Benefits of Improving Trace Mineral Status of Dairy Replacement Heifers

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Introduction

Because dairy replacement heifers generally do not generate revenue until after first parturition, the management and nutritional needs of heifers receive lower priority than those of the lactating cows. However, minimizing health disorders of replacement heifers decreases mortality before first parturition and increases the likelihood that they will enter the milking herd (Warnick et al., 1995). Furthermore, lessening the incidence of calfhood respiratory diseases has been correlated with decreased age at first calving (Warnick et al., 1994) while minimizing incidence of claw lesions in heifers has been associated with increased milk production during first lactation (Drendel et al., 2005). Clearly, improving health, as well as performance, of dairy replacement heifers has a positive impact on dairy profitability. This paper will focus on one factor affecting health and performance of dairy replacements heifers, trace mineral status.

Incidence of Health Problems in Heifers in the United States

Results of the National Animal Health Monitoring Systems (NAHMS) 2002 dairy survey indicate that 11.2% of dairy calves are born dead. For calves born alive, preweaning is the time period of greatest risk for diseases as 10.5% of preweaned calves die compared to 2.8% of weaned calves. Scours and respiratory problems are the two greatest disease challenges in the preweaning period with 62.1% of calf mortalities being attributed to scours and 21.3% of calf mortalities attributed to respiratory diseases.

Effect of Improving Trace Mineral Status on Incidence of Immune Function

Research examining the effect of trace mineral status on disease incidence in dairy replacement animals is limited. However, there is a considerable amount of data examining the effect of improving trace mineral status of livestock and poultry on disease incidence and severity.

Zinc is a trace mineral that has a crucial role in maintaining the functionality of the immune system. The role of Zn in maintaining epithelial tissue integrity, a key component of the innate immune system, is evident as parakeratotic lesions of skin, rumen papillae and esophageal mucosa are common manifestations of a Zn deficiency (Miller et al., 1988). Thus it is not surprising that coccidia-challenged broilers fed 40 ppm of Zn from the more bioavailable Zn source, Zn AA complex, had lower intestinal lesion scores than those fed 40 ppm of Zn from Zn sulfate (Rapp et al., 2001, Figure 1).

Zinc affects cell-mediated immune response as evidenced by calves fed a Zn deficient diet for 22 days eliciting only minimal swelling in response to an intradermal injection of phytohemagglutinin (Figure 2, Engle et al., 1997). Zinc status has also been shown to affect humoral immune response of calves. Replacing Zn oxide with Zn Met increased antibody titers following vaccination against bovine herpes virus I (infectious bovine rhinotracheitis virus (IBRV); Spears et al., 1991).

Thus, improved Zn status may explain why calves fed additional Zn in the form of Zn Met performed better than control calves when disease challenged. In a study conducted in Texas, dry
Figure 1. Effect of Zn source on intestinal lesion scores of broilers exposed to coccidia (Rapp et al., 2001).

- a 40 ppm of Zn from Zn sulfate
- b ZINPRO® zinc methionine (40 ppm Zn)
- c ZinPLEX® (ZINPRO zinc methionine and LyZin® zinc lysine, 40 ppm Zn)
- d Availa® zinc amino acid complex (40 ppm Zn)

xyz Means lacking a common superscript letter differ (P<0.05)

Figure 2. Effect of feeding calves a diet with adequate levels of Zn (control, 40 ppm Zn, ZnSulfate) or a diet with no added Zn (17 ppm Zn) on cell-mediated immune response (Engle et al., 1997).

Cell-mediated immune response was measured as swelling response to an intradermal injection of phytohemagglutinin.

yz Means at single time points lacking a common superscript letter differ (P <0.05)
matters intakes dropped less and returned faster to pre-challenge intakes when IBRV-challenged calves were supplemented with Zn Met as compared to no Zn supplementation (Figure 3, Chirase et al., 1991). Furthermore, rectal temperatures were higher in unsupplemented calves than Zn Met supplemented calves suggesting greater immune incompetence.

In a follow-up study, Zn oxide and Mn oxide were compared with Zn Met and Mn Met in mitigating the effects of a disease challenge (Chirase et al., 1994). In comparison to unsupplemented control calves, supplementing IBRV-challenged calves with Zn Met and Mn Met minimized the drop in dry matter intake and suppressed the increase in rectal temperatures. In comparison, changes in dry matter intake and rectal temperatures were similar between the control calves and calves supplemented with Zn oxide and Mn oxide. Not surprisingly, the drop in body weight following the IBRV-challenge was lowest for calves supplemented with Zn Met and Mn Met.

While mitigation of disease severity for calves supplemented with Zn Met and Mn Met is due in part to improved Zn status, the role of improved Mn status in decreasing disease severity should not be ignored. Manganese affects immune function as it is involved in the removal of superoxides through the activity of the Mn containing enzyme, superoxide dismutase (Keen and Zidenberg-Cherr, 1990).

In addition to Zn and Mn, Cu and Co have important roles in immune function. Research with rats and mice indicate that both cell-mediated and humoral immunity are greatly depressed by Cu deficiency (Spears, 2000). Research examining the effect of Co on immune function is limited, but it has been shown that a Co deficiency affects neutrophil function and resistance of animals to parasitic infections (Spears, 2000).

Feeding a combination of Zn Met, Mn Met, Cu Lys and Co glucoheptonate to stressed calves, in place of inorganic sources of these trace minerals, resulted in improved antibody titer response to IBRV vaccination and cell-mediated immunity as noted by increased skin-swelling response 48 hours after intradermal injection of phytohemagglutinin (George et al., 1997). Calves received the IBRV vaccination upon entering the feedlot and cell-mediated immune response was measured 21 days later. Supplementing calves with three times the

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Figure 3. Change in dry matter intake (DMI) for steers fed Zn Met and challenged with IBRV (Chirase et al., 1991).
recommended level of Zn Met, Mn Met, Cu Lys and Co glucoheptonate for the first 14 days in the feedlot and then the recommended level of these products for remainder of the 28 day study, did not improve antibody titer response to IBRV vaccination. However, calves supplemented with the higher amounts of trace minerals had improved cell-mediated immune response at Day 21 as noted by increased skin-swelling response to the intradermal phytohemagglutinin injection (Figure 4).

With increased trace mineral status resulting in improved vaccination responses, improved cell-mediated immune responses and improved gut integrity, it is not surprising that trace mineral status reduces morbidity in calves. Nebraska researchers found that increasing trace mineral status of calves by supplementing cow/calf pairs with a combination of Zn met (482 g Zn/d per cow/calf pair), Mn Met (266 g Mn/d per cow/calf pair), Cu Lys (166 mg Cu/d per cow/calf pair) and Co glucoheptonate (33 mg Co/d per cow/calf pair) reduced morbidity of calves while in the feedlot, in comparison to calves supplemented with no trace minerals or only inorganic trace minerals (Figure 5; Grotelueschen et al., 2001). It should be noted that despite the fact that cow/calf pairs fed inorganic trace minerals received twice the amount of Zn, Mn, Cu and Co as cow/calf pairs receiving the metal AA complexes and Co glucoheptonate, Zn and Cu content of liver was higher in calves receiving the metal AA complexes and Co glucoheptonate.

**Effect of Improving Trace Mineral Status on Feed Efficiency**

Feed costs are by far the largest expense in rearing dairy replacement heifers, comprising approximately 60% of expenses (Moore et al., 2005). Reducing feed shrink and improving conversion of feed to gain are important means by which dairy producers can help reduce the cost of raising heifers from birth to first parturition.

Research has not examined the effect of improving trace mineral status on feed efficiency of dairy replacement heifers. However, a sizeable database exists demonstrating that improved trace mineral status enhances conversion of feed to gain in growing beef cattle. Engle et al. (1995) found that feed conversion efficiency of growing calves was reduced by more than 40%, 18 days after

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Figure 4. Effect of trace mineral level and source on primary cell-mediated immune response of calves 21 days after arrival in the feedlot (George et al., 1997).
Figure 5. Effect of trace mineral level and source on Cu and Zn status and feedlot morbidity (Grotelueschen et al., 2001).

\[a\] 2X sulfate provided 947 mg Zn, 535 mg Mn, 265 mg Cu and 76 mg Co

\[b\] 4-Plex: ZINPRO zinc methionine, MANPRO manganese methionine CuPLEX copper lysine and COPRO cobalt glucoheptonate provided 482 mg Zn, 266 mg Mn, 166 mg Cu and 33 mg Co on cow/calf pair/d basis

\[\text{xyz Bars lacking a common superscript letter differ (} P < 0.05)\]
cattle began receiving a Zn deficient diet (Figure 6). A 22 trial feedlot summary found that supplementing growing beef cattle with 360 mg of Zn from Zn Met improved feed conversion by 4.05% (Figure 7; Zinpro TB-B- 9202-C).

Because most heifer diets are comprised primarily of forages, improving fiber digestion should improve feed efficiency. Allen (1988) observed, in vitro, that replacing Co sulfate with Co glucoheptonate numerically increased ADF and NDF digestion (Table 1). Similarly, Kincaid et al. (2003) observed that increasing Co supplementation of lactating dairy cows from 0 to 25 mg/hd/d numerically increased the conversion of feed to milk.

Figure 6. Effect of feeding calves a diet with adequate levels of Zn (control, 40 ppm Zn, ZnSulfate) or a diet with no added Zn (17 ppm Zn) on gain/feed (Engle et al., 1995).

Figure 7. Summary of 22 trials examining the effect of supplementing feedlot cattle with ZINPRO Zn Met on feed efficiency.
Development of Claw Lesions in Heifers Is a Risk Factor for Development of Claw Lesions in Lactation

According to the National Animal Health Monitoring Systems (2002) survey, 16.3% of dairy cows are culled due to lameness. However, this survey may underestimate dairy cows culled due to lameness because cows culled for low production (19.3%) or reproductive failure (26.5%) may have been lame, resulting in productive or reproductive failure. Lameness has been shown to reduce milk production (Hernandez et al., 2002b; Juarez et al., 2003) and reproductive performance (Sprecher et al., 1997; Hernandez et al., 2002a; Melendez et al., 2002). In addition, dairy producers tend to underestimate extent and severity of lameness within their herds (Whay et al., 2002).

Research indicates that mature cows that develop claw disorders are more prone to future reoccurrences of these claw disorders (Peterse, 1986; Raven, 1989; Enevoldsen et al., 1991). Recently Drendel et al. (2005) found that heifers, 12 months of age, that developed claw lesions were 27.7 times more likely to develop claw lesions in early lactation than heifers that did not develop claw lesions. At one-month prepartum, heifers that had claw lesions were 15.1 times more likely to have a claw lesion at 2 months postpartum. It should be noted that the claw lesions in heifers at 12 months of age and at one-month prepartum were of minor severity and the vast majority of heifers were not lame. Thus, preventing growing animals from developing even minor claw lesion must be a key management objective.

Incidence of Claw Lesions in Dairy Replacement Heifers

In a recent study, Drendel et al. (2005) found that at 12 months of age, 74.5% of heifers had a claw lesion. The predominant claw lesions at 12 months of age were white line separation (42.5% incidence), sole hemorrhage (35.9% incidence) and heel erosion (23.4% incidence). At one-month prepartum, 85.7% of heifers had a claw lesion, with heel erosion (60.6% incidence), sole hemorrhages (40.3% incidence) and white line separation (22.8% incidence) being the predominant lesions.

Ohio State researchers found that 84% of 12- to 13-month-old Holstein heifers had white line separation and 79% had sole hemorrhages, respectively (Hoblet et al. 2000). Vermunt and Greenough (1996) observed that 77% of 13-month-old Holstein heifers had sole hemorrhages. Similarly, in a survey of 1,141 females on 128 dairies in The Netherlands, researchers found that 70% of Friesian/Holstein heifers had sole hemorrhages at 40 week of age (Frankena et al., 1992). It should be noted that in this study, researchers observed sole hemorrhages in heifers as young as 11 weeks of age and that as age of heifers increased from 10 to 52 weeks of age, sole hemorrhages became increasingly more prevalent (Figure 8). Clearly, claw lesions are prevalent in dairy replacement heifers.

Table 1. Effect of Co source on diet digestibility and vitamin B\textsubscript{12} production in continuous culture fermentors (Allen, 1988).

<table>
<thead>
<tr>
<th>Item</th>
<th>Cobalt Glucoheptonate*</th>
<th>Cobalt Dextrolactone</th>
<th>Cobalt Sulfate</th>
</tr>
</thead>
<tbody>
<tr>
<td>True organic matter</td>
<td>56.6</td>
<td>56.6</td>
<td>57.4</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>32.8</td>
<td>27.8</td>
<td>29.0</td>
</tr>
<tr>
<td>Acid detergent fiber</td>
<td>41.0</td>
<td>34.7</td>
<td>38.5</td>
</tr>
<tr>
<td>Total nonstructural carbohydrates</td>
<td>89.7</td>
<td>91.0</td>
<td>89.3</td>
</tr>
<tr>
<td>Vitamin B\textsubscript{12} µg flow/d</td>
<td>72.0\textsuperscript{r}</td>
<td>71.3\textsuperscript{r}</td>
<td>65.4\textsuperscript{r}</td>
</tr>
</tbody>
</table>

* COPRO\textsuperscript{®} cobalt glucoheptonate
\textsuperscript{r} Means lacking a common superscript letter differ (\(P < 0.05\)
Risk Factors for Development of Claw Lesions in Heifers

In the survey of 128 dairies, Frankena et al. (1992) found that incidence of sole hemorrhages in heifers between 10 and 52 weeks of age varied substantially across herds. In approximately 17% of herds, less than 10% of heifers had a sole hemorrhage (Figure 9). In comparison, 14.1% of herds had a sole hemorrhage incidence rate in heifers of more than 70%. The variation in prevalence of sole hemorrhages across herds indicates that opportunities exist to reduce occurrence.

Factors observed to be associated with increased incidence of claw lesions include purchasing heifers (Frankena et al., 1992), rearing heifers indoors on concrete (Vermunt and Greenough, 1996), raising heifers in free stalls or on slatted floors (Frankena et al., 1992), feeding only forage (Frankena et al., 1992), not feeding any dry hay (Frankena et al., 1992), feeding a diet composed only of wet silage (Offer et al., 2001; Offer et al., 2003) and not using an insecticide on heifers (Frankena et al., 1992).

Due to the dynamics of horn generation in the bovine claw, the effect of environmental and nutritional insults may not be evident immediately. Horn on the dorsal surface of the claw grows at an average rate of 2.5 mm per month in beef cattle and 5 to 6 mm per month in more intensively fed cattle, like lactating dairy cattle (Greenough, 1997). The length of the dorsal wall of the medial claw is approximately 7.5 cm when measured from the apex to the coronary band (Greenough, 1997). Based upon these measurements, the horn capsule of the claw is a composite of horn produced over the past 12 to 15 months. So, it is plausible that interactions of environmental and nutritional conditions during rearing would require a considerable length of time to be fully expressed as claw lesions.

This hypothesis is supported by Webster (2002), who observed that heifers housed in straw yards for the last 4 weeks of gestation and the first 8 weeks of lactation had fewer sole hemorrhages and white line lesions than heifers housed in free stalls during this same period. Critically, Webster (2002) observed that heifers housed in straw yards for the last 4 weeks of gestation and first 8 weeks of lactation had fewer sole hemorrhages, even 16 weeks after being moved into free stalls, than heifers housed in free stalls for last 4 weeks of gestation and first 8 weeks of lactation.

Similarly, Offer et al. (2001) found that feeding meadow hay instead of grass silage for a period of 98 days to growing heifers, early in gestation,
reduced claw lesions in the first lactation (Offer et al., 2001). In a follow-up study, heifers were fed either a diet based upon grass silage or straw and concentrate (Offer et al., 2003). Heifers fed the grass silage diet had higher incidence of sole and white line lesions, not only during rearing but also during lactation. Even seven months after treatments were discontinued, heifers fed the grass silage diet during rearing had higher incidence of white line and sole lesions. Altogether, these results suggest (Offer et al., 2001; Offer et al., 2003; Webster, 2002) that dietary and environmental interactions related to claw lesions are complex and may extend over long time periods.

**Effect of Improving Trace Mineral Status of Dairy Heifers on Incidence of Claw Lesions**

Research examining the effect of improving trace mineral status on incidence of claw lesions in growing dairy replacements through the feeding of additional trace minerals in a more bioavailable form is very limited. Drendel et al. (2005) found that adding a combination of AA complexes of Zn, Mn and Cu and Co glucoheptonate (Availa®4) to a diet fortified in excess of NRC (2001) requirements for Zn, Mn, Cu and Co did not reduce incidence and severity of claw lesions during rearing. To the contrary, heifers fed the additional trace minerals in the form of AA complexes and a glucoheptonate salt actually had greater overall incidence and severity of lesions at one month prepartum (Table 2). In particular, incidence and severity of heel erosion and sole hemorrhages were greater one month prepartum.

The ineffectiveness of the combination of AA complexes of Zn, Mn and Cu and Co glucoheptonate lack explanation. Previous research has shown that feeding this combination of trace minerals to lactating dairy cows decreases claw lesions (Ballantine et al., 2002; Nocek et al. 2000). One plausible explanation is that one month prepartum, heifers had not received the trace mineral supplement for a sufficient time period. As noted above, horn on the dorsal surface of the claw grows at an average rate of 2.5 mm/mo in beef cattle and 5 to 6 mm/mo in more intensively fed cattle such as lactating dairy cattle (Greenough, 1997), resulting in the horn capsule of the claw being a composite of horn produced over the past 12 to 15 mo.

This may explain why at two months postpartum, these Wisconsin researchers found that
heifers fed the additional trace minerals in the form of AA complexes and a glucoheptonate salt actually had a decrease in overall incidence and severity of claw lesions (Table 2). In particular, incidence and severity of white line lesions and sole ulcers were decreased.

Furthermore, heifers not fed the additional trace minerals during the rearing phase that developed a claw lesion in early lactation had a 5503-lb reduction in their 305 Mature Equivalent milk yield (Table 3). In contrast, heifers fed the additional trace minerals during the rearing phase that developed a claw lesion in early lactation had only a 1901-lb decrease in their 305 Mature Equivalent milk yield.

Based upon the impact of claw lesions on first lactation performance of heifers, feeding this combination of Zn, Mn and Cu AA complexes and

<table>
<thead>
<tr>
<th>Claw Disorder</th>
<th>1 Months Prepartum</th>
<th>2 Months Postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>CTM</td>
</tr>
<tr>
<td>Overall claw disorder</td>
<td>3.8d</td>
<td>4.8e</td>
</tr>
<tr>
<td>Dorsal wall ridge</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Heel erosion</td>
<td>29.4d</td>
<td>34.5e</td>
</tr>
<tr>
<td>Abaxial wall fissure</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Double sole</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>White line separation</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Sole hemorrhage</td>
<td>9.7f</td>
<td>16.7g</td>
</tr>
<tr>
<td>Sole ulcer</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Digital dermatitis</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Interdigital dermatitis</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 2. Effect of feeding complexed trace minerals (CTM)* to growing heifers on incidence and severity of claw disorders as measured by the claw disorder incidence and severity (CIS) indexb during rearing and the subsequent lactation.

<table>
<thead>
<tr>
<th>Item</th>
<th>305 d ME, lb</th>
<th>Reduction in 305 d ME due to claw disorders*, lb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>CTM</td>
</tr>
<tr>
<td>Milk</td>
<td>26,079</td>
<td>26,315</td>
</tr>
<tr>
<td>Fat</td>
<td>893</td>
<td>906</td>
</tr>
<tr>
<td>Protein</td>
<td>776</td>
<td>791</td>
</tr>
<tr>
<td><strong>Reduction in 305 d ME due to claw disorders</strong>, lb</td>
<td><strong>-5503e</strong></td>
<td><strong>-1901</strong></td>
</tr>
<tr>
<td>Milk</td>
<td>-19.64</td>
<td>-38.80</td>
</tr>
<tr>
<td>Protein</td>
<td>-147.55</td>
<td>57.33</td>
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</tbody>
</table>

Table 3. Effect of feeding complexed trace minerals (CTM)* during the rearing phase on 305 d Mature Equivalents (ME) and the reduction in 305 d ME yields due to presence of claw disorders in early lactation.

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>CTM</th>
<th>P=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>26,079</td>
<td>26,315</td>
<td>0.67</td>
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<tr>
<td>Fat</td>
<td>893</td>
<td>906</td>
<td>0.71</td>
</tr>
<tr>
<td>Protein</td>
<td>776</td>
<td>791</td>
<td>0.58</td>
</tr>
</tbody>
</table>

| **Reduction in 305 d ME due to claw disorders**, lb | **-5503e** | **-1901** | — |
| Milk                              | -19.64   | -38.80 | — |
| Protein                           | -147.55  | 57.33 | — |

* Provided daily/heifer an additional 360 mg Zn, 200 mg Mn and 125 mg Cu from amino acid complexes, and 12 mg Co from Co glucoheptonate

b Regression coefficients of the relationship between 305 d ME milk, fat and protein yields and presence of claw disorders in early lactation.

c Differs from zero (P ≤ 0.15)
Co glucoheptonate to heifers for 12 months prior to calving at a cost per day of $0.035 per heifer yields a 24.1:1 return on investment (Figure 10). This assumes that primiparous cows have a claw lesion incidence of 73.8% at 2 months postpartum and milk price is $12/cwt. Even if incidence of claw lesions was only 8.8%, dairy producers would receive a 2:1 return on their investment in feeding Availa-4 to dairy replacement heifers (Figure 10).

Conclusions
Improving trace mineral status of heifers through feeding AA complexes of Zn, Mn and Cu, and Co glucoheptonate can help dairy producers grow replacements that are healthier, more efficient at converting feed to gain and that have fewer claw lesions. In addition, the nutritional practice of feeding AAs complexes of Zn, Mn and Cu and Co glucoheptonate to dairy replacement heifers has been shown to be highly cost-effective.

<table>
<thead>
<tr>
<th>Economics of Feeding Availa-4 to Dairy Replacements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUTS:</strong></td>
</tr>
<tr>
<td>Current incidence of claw lesions in first calf heifers at two months postpartum</td>
</tr>
<tr>
<td>Current milk price</td>
</tr>
<tr>
<td>Number of heifers calved/year</td>
</tr>
<tr>
<td>Average 305 Mature Equivalent milk yield for heifers</td>
</tr>
<tr>
<td>Availa-4 Investment</td>
</tr>
<tr>
<td>Additional Income/First Calf-Heifer By Feeding Availa-4 to Replacements</td>
</tr>
<tr>
<td>Additional Income/Herd By Feeding Availa-4 to Replacements</td>
</tr>
<tr>
<td>Return on Investment for Feeding Availa-4 to Dairy Replacements</td>
</tr>
<tr>
<td>Minimum Incidence of Claw Lesions In Herd Resulting in a 2:1 Return on Availa-4 Investment</td>
</tr>
</tbody>
</table>

**Assumptions:**
1. Research indicates that heifers that develop claw lesions in early lactation that were fed Availa-4 during the last 12 months of rearing have a 7.2% reduction in their 305 ME milk yield, while heifers not fed Availa-4 during the last 12 months of rearing that develop claw lesions in early lactation have 21.1% reduction in their 305 ME milk yield.
2. Research indicates that greater than 70% of heifers have a claw lesion at 2 months postpartum.
3. Profitability numbers assume that Availa-4 is fed for 365 days prior to calving.
4. Feeding Availa-4 to heifers during the rearing phase decreased incidence and severity of claw lesions at 2 months postpartum.
This decrease in incidence and severity of claw lesions in early lactation is not accounted for in this economic spreadsheet.

Figure 10. Economics of feeding a combination of Zn, Mn and Cu AA complexes and Co glucoheptonate to dairy replacement heifers.

References


Notes