in antibiotic usage, and overall health of the animal are considered (i.e. decreased veterinary costs, decreased milk loss from antibiotic treatment and metabolic conditions, etc.) rather than only milk yield and mastitis prevention. Most importantly, a reduction in any disease or condition that leads to premature culling or death of the animal has obvious implications for reducing the cost of maintaining number of cows in the herd. If milking is initiated before accumulation or development of edema in the teats, then the teats remain soft, pliable and functional (impairment of complete milk removal does not occur).

Conclusion

Initiating milking prepartum when fullness of the teats appear large enough to support a milking unit and before edema and congestion of the udder occurs might prove beneficial for improving subsequent milk production, reproduction and overall health of the animal during first lactation.

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