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# DAIRY RESEARCH 2008

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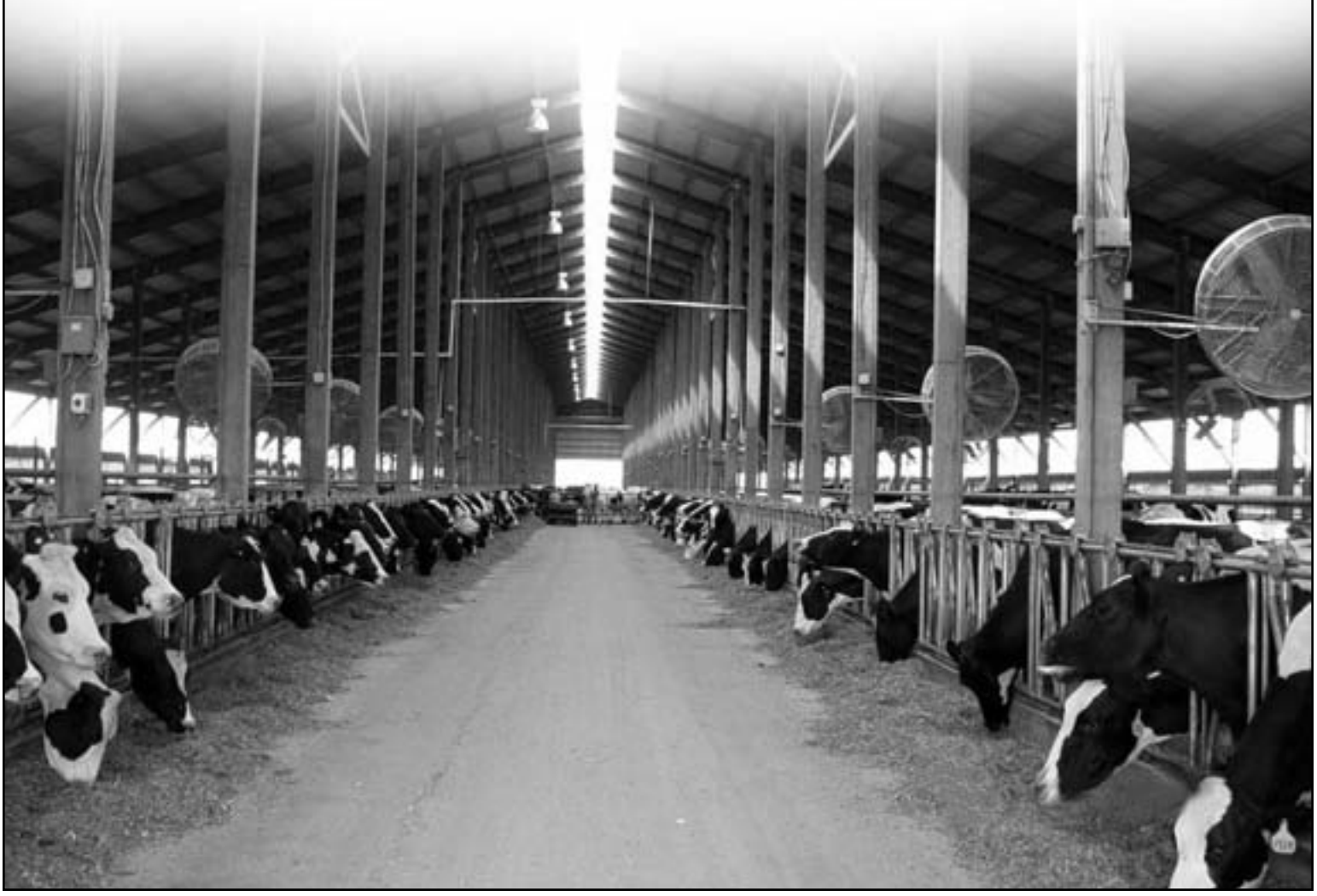
K-STATE Kansas State University

Kansas State University
Agricultural Experiment
Station and Cooperative
Extension Service

DAIRY TEAM
KANSAS STATE UNIVERSITY



# DAIRY DAYS PROGRAM

**Effects of alfalfa inclusion rate in diets based on wet corn gluten feed**
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**Impact of phosphorus source on utilization in lactating dairy cattle**
***Kevin Lager***

**Fertility after timed artificial insemination in response to a controlled internal drug release (CIDR) insert in lactating dairy cows**
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***John Smith***

## February 12, 2009
Valentino's Restaurant
Seneca, KS

## February 26, 2009
Whiteside Amish Community Building
Whiteside, KS

# DAIRY RESEARCH 2008

## Foreword

Members of the Dairy Team at Kansas State University are pleased to present the 2008 Dairy Research Report of Progress. Dairying continues to be a viable business and contributes significantly to the agricultural economy of Kansas. In 2007, dairy farms accounted for 2.9% or $296 million of all Kansas farm receipts, ranking seventh overall among all Kansas farm commodities. In the United States, Kansas had the greatest percentage increase in milk produced between 1999 and 2004 (+57.7%). During 2002, Kansas moved into the top 10 (#8) for milk production per cow. At the end of 2006, Kansas ranked #9 (20,920 lb). Currently, Kansas ranks 15th nationally in milk yield at 19,734 lb. Wide variation exists in the productivity per cow as indicated by the Heart of America Dairy Herd Improvement Association (DHIA) production testing program. Nearly 109,000 cows were enrolled in the DHI program from Kansas, Nebraska, Oklahoma, Arkansas, North Dakota, and South Dakota, including herds from Colorado (3), Iowa (22), Missouri (10), Montana (10), and Texas (1). A comparison of Kansas DHIA cows with all those in the Heart of America DHIA program for 2007 is shown in the following table.

**Comparison of Heart of America (HOA) Cows with Kansas Cows - 2007**

| Item | HOA | KS |
|---|---|---|
| No. of herds | 633 | 213 |
| No. of cows/herd | 175 | 131 |
| Milk, lb | 20,837 | 21,077 |
| Fat, lb | 771 | 787 |
| Protein, lb | 646 | 653 |
| SCC × 1,000 | 328 | 380 |
| Calving interval, mo. | 13.9 | 14.2 |

Most of this success occurs because dairy producers better manage what is measured in monthly DHI records. Continued emphasis should be placed on furthering the DHI program and encouraging use of its records in making management decisions. In addition, continued use of superior, proven sires and emphasis on use of superior genetics in artificial insemination programs is essential.

The excellent functioning of the Dairy Teaching and Research Center (DTRC) is due to the special dedication of our staff. We acknowledge our current DTRC staff for their dedication: Michael V. Scheffel (Manager), Daniel J. Umsheid, Alan J. Hubbard, and Kris Frey. Special thanks are given to Jamie Wilson, Cheryl K. Armendariz, and a host of graduate and undergraduate students for their technical assistance in our laboratories and at the DTRC.

Milk production from 256 cows at the DTRC continues to improve according to our last test day in October 2008. Our rolling herd average for milk surpassed 30,000 lb for the first time in August 2006. Now without bST use, our rolling herd averages for the October 2008 test day were 29,020 lb of milk, 1,024 lb of fat, and 907 lb of protein.

Thorough, quality research is not only time intensive and meticulous but also expensive. However, each dollar spent for research yields a 30 to 50% return in practical application. Those interested in supporting dairy research are encouraged to consider participation in the Livestock and Meat Industry Council (LMIC), a philanthropic organization dedicated to furthering academic and research pursuits by the Department of Animal Sciences and Industry. Additional details about the LMIC are found at the end of this report.

J. S. Stevenson, Editor
2008 Dairy Research Report of Progress

# DAIRY RESEARCH 2008

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# Biological Variability and Chances of Error

Variability among individual animals in an experiment leads to problems in interpreting the results. Although the cattle on treatment X may have produced more milk than those on treatment Y, variability within treatments may indicate that the differences in production between X and Y were not the direct result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences occur because of the treatment applied rather than from chance.

In some of the articles herein, you will see the notation "$P < 0.05$." That means the probability of treatment differences resulting from chance is less than 5%. If two averages are reported to be "significantly different," the probability is less than 5% that the difference is from chance, or the probability exceeds 95% that the difference resulted from the treatment applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or −1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as $2.5 \pm 0.1$. The 2.5 is the average; 0.1 is the "standard error." The standard error is calculated to be 68% certain that the real average (with an unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Using many animals per treatment, replicating treatments several times, and using uniform animals increases the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals in the experiment. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

# Alfalfa Hay Inclusion Rate in Wet Corn Gluten Feed Based Diets

*C. R. Mullins, K. N. Grigsby, and B. J. Bradford*

## Summary

In this experiment, we evaluated the effects of varying alfalfa inclusion rate in diets containing 31% wet corn gluten feed on a dry matter basis. Eighty lactating Holstein cows were allocated into groups of 10 and assigned to 1 of 8 pens balanced for parity, stage of lactation, and milk yield. Diets were formulated to contain 0, 7, 14, or 21% alfalfa on a dry matter basis. Diets containing greater proportions of alfalfa had less corn silage and soybean meal but more corn grain. Feed intake, milk production, body weight, and body condition score were monitored, and effects of increasing alfalfa inclusion rate were assessed. As more alfalfa was included in the ration, cows consumed more feed and had a tendency to produce more solids- and energy-corrected milk. In contrast, body weight gain decreased in diets with more alfalfa. These changes in milk and body weight indicate that metabolizable energy utilization shifted from body weight gain to milk production when more alfalfa was fed. With this in mind, an economic model was constructed to determine whether the added production from including alfalfa is enough to justify incorporating it in this type of ration. The model demonstrated that, despite minor losses in productivity, decreasing alfalfa inclusion rate may improve farm profitability by reducing feed costs and expenses associated with manure handling.

## Introduction

Dairy nutritionists have traditionally relied heavily on alfalfa in formulating lactation rations; however, since 1995, the amount of land devoted to alfalfa production has declined by nearly 4 million acres. Not surprisingly, as the availability of alfalfa has decreased, its cost has increased nearly 50% in the last 20 years. As a result, nutritionists and producers are reconsidering the role of alfalfa in dairy rations.

Costs of other traditional feedstuffs also are increasing. As a result, dairy producers are adopting novel diet formulation strategies to help keep feed costs in check. Some producers have incorporated corn milling coproducts, in particular wet corn gluten feed (**WCGF**), into the ration. Wet corn gluten feed is a high-fiber feedstuff that can easily be incorporated into dairy cattle diets; however, researchers have observed mixed results when feeding WCGF at high levels.

It is easy to chemically balance a ration that includes large amounts of WCGF, but physical characteristics of the total mixed ration (**TMR**) must be accounted for. Although WCGF is relatively high in fiber, the small fiber particles provide little physically effective fiber. Many investigators have shown that physically effective fiber is necessary for maintaining proper rumen function and preventing milk fat depression. In ruminants, physically effective fiber stimulates rumination, which facilitates saliva secretion that, in turn, buffers the rumen. Because of the mechanical stimulation provided by alfalfa particles, feeding high levels of WCGF without alfalfa could lead to milk fat depression. Therefore, the objective of this study was to evaluate the effects of varying alfalfa inclusion rate in diets containing 31% WCGF on overall cow performance.

## Experimental Procedures

Eighty lactating cows (averaging 178 days in milk) were allocated into groups of 10 and assigned to 1 of 8 pens. Pens were balanced for parity, stage of lactation, and milk yield. Diets containing 0, 7, 14, and 21% alfalfa on a dry matter (**DM**) basis were balanced for similar concentrations of crude protein, neutral detergent fiber, non-fiber carbohydrates, and starch. As a result, diets containing more alfalfa had less corn silage and soybean meal but more corn grain. Ingredients and nutrient composition of diets are listed in Table 1. Cows were fed a TMR twice daily, and amounts fed and refused were recorded daily by pen for each of the four 28-day periods. Feed samples of individual ingredients were collected on days 19, 21, 26, and 28 and composited by period for analysis. Cows were milked twice daily, and milk yield was recorded. Milk samples were collected for composition analysis from both milkings on days 21 and 28 of each period. Body weight was measured at the beginning and end of each period. Particle size of the TMR and refusals were measured by using the Penn State Particle Separator.

A breakeven analysis was conducted to determine whether the added milk production from including alfalfa is enough to justify feeding it in this type of ration. Changes in milk income, feed consumed, and feed costs were incorporated in a model to determine the relative difference in alfalfa vs. corn silage value (DM basis) at different milk:feed cost ratios. Diets compared were the 0 and 21% alfalfa treatments, and production and intake means for these treatments were used in this model. The value of alfalfa hay was fixed at $250/ton DM, and milk value was fixed at $20/hundred weight, whereas the value of corn silage and TMR cost varied with the alfalfa price differential and the milk:feed cost ratio, respectively. Addition of 21% alfalfa also allowed the exchange of 5% soybean meal for corn grain, and the cost differential between these commodities was set at $110/ton DM (soybean meal – corn grain). Changes to the fixed values had little effect on the results as presented, although the model was somewhat sensitive to the corn grain to soybean meal price differential.

## Results and Discussion

### Feed Intake, Milk Production, and Energetics

As the alfalfa inclusion rate increased, dry matter intake (**DMI**) increased ($P < 0.05$), and solids- and energy-corrected milk production tended ($P < 0.10$) to increase (Table 2). In contrast, as these variables either increased or tended to increase, body weight gain decreased ($P < 0.05$). As expected, increasing the alfalfa inclusion rate increased the proportion of large particles in diets, yet treatments did not affect milk fat yield or concentration. Lack of change in milk fat was partly because the amount of total fiber offered was similar across treatments. Furthermore, cows sorted against longer particles in the high alfalfa diets, resulting in smaller differences in particle sizes of the treatments as consumed.

Figure 1 represents the net energy used for body weight and milk production of cows consuming each diet. Because total net energy for productive use decreased with greater alfalfa inclusion, even as DMI increased, this relationship indicates that adding alfalfa hay decreased DM digestibility. In addition, because fecal production is highly dependent on DM digestibility, cows consuming diets that included more alfalfa probably produced more manure than cows on treatments with less alfalfa.

### Economic Analysis

Although feeding greater levels of alfalfa tended to increase energy-corrected milk production, it also led to greater DMI, leading one to question whether it is economically beneficial to have

alfalfa in the ration. According to the breakeven analysis presented in Figure 2, if the price differential between alfalfa hay and corn silage falls below the breakeven line at a given milk:feed cost ratio, it is profitable to incorporate alfalfa into this type of ration. However, on the basis of responses to the 0 and 21% alfalfa treatments in this study, adding alfalfa to diets with high WCGF inclusion rates may not be profitable in current market conditions.

**Table 1.** Ingredient and nutrient composition of dietary treatments

| | Dietary alfalfa | | | |
|---|---|---|---|---|
| Item | 0% | 7% | 14% | 21% |
| % As-fed | | | | |
| Corn silage | 58.0 | 50.9 | 42.8 | 33.3 |
| Wet corn gluten feed | 26.0 | 27.8 | 29.9 | 32.4 |
| Alfalfa | 0.0 | 4.1 | 8.7 | 14.2 |
| Cottonseed | 4.2 | 4.5 | 4.8 | 5.2 |
| Corn grain | 5.5 | 7.0 | 8.8 | 10.9 |
| Soybean meal | 2.8 | 2.0 | 1.1 | 0.0 |
| Molasses | 0.3 | 0.4 | 0.4 | 0.4 |
| Expeller soybean meal | 1.4 | 1.5 | 1.7 | 1.8 |
| Micronutrient premix | 1.8 | 1.8 | 1.8 | 1.8 |
| % Dry matter | | | | |
| Corn silage | 41.0 | 33.9 | 26.7 | 19.4 |
| Wet corn gluten feed | 30.9 | 31.1 | 31.4 | 31.6 |
| Alfalfa | 0.0 | 6.6 | 13.4 | 20.2 |
| Cottonseed | 7.3 | 7.3 | 7.4 | 7.5 |
| Corn grain | 9.7 | 11.6 | 13.5 | 15.6 |
| Soybean meal | 4.9 | 3.4 | 1.7 | 0.0 |
| Molasses | 0.4 | 0.4 | 0.4 | 0.4 |
| Expeller soybean meal | 2.5 | 2.5 | 2.6 | 2.6 |
| Micronutrient premix | 3.2 | 3.1 | 2.8 | 2.6 |
| Nutrients[1] | | | | |
| Dry matter, % as-fed | 52.5 | 55.8 | 59.5 | 63.9 |
| Crude protein | 16.5 | 16.5 | 16.7 | 16.7 |
| Neutral detergent fiber | 34.6 | 34.7 | 34.5 | 34.7 |
| Starch | 17.7 | 16.3 | 16.6 | 15.8 |
| Non-fiber carbohydrate | 36.0 | 36.0 | 36.4 | 36.5 |
| Ether extract | 3.8 | 3.7 | 3.6 | 3.6 |
| Ash | 9.1 | 9.0 | 8.8 | 8.6 |

[1]Nutrients other than dry matter expressed as a percentage of diet dry matter.

**Table 2.** Effects of treatments on performance of lactating cows

| | Dietary alfalfa[1] | | | | | *P* value | |
|---|---|---|---|---|---|---|---|
| | 0% | 7% | 14% | 21% | SEM | Linear | Quadratic |
| Dry matter intake, lb/day | 58.9 | 60.2 | 60.4 | 60.6 | 2.6 | 0.05 | 0.33 |
| Milk yield, lb/day | 68.1 | 68.6 | 69.9 | 69.0 | 3.3 | | * |
| Milk fat, % | 3.75 | 3.81 | 3.75 | 3.79 | 0.11 | 0.79 | 0.83 |
| Milk protein, % | 3.47 | 3.46 | 3.44 | 3.44 | 0.07 | 0.38 | 0.84 |
| Lactose, % | 4.77 | 4.75 | 4.81 | 4.76 | 0.03 | 0.64 | 0.44 |
| Somatic cell count, log | 2.17 | 2.19 | 2.18 | 2.22 | 0.06 | 0.46 | 0.80 |
| Milk urea nitrogen, mg/dL | 12.6 | 13.0 | 12.7 | 12.5 | 0.48 | 0.31 | 0.05 |
| Milk fat, lb/day | 2.51 | 2.58 | 2.60 | 2.60 | 0.13 | 0.21 | 0.44 |
| Milk protein, lb/day | 2.34 | 2.34 | 2.38 | 2.36 | 0.07 | 0.15 | 0.48 |
| Milk lactose, lb/day | 3.26 | 3.26 | 3.40 | 3.33 | 0.18 | 0.02 | 0.18 |
| Solids-corrected milk, lb/day | 65.9 | 66.6 | 67.9 | 67.3 | 3.0 | 0.07 | 0.30 |
| Energy-corrected milk, lb/day | 72.5 | 73.4 | 74.5 | 74.1 | 3.2 | 0.09 | 0.32 |
| Feed efficiency, ECM/DMI | 1.16 | 1.14 | 1.16 | 1.15 | 0.03 | 0.75 | 0.88 |
| Body weight change, lb/month | 50.7 | 39.7 | 24.7 | 20.9 | 7.9 | 0.02 | 0.69 |
| Body condition score change, unit/month | 0.014 | 0.031 | -0.006 | -0.013 | 0.041 | 0.57 | 0.80 |

[1]Dry matter basis.
*Significant treatment by period interaction.

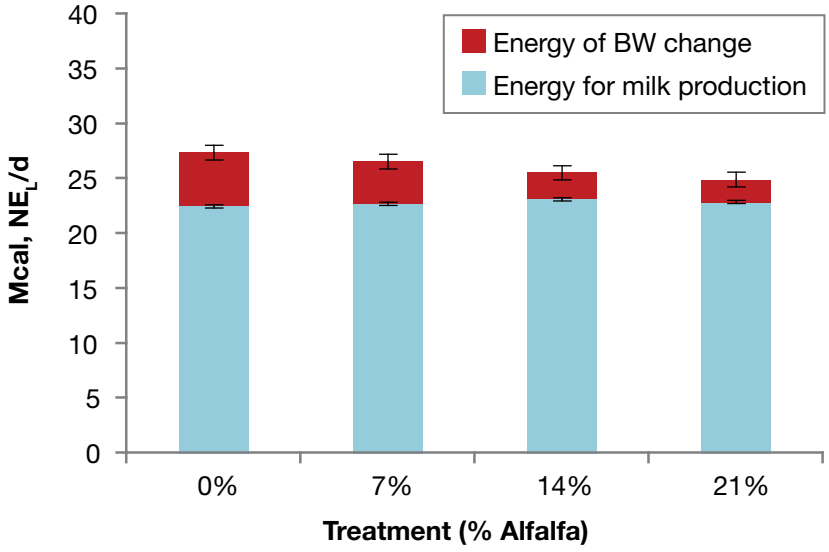


**Figure 1**. Total energy partitioned to milk production and body weight gain in cows fed varying levels of alfalfa. As alfalfa was added, total energy utilization tended ($P = 0.06$) to decrease linearly. For calculations, body weight gain was attributed to body fat gain.

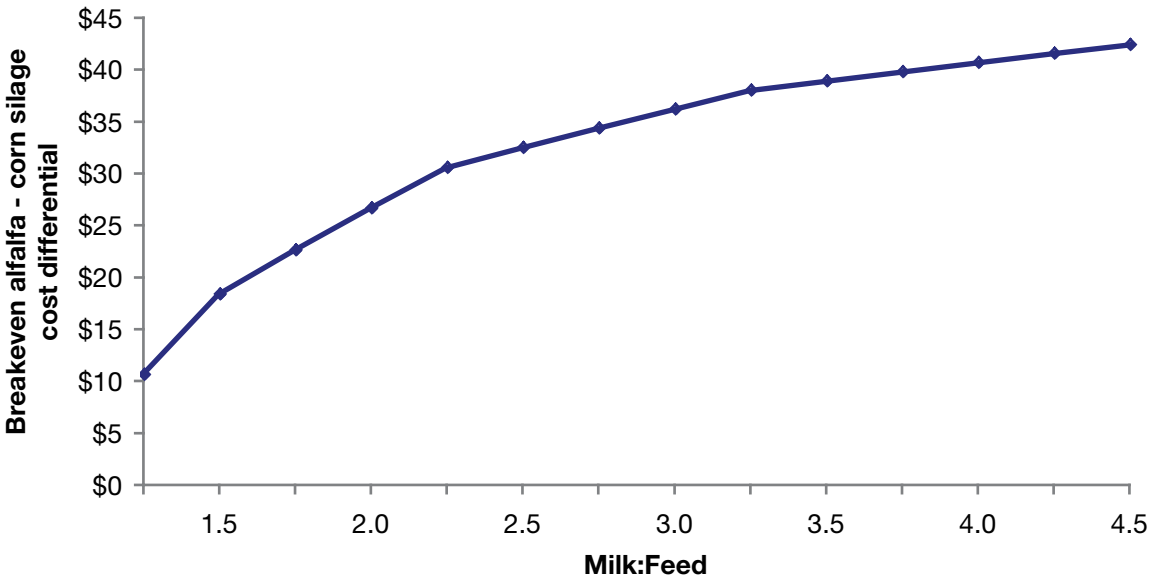


**Figure 2.** Breakeven analysis of alfalfa:corn silage cost differential. Breakeven analysis was conducted to determine whether the added milk production from including alfalfa is enough to justify feeding it in this type of ration. The line indicates the breakeven additional cost that can be paid for alfalfa compared with corn silage (per ton of dry matter) at a given milk:feed cost ratio. Values were calculated by using milk production and dry matter intake data from the 0 and 21% alfalfa diets.

# Dietary Molasses Enhances Ruminal Biohydrogenation and Partially Alleviates Diet-Induced Milk Fat Depression

*B. J. Bradford and E. C. Titgemeyer*

## Summary

Milk fat depression remains a problem on dairy farms, and in recent years, incorporation of distillers grains (typically with solubles added and often dried) has contributed to this problem on some farms. In this study, we evaluated whether molasses could prevent milk fat depression in cows fed a high-risk diet. Replacing up to 5% of dietary corn with cane molasses linearly increased the yield of short- and medium-chain fatty acids in milk, indicating a positive effect on de novo fatty acid synthesis in a milk fat depression environment. Molasses, however, tended to linearly decrease milk yield and linearly decreased milk protein yield, resulting in no net effect on energy- or solids-corrected milk yield. These results indicate that the potential exists for sources of dietary sugar to prevent milk fat depression, but further research is needed to determine when sugar sources might be most effective.

## Introduction

Production of ethanol is increasing rapidly in the United States. In the past 5 years alone, ethanol production capacity has more than doubled, as has production of dried distillers grains with solubles (**DDGS**). Although much work has been done to assess the effects of DDGS on productivity of lactating dairy cows, many nutritionists and dairy producers remain skeptical of its value in lactation diets. Reports of milk fat depression (**MFD**) in herds incorporating DDGS are widespread, and this issue continues to limit use of DDGS in the dairy industry. Milk fat depression is caused by an interaction of dietary factors that influence ruminal fermentation and availability of unsaturated fatty acids. Unique fatty acids produced in this rumen environment are capable of altering mammary function to decrease synthesis of milk fat. Therefore, unsaturated fatty acids provided by DDGS can lead to MFD.

One way to prevent MFD when feeding DDGS is to increase dietary fiber content; unfortunately, higher fiber diets limit energy intake and productivity. Increasing dietary sugar content may provide an alternative method of preventing MFD from DDGS. Fiber-digesting bacteria are thought to be primarily responsible for ruminal biohydrogenation of fatty acids, suggesting that dietary molasses may be capable of enhancing biohydrogenation of unsaturated fatty acids. Complete biohydrogenation of unsaturated fatty acids eliminates potential negative effects on milk fat synthesis; therefore, molasses may be capable of preventing diet-induced MFD. Our objective was to determine whether replacing corn grain with molasses at up to 5% of diet dry matter (**DM**) would prevent MFD from a high-concentrate ration including DDGS.

## Experimental Procedures

Twelve second-lactation Holstein cows (134 days in milk) were randomly assigned to square and sequence within square in a replicated 3 × 3 Latin square design balanced for carryover effects. The control diet, formulated with the intention of causing MFD, included 36.6% forage and 21.2% corn DDGS, resulting in a diet with 26.2% neutral detergent fiber, 46.4% non-fiber car-

bohydrate, and 4.4% crude lipid. The remaining 2 diets were identical to the control diet except for the inclusion of cane molasses at 2.5 or 5% of diet DM to replace a portion of the corn grain. Composition and nutrient densities for the experimental diets are shown in Table 1. A common base mix representing 95% of diet DM was prepared daily, and ground corn grain, molasses, or both were added to complete each total mixed ration. Throughout the experiment, cows were housed in a tie-stall facility, milked twice daily (0500 and 1600 hours), and fed twice daily (0630 and 1700 hours) for ad libitum intake.

Treatment periods were 28 days, with 14 days for diet adaptation and 14 days for sample and data collection. All cows were treated with Posilac (Monsanto, St. Louis, MO) on days 1 and 15 of each period. To avoid potential interactions of dietary treatments with the Posilac treatment schedule, feed samples, DM intake, milk yield, and milk samples were collected on days 16, 19, 22, 25, and 28 of each period. Two milk samples were collected at each milking on these days, and milk samples were analyzed to determine concentrations of fat, protein, lactose, and urea nitrogen (Heart of America DHIA laboratory, Manhattan, KS) as well as fatty acid profile.

One cow was removed from the study early in period 3 because of mastitis. Data were analyzed by using mixed models including the fixed effect of treatment and the random effects of period and cow. Linear and quadratic contrasts were used to assess the effects of molasses inclusion rate for each variable.

## Results and Discussion

Feeding a high-concentrate diet including 21% corn DDGS decreased milk fat concentration from 3.28% before the study to 2.61% during the study. Despite the extreme nature of the diet (predicted $NE_L$ density of 0.81 Mcal/lb DM), cows appeared healthy and ate well throughout the study. In addition, feed efficiency values (mean: 1.33 lb energy-corrected milk per pound of DM intake) suggest the control diet did not dramatically impair nutrient digestion.

### Productivity and Milk Fat Yield

Effects of molasses inclusion on productivity in this setting are shown in Table 2. Treatments had no effect on DM intake or feed efficiency. Increasing molasses inclusion rate tended ($P = 0.09$) to linearly decrease milk yield. Molasses, however, increased milk fat concentration (linear effect, $P < 0.001$; quadratic effect, $P = 0.09$), resulting in similar yields of fat- and solids-corrected milk across treatments. Despite the highly significant effect of molasses on milk fat concentration, milk fat yield was not significantly altered by treatment.

To further investigate the effects of dietary molasses on milk fat synthesis, we measured the profile of fatty acids in milk; this summary is shown in Table 3. Adding molasses linearly decreased ($P < 0.05$) yields of *trans*-10 C18:1 and total *trans*-C18:1 fatty acids in milk. These fatty acids are nearly always elevated in cases of MFD and can be used as markers of ruminal conditions that promote MFD. In contrast, molasses inclusion did not significantly alter yield of *trans*-10, *cis*-12 CLA, the fatty acid thought to be responsible for many cases of MFD. Nevertheless, the significant decrease in milk *trans* fatty acid secretion indicates that molasses inclusion enhanced ruminal fatty acid biohydrogenation.

In severe cases of MFD, both de novo fatty acid synthesis (responsible for short- and medium-chain fatty acids in milk) and use of circulating fatty acids (the source of long-chain fatty acids in milk) are typically decreased. In the current study, inclusion of molasses did not significantly al-

ter yields of C16 or long-chain fatty acids but linearly increased ($P < 0.01$) the yield of short- and medium-chain fatty acids. This fatty acid response indicates a specific effect of dietary molasses on de novo fatty acid synthesis in the mammary gland, resulting in partial alleviation of MFD.

## Milk Protein Yield

Increasing dietary molasses linearly decreased ($P = 0.03$) milk protein yield (Table 3), with the high molasses treatment causing a 7% decrease in protein yield. Dietary crude protein was similar across diets (Table 1), and neither corn grain nor cane molasses at 5% of diet DM provided a substantial amount of the dietary protein. Therefore, it is unclear why dietary molasses decreased milk protein synthesis. Nevertheless, this problem must be addressed before this approach to preventing MFD can be applied extensively in dairy nutrition.

**Table 1**. Ingredient and nutrient composition of diets[1]

| | Dietary molasses | | |
|---|---|---|---|
| | 0% | 2.5% | 5% |
| Ingredient | | | |
| Corn silage | 24.7 | 24.7 | 24.7 |
| Alfalfa hay | 11.9 | 11.9 | 11.9 |
| Corn DDGS[2] | 21.2 | 21.2 | 21.2 |
| Ground corn grain | 33.9 | 31.4 | 28.9 |
| Molasses | – | 2.5 | 5.0 |
| Soybean meal | 4.0 | 4.0 | 4.0 |
| Expeller soybean meal | 2.6 | 2.6 | 2.6 |
| Limestone | 1.1 | 1.1 | 1.1 |
| Trace mineral salt | 0.4 | 0.4 | 0.4 |
| Micronutrient premixes | 0.2 | 0.2 | 0.2 |
| Nutrient | | | |
| Dry matter | 64.3 | 64.1 | 63.9 |
| Crude protein | 17.4 | 17.2 | 17.1 |
| Neutral detergent fiber | 26.2 | 26.3 | 26.3 |
| Non-fiber carbohydrate | 46.4 | 46.3 | 46.2 |
| Ether extract | 4.4 | 4.4 | 4.3 |
| Ash | 5.5 | 5.7 | 5.9 |

[1] Values other than dry matter are expressed as a percentage of diet dry matter.
[2] Dried distillers grains with solubles.

**Table 2**. Effects of molasses inclusion rate on productivity of lactating dairy cows

| | Dietary molasses | | | | *P* value[1] | |
|---|---|---|---|---|---|---|
| | 0% | 2.5% | 5% | SEM | Linear | Quad |
| Dry matter intake, lb/day | 57.3 | 57.8 | 56.9 | 2.2 | 0.82 | 0.69 |
| Milk yield, lb/day | 82.9 | 81.4 | 78.3 | 6.6 | 0.09 | 0.80 |
| Milk fat, % | 2.61 | 2.65 | 3.01 | 0.21 | 0.001 | 0.09 |
| Milk protein, % | 3.35 | 3.32 | 3.31 | 0.09 | 0.25 | 0.88 |
| Milk lactose, % | 4.74 | 4.68 | 4.7 | 0.12 | 0.31 | 0.34 |
| Milk fat, lb/day | 2.16 | 2.14 | 2.32 | 0.22 | 0.15 | 0.39 |
| Milk protein, lb/day | 2.76 | 2.67 | 2.56 | 0.18 | 0.03 | 0.91 |
| Milk lactose, lb/day | 3.97 | 3.86 | 3.73 | 0.37 | 0.11 | 0.95 |
| Milk urea nitrogen, mg/dL | 12.5 | 11.7 | 11.6 | 0.7 | 0.04 | 0.44 |
| Fat-corrected milk, lb/day | 70.6 | 69.7 | 71.0 | 6.0 | 0.86 | 0.64 |

[1] Contrasts: Linear = linear effect of molasses inclusion rate; Quad = quadratic effect of molasses inclusion rate.

**Table 3.** Effects of molasses inclusion rate on milk fatty acid yield

| | Dietary molasses | | | | *P* value[1] | |
|---|---|---|---|---|---|---|
| Yield, lb/day | 0% | 2.5% | 5% | SEM | Linear | Quad |
| *trans*-10 C18:1 | 0.073 | 0.060 | 0.050 | 0.014 | 0.02 | 0.88 |
| Total *trans* C18:1[2] | 0.114 | 0.108 | 0.097 | 0.011 | 0.04 | 0.70 |
| Total unsaturated | 0.90 | 0.89 | 0.87 | 0.06 | 0.52 | 0.86 |
| Short- and medium-chain (< C16) | 0.58 | 0.58 | 0.69 | 0.09 | 0.01 | 0.17 |
| C16 | 0.59 | 0.57 | 0.61 | 0.06 | 0.31 | 0.18 |
| Long-chain (> C16) | 0.99 | 1.01 | 1.00 | 0.07 | 0.91 | 0.78 |

[1] Contrasts: Linear = linear effect of molasses inclusion rate; Quad = quadratic effect of molasses inclusion rate.
[2] Includes *trans*-9, *trans*-10, and *trans*-11 C18:1.

# High Inclusion Rate of Wet Corn Gluten Feed on Performance of Late-Lactation Holstein Cows: Preliminary Results

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## Summary

A novel diet formulation strategy incorporating wet corn gluten feed at 47% of diet dry matter was evaluated in late-lactation cows. Diets were formulated for similar protein and energy concentrations with dramatic differences in forage sources. Milk fat and protein concentrations increased with the high wet corn gluten feed inclusion rate, and this diet tended to increase milk fat yield. The preliminary work indicates that very low cost rations incorporating wet corn gluten feed may be formulated to maintain milk production, at least in late-lactation cows.

## Introduction

In recent years, use of fermentation coproducts as an alternative energy source for animal feed has increased. The primary coproduct of the wet milling industry is wet corn gluten feed (**WCGF**). Traditionally, most dairy nutritionists have been hesitant to include WCGF at more than 25% of diet dry matter (**DM**); however, previous research at Kansas State University has demonstrated that incorporation of WCGF at up to 36% of DM increased milk production. Wet corn gluten feed is a relatively energy-dense feed that does not promote ruminal acidosis, suggesting that WCGF could replace an even greater combination of forage and concentrate, thus decreasing ration costs. The aim of this preliminary study was to determine the effects of a high inclusion rate of WCGF (47% of DM) on milk and milk component yield.

## Experimental Procedures

Twenty open, multiparous, late-lactation Holstein cows (374 days in milk) were randomly allocated to 2 pens of 10 cows each for a 2-period crossover design study. Periods were 21 days, with 17 days for diet adaptation and 4 days for data and sample collection. Cows were housed in adjacent freestall pens, fed once daily, and milked 3 times daily (0400, 1200, and 2000 hours). One diet was formulated to incorporate a high concentration of WCGF while meeting all nutrient requirements. The second diet was the normal high group ration fed at the Kansas State University Dairy Unit (Manhattan, KS); this ration includes 34% WCGF. Composition of the experimental diets is shown in Table 1.

Milk yield was recorded at each milking for the final 4 days of each period. Milk samples were collected on the final day of each period for analyses of fat, true protein, lactose, urea nitrogen, and somatic cells (Heart of America DHIA laboratory, Manhattan, KS). Data were analyzed by mixed model analysis including fixed effects of pen and treatment and the random effects of milking time within period and cow within pen.

## Results and Discussion

Milk yield was not significantly affected by treatment, nor were energy- or fat-corrected milk yield (Table 2). Differences were noted, however, for fat and protein concentrations ($P = 0.006$ and $P = 0.004$, respectively) in favor of the WCGF treatment. The WCGF treatment tended

($P = 0.09$) to increase milk fat production and increased milk urea nitrogen ($P = 0.03$) relative to the control treatment.

Incorporating a large amount of prairie hay in the WCGF diet provided more than enough effective fiber, evidenced by the fact that milk fat concentration increased to 4.14% when cows were fed this diet. In addition, cows seemed to sort against the prairie hay in this diet, suggesting that the diet consumed actually contained even less forage fiber. These results indicate that WCGF fiber can contribute substantially to the fiber requirement of lactating cows and encourage further investigation of diets incorporating large amounts of non-forage fiber sources.

**Table 1.** Ingredient composition of diets

| | Treatment | |
|---|---|---|
| Ingredient, % dry matter | Control | WCGF[1] |
| Alfalfa hay | 13.9 | – |
| Prairie hay | – | 20.9 |
| Corn silage | 21.8 | – |
| WCGF[1] | 33.8 | 47.1 |
| Cottonseed | 5.0 | 7.4 |
| Dry-rolled corn | 17.1 | 16.8 |
| Expeller soybean meal | 4.9 | 3.8 |
| Menhaden fish meal | 0.4 | – |
| Micronutrient premix | 3.1 | 4.0 |

[1]Wet corn gluten feed (Sweet Bran, Cargill, Inc., Blair, NE).

**Table 2.** Effect of treatment on performance of late-lactation Holsteins

| | Treatment | | | |
|---|---|---|---|---|
| | Control | WCGF[1] | SEM | *P* |
| Milk yield, lb/day | 42.3 | 41.0 | 3.7 | 0.59 |
| Energy-corrected milk, lb/day | 43.9 | 45.9 | 4.4 | 0.45 |
| Fat-corrected milk, lb/day | 42.8 | 45.4 | 4.4 | 0.32 |
| Fat % | 3.70 | 4.14 | 0.2 | 0.006 |
| Fat yield, lb/day | 1.52 | 1.72 | 0.02 | 0.09 |
| Protein % | 3.37 | 3.43 | 0.6 | 0.004 |
| Protein yield, lb/day | 1.46 | 1.39 | 0.01 | 0.72 |
| Lactose % | 4.61 | 4.57 | 0.1 | 0.29 |
| Lactose yield, lb/day | 1.98 | 1.92 | 0.02 | 0.44 |
| Milk urea nitrogen, mg/dL | 14.0 | 14.5 | 0.4 | 0.03 |
| Somatic cell count | 198 | 239 | 75 | 0.13 |

[1]Wet corn gluten feed (Sweet Bran, Cargill, Inc., Blair, NE).

# Progesterone, Follicular, and Estrual Responses to Progesterone-Based Estrus and Ovulation Synchronization Protocols at Five Stages of the Estrous Cycle

*J. S. Stevenson*

## Summary

The objective of this study was to monitor changes in ovarian status in heifers exposed to a progesterone insert with or without concurrent gonadotropin-releasing hormone (GnRH) injection. Estrus was manipulated in 283 heifers (31 breeding clusters) by administering GnRH, progesterone, and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) at 5 stages of the estrous cycle. Estrus was presynchronized with a progesterone insert for 7 days before $PGF_{2\alpha}$ was administered 24 hours before insert removal. Successive clusters of heifers were assigned to treatments (2 heifers per treatment) on cycle day 2, 5, 10, 15, and 18. Treatments consisted of a progesterone insert (day 0) for 7 days plus (1) $PGF_{2\alpha}$ on day 6, 24 hours before insert removal (early PGF); (2) GnRH on day 0 + early $PGF_{2\alpha}$ (GnRH + early PGF); (3) $PGF_{2\alpha}$ at insert removal (late PGF); or (4) GnRH on day 0 + late PGF (GnRH + late PGF). Controls received GnRH on day 0 and $PGF_{2\alpha}$ on day 7. Ovaries were scanned by transrectal ultrasonography on days 0, 2, 7, 9, and 11 to assess follicle diameters and ovulation. Blood was collected on days 0, 2, 6, 7, 8, and 9 to quantify serum concentrations of progesterone. Insemination occurred after detected estrus or by timed artificial insemination (TAI) 64 hours after insert removal. Only 25% of 141 GnRH-treated heifers ovulated by day 2; twice as many ovulated when treatment was initiated on day 5 (46.4%) than on other cycle days (20.3%). Compared with controls, progesterone concentration was greater in all progesterone-treated heifers on days 2 and 6. Early- vs. late-PGF treatment resulted in less progesterone on days 7 and 8. Pregnancy rates were less after TAI (44%) than after detected estrus (56%) and less in controls than in all progesterone treatments. Heifers in which treatments were initiated on day 10 of the cycle had the most consistent (estrus vs. TAI) pregnancy rates (65.4%) compared with heifers in which treatments were initiated on other cycle days. Compared with controls, more progesterone-treated heifers ovulated by 96 hours after insert removal. Application of the progesterone insert reduced variance of the interval to estrus after insert removal (or $PGF_{2\alpha}$ injection in controls) by 1.6-fold compared with controls. These results do not support use of GnRH in a progesterone-based synchronization protocol.

## Introduction

A timed artificial insemination (**TAI**) protocol for heifers that provides consistently acceptable pregnancy rates is lacking. Attempts to use the Ovsynch protocol as a TAI protocol for dairy heifers have proved disappointing because of poor fertility of heifers with premature expression of estrus between the first GnRH injection and $PGF_{2\alpha}$. When estrus occurs prematurely after $PGF_{2\alpha}$, a single TAI will not produce a high likelihood of conception. Most heifer developers in the beef and dairy industries desire acceptable protocols that employ TAI.

Earlier research in heifers using a progesterone-releasing intravaginal device (**PRID**), norgestomet implants, and the progesterone-releasing controlled internal drug release (**CIDR**) insert confirms the benefit of using a progestin to prevent premature expression of estrus. Expression of estrus in heifers was reported in those studies after various treatment combinations of progestins (PRID for 6 or 7 days, norgestomet for 7 days, or CIDR for 7 days, respectively) and $PGF_{2\alpha}$ given at or 24 hours before progestin withdrawal. Estrus tended to be more closely synchronized in heifers treated with $PGF_{2\alpha}$ 24 hours before progestin withdrawal than in those treated with $PGF_{2\alpha}$ concurrent with progestin removal or with $PGF_{2\alpha}$ alone. When $PGF_{2\alpha}$ was injected 24 hours before removal of the PRID or norgestomet, 76% of treated heifers were in estrus during a 24-hour period.

A recent study in beef heifers employed GnRH, progesterone (CIDR), and $PGF_{2\alpha}$ and combinations of detected estrus before AI, TAI, or both. In that 12-location study, the treatment in which GnRH was administered concurrently with a 7-day progesterone insert and TAI conducted 60 hours after insert removal and $PGF_{2\alpha}$ injection consistently produced the best pregnancy rates across locations. Necessity of the upfront GnRH injection is questionable because small differences (2.8 to 4 percentage points) in pregnancy rates were detected for heifers receiving and not receiving that injection.

The hypothesis of the current experiment was that including a progestin in a GnRH + $PGF_{2\alpha}$ protocol could prevent premature expression of estrus to facilitate TAI without loss of fertility. Variation in fertility may depend on effectiveness of the upfront GnRH injection to ovulate a dominant follicle. Further, turnover of a dominant follicle in nulliparous heifers is less successful than in lactating dairy cows, and little is known about follicle turnover or ovulatory response to GnRH in heifers treated concurrently with progesterone.

The objective of the current study was to assess follicular responses, ovulation, luteal function (concentrations of progesterone in serum), and incidences of estrus in response to combinations of GnRH, $PGF_{2\alpha}$, and progesterone applied for synchronization of estrus, ovulation, or both in nulliparous replacement heifers. An ancillary objective was to monitor pregnancy rates to determine whether a TAI protocol was feasible after using protocols consisting of GnRH, $PGF_{2\alpha}$, and progesterone.

## Experimental Procedures

Holstein heifers ranging in age from 11.6 to 16.5 months (13.3 ± 0.95 months; mean ± SD) and body weight from 315 to 501 kg (410 ± 34 kg; mean ± SD) were housed at the Kansas State University Dairy Teaching and Research Center (Manhattan, KS) and maintained on dry lots with covered freestalls and a concrete feed apron. Heifers were fed a total mixed ration consisting of chopped prairie or alfalfa hay, corn or milo grain, soybean meal, and minerals and vitamins to exceed National Research Council guidelines for growing heifers.

Estrous cycles of dairy heifers (electronic estrus-detection patches were applied; HeatWatch, Cow Chips, LLC, Denver, CO) were presynchronized by placing a progesterone insert containing 1.38 g progesterone (Eazi-Breed CIDR, Pfizer Animal Health, New York, NY) for 7 days and administering 25 mg $PGF_{2\alpha}$ (Lutalyse, Pfizer Animal Health, New York, NY) 24 hours before insert removal. After detection of estrus, heifers were assigned randomly to treatment schemes at 5 stages of the estrous cycle (days 2, 5, 10, 15, and 18).

Between February 2003 and March 2006, estrous cycles of 31 clusters of heifers (10 heifers per cluster except for 8 clusters that varied in size from 5 to 12 heifers) were presynchronized as described previously to initiate treatments in a rotating pattern starting on cycle day 2, 5, 10, 15, and 18, and then that pattern was repeated during the course of the experiment. Generally, 2 heifers per cluster were assigned randomly to each of 5 treatment schemes (Figure 1) consisting of a progesterone insert (day 0) for 7 days plus (1) 25 mg of $PGF_{2\alpha}$ (Lutalyse) on day 6, 24 hours before insert removal (early PGF); (2) 100 µg GnRH (Cystorelin, Merial, Athens, GA) on day 0 + $PGF_{2\alpha}$ on day 6 (GnRH + early PGF); (3) $PGF_{2\alpha}$ at insert removal (day 7; late PGF); or (4) 100 µg GnRH on day 0 + late $PGF_{2\alpha}$ (GnRH + late PGF) and (5) controls, which only received GnRH on day 0 and $PGF_{2\alpha}$ on day 7.

Blood was collected from a coccygeal blood vessel on days 0, 2, 6, 7, 8, and 9 (Figure 1). Blood sera concentrations of progesterone were later quantified by radioimmunoassay. Ovaries were examined by transrectal ultrasonography on days 0, 2, 7, 9, and 11 from initiation of each synchronization treatment to assess diameter of all follicles > 5 mm (days 0, 2, 6, 7, and 9), evidence for ovulation on day 2 in heifers treated with GnRH on day 0, and evidence for post-AI ovulation (day 11 or 96 hours after insert removal).

Heifers were inseminated either on the basis of standing estrus (detected by HeatWatch) or at 63.7 ± 0.8 (SD) hours (range of 61 to 65 hours) after removal of the insert. Pregnancy was diagnosed by transrectal ultrasonography at 32 or 33 days after AI. Presence of a viable embryo (heartbeat) was evidence for a confirmed pregnancy. Pregnancy rates were calculated as number of heifers pregnant after AI divided by total number of heifers inseminated.

## Results and Discussion

Heifers in 2 treatments received GnRH concurrent with insertion of the progesterone insert; the control (no progesterone) received GnRH at the same time. The proportion of heifers with new ovulatory structures was evaluated 48 hours after GnRH injection. Only 25.1% of 141 heifers had new luteal structures, and a new CL was detected 48 hours after progesterone treatment in 1 heifer on cycle day 2 (Table 1). Proportions were similar among the 3 treatments in which GnRH was administered. More ($P < 0.05$) heifers ovulated on cycle day 5 than at any other stage of the cycle. No interaction was detected between stage of cycle and treatment. Concurrent administration of progesterone via the insert did not reduce subsequent ovulation because proportions of control heifers having a new luteal structure 48 hours after GnRH: day 2 (22.2%, 2/9); day 5 (55.6%, 5/9); day 10 (11.1%, 1/9); day 15 (30%, 3/10; and day 18 (27.2%, 3/11) were similar to GnRH- and progesterone-treated heifers: day 2 (21.1%, 4/19); day 5 (42.1%, 8/19); day 10 (22.2%, 4/18); day 15 (21.1%, 4/19); and day 18 (11.1%, 2/18).

Regardless of treatment, stage of estrous cycle at onset of treatment influenced largest follicle diameter on experimental day 2 because late-cycle heifers (day 15 = 9.4 ± 0.6 mm and day 18 = 8.6 ± 0.6 mm) had larger ($P < 0.05$) follicles than cycle day 10 heifers (6.1 ± 0.7 mm). By day 7, these differences were negligible, but by day 9, the largest follicle was greater ($P < 0.05$) in diameter for heifers initiating treatment on cycle days 2 (13.5 ± 0.4 mm), 10 (13.3 ± 0.4 mm), and 18 (14.6 ± 0.5 mm) than on cycle day 5 (11.7 ± 0.4 mm).

Concentrations of progesterone assessed on experimental days 0, 2, 6, 7, 8, and 9 are illustrated in Figure 2. At the onset of treatment, concentration of progesterone did not differ among heifers assigned to various treatments. By 48 hours after onset of treatment, progesterone-treated

heifers had greater ($P < 0.001$) concentrations than controls. This difference ($P < 0.05$) persisted until day 6, but among progesterone-treated heifers, those that received GnRH tended ($P = 0.08$) to have greater concentrations of progesterone than those not treated with GnRH. On day 7, 24 h after early PGF heifers were injected with PGF2α, progesterone was reduced compared with late PGF heifers. By day 8, 24 hours after insert removal, early PGF heifers tended ($P = 0.08$) to maintain lower concentrations of progesterone than late PGF heifers. By day 9, all progesterone-treated heifers had less ($P < 0.001$) progesterone than controls.

Distribution of estrus after insert removal on experimental day 7 is illustrated in Figure 3. Included in this comparison are combined treatment responses and presynchronizaton response of all heifers (pre-early PGF) in which heifers received a progesterone insert for 7 days and $PGF_{2\alpha}$ was injected 24 hours before insert removal (as in the early PGF treatment). Injection of GnRH on day 0 had no effect on onset of estrus; thus, the 2 early PGF treatments were combined as were the 2 late PGF treatments.

Among progesterone-treated heifers, distribution of estrus was shifted slightly to the left for those treated with $PGF_{2\alpha}$ 24 hours before insert removal compared with those receiving $PGF_{2\alpha}$ at insert removal. Both the pre-early PGF and early PGF (treated similar to pre-early PGF) had similar distribution patterns. Mean intervals to estrus were 44.8 ± 2.1 (pre-early PGF), 45.3 ± 3.2 (early PGF), 52.6 ± 3.3 (late PGF), and 33.4 ± 4.8 hours (control). Variances were 1,013, 829, 768, and 2,718, respectively. Variance of the first 3 groups was less ($P < 0.001$) than that of the control (Levene's test). Distribution pattern of controls was more variable because no progesterone insert was used to prevent premature expression of estrus in heifers started on treatment on cycle days 15 and 18.

Although heifers receiving $PGF_{2\alpha}$ 24 hours before insert removal were in estrus 2 to 10 hours earlier than comparable late PGF heifers, interval to estrus did not differ. Controls had a shorter ($P < 0.05$) interval to estrus than all heifers receiving progesterone inserts. Variances also differed ($P < 0.001$) among treatments and were 1.3 to 1.6 greater in control than progesterone treatments.

Post-treatment ovulation by 96 hours after insert removal is reported in Table 1. Incidence of ovulation was less ($P < 0.05$) in controls compared with progesterone treatments. Day of cycle at which treatment was initiated affected ($P = 0.001$) ovulation. Least incidence of post-treatment ovulation occurred in heifers initiating treatment on cycle day 2, and the best incidence of ovulation was detected in cycle day 10 heifers. Reduced post-treatment ovulation in control heifers was a result of premature expression of estrus and early ovulation before treatment with PGF2α and more luteolytic failures.

Pregnancy rates were recorded, but inadequate numbers of heifers were treated to detect potential differences in fertility (Table 2). Nonetheless, pregnancy rates in control heifers differed ($P < 0.05$) from those in heifers that received progesterone, and pregnancy rates after TAI were less ($P < 0.05$) than those in heifers inseminated after detected estrus. Numerically greater pregnancy rates were observed in late PGF (51.5%) than early PGF (41.3%) treatments regardless of GnRH administration. Cycle day 10 heifers had the most consistent pregnancy rates exceeding 65% regardless whether insemination occurred after detected estrus or by appointment.

One objective was to determine ovarian follicular responses to GnRH and subsequent ovulation after treatment. Injection of GnRH was rather ineffective in inducing ovulation in dairy heifers (Table 1) compared with earlier reports in heifers. Although others have suggested heifers tend to have a lesser ovulatory response to GnRH than cows because of shorter follicular waves and dominant follicles of lesser maximum diameter, a major difference in our study was the concurrent inclusion of a progesterone insert at the time of GnRH injection in all but controls. Ovulatory response to GnRH was poor and similar regardless whether GnRH administration was concurrent with progesterone. Injection of GnRH resulted in smaller follicle diameters 2 days after treatment, but compensation in rate of follicle growth produced follicles of similar size 7 days later. Injection of GnRH tended to increase serum progesterone at day 6 after onset of treatment but had no effect of interval to or duration of estrus. In contrast, GnRH-treated heifers received more mounts of greater duration during estrus. Pregnancy rates were reduced in heifers receiving TAI 64 hours after insert removal compared with those inseminated after detection of estrus. Pregnancy rates were less in controls not treated with progesterone. Administration of progesterone resulted in a more consistent and less variable pattern of estrus distribution compared with controls. Heifers initiating treatment on day 10 seemed to have the best pregnancy rates regardless whether inseminated after estrus or by appointment 64 hours after insert removal. No difference in average or variance of interval to estrus after insert removal regardless whether $PGF_{2\alpha}$ was injected at or 24 hours before insert removal justifies concurrent insert removal and $PGF_{2\alpha}$ injection. Although nonsignificant, pregnancy rates favored that management choice.

**Table 1.** Incidence of ovulation after gonadotropin-releasing hormone (GnRH) and post-treatment on the basis of stage of cycle at onset of treatment

| | % ovulation[1] (no.) | |
|---|---|---|
| Item | Response to GnRH[2] | Post-treatment[2] |
| Treatment[2] | | |
| Early $PGF_{2\alpha}$ | 2.1[a] (47) | 91.5[a] (47) |
| GnRH + early $PGF_{2\alpha}$ | 28.9[b] (45) | 88.9[a] (45 |
| Late $PGF_{2\alpha}$ | 0.0[a] (47) | 89.4[a] (47) |
| GnRH + late $PGF_{2\alpha}$ | 18.8[b] (48) | 89.6[a] (48) |
| Control | 29.2[b] (48) | 68.8[b] (48) |
| Day of estrous cycle[3] | | |
| 2 | 21.4[a] (28) | 75.6[ab] (45) |
| 5 | 46.4[b] (28) | 78.0[a] (50) |
| 10 | 18.5[a] (27) | 100.0[c] (45) |
| 15 | 24.1[a] (29) | 87.8[bc] (49) |
| 18 | 17.2[a] (29) | 87.0[bc] (46) |

[a-c] Mean percentages within column and item having different superscript letters differ ($P < 0.05$).

[1] Determined by transrectal ultrasonographic evidence of follicle disappearance and presence of new luteal tissue 48 hours after GnRH injection or 96 hours after progesterone insert removal.

[2] All treatments except control included a 7-day progesterone insert with or without a concurrent injection of GnRH, and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) was given either at insert removal or 24 hours earlier. Control heifers received GnRH followed in 7 days by $PGF_{2\alpha}$.

[3] Stage of estrous cycle at onset of treatment. Excludes heifers in GnRH + early $PGF_{2\alpha}$ and GnRH + later $PGF_{2\alpha}$ heifers that did not receive a GnRH injection.

**Table 2.** Pregnancy rates in response to treatment with gonadotropin-releasing hormone (GnRH), progesterone, and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) after detected estrus or timed artificial insemination (TAI)[1]

| | % Pregnant (no.) | | |
|---|---|---|---|
| Item | Estrus | TAI | Total |
| Treatment[2] | | | |
| Early $PGF_{2\alpha}$ | 53.3 (15) | 40.0 (40) | 43.6[x] (55) |
| GnRH + Early $PGF_{2\alpha}$ | 50.0 (16) | 42.5 (40) | 44.6[x] (56) |
| Late $PGF_{2\alpha}$ | 42.9 ( 7) | 54.2 (48) | 52.7[x] (55) |
| GnRH + Late $PGF_{2\alpha}$ | 63.6 (11) | 49.0 (49) | 51.7[x] (60) |
| Control | 75.0 ( 8) | 30.4 (46) | 37.0[y] (54) |
| Total | 56.1[a] (57) | 44.0[b] (223) | 46.4 (280) |
| Early $PGF_{2\alpha}$ | 51.6 (31) | 41.3 (80) | 44.1 (111) |
| Late $PGF_{2\alpha}$ | 55.6 (18) | 51.5 (97) | 52.2 (115) |
| Day of estrous cycle[3] | | | |
| 2 | 66.7 ( 6) | 34.7 (49) | 38.2 (55) |
| 5 | 33.3 ( 3) | 37.9 (58) | 37.7 (61) |
| 10 | 66.7 ( 9) | 65.2 (46) | 65.4 (55) |
| 15 | 62.5 (16) | 42.5 (40) | 48.2 (56) |
| 18 | 47.8 (23) | 36.7 (30) | 41.5 (53) |

[a-b] Mean percentages within row having different superscript letters differ ($P < 0.05$).
[x-y] Mean percentages within column having different superscript letters differ ($P < 0.05$).
[1] Pregnancy rates determined by transrectal ultrasonographic evidence of fluid, embryonic heart beat, and presence of a corpus luteum at 32 to 33 days post-TAI.
[2] All treatments except control included a 7-day insert with or without a concurrent injection of GnRH, and $PGF_{2\alpha}$ was given at either insert removal or 24 hours earlier. Control heifers received GnRH followed in 7 days by $PGF_{2\alpha}$.
[3] Stage of estrous cycle at onset of treatment.

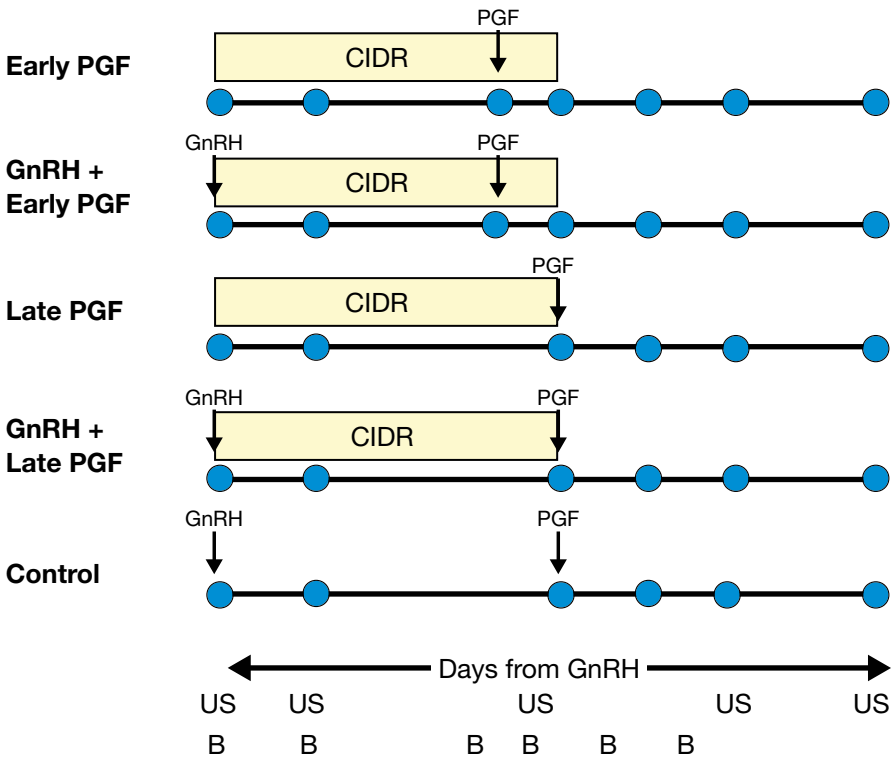



**Figure 1.** Experimental design of treatments. All treatments except control included a 7-day progesterone insert with or without a concurrent injection of GnRH. An injection of $PGF_{2\alpha}$ (PGF) was given either at insert removal or 24 hours earlier. Control heifers received GnRH followed in 7 days by $PGF_{2\alpha}$. CIDR = 1.38 g of progesterone controlled internal drug release insert; GnRH = 100 µg of GnRH; PGF = 25 mg of $PGF_{2\alpha}$; US = transrectal ultrasonography; and B = blood collection.

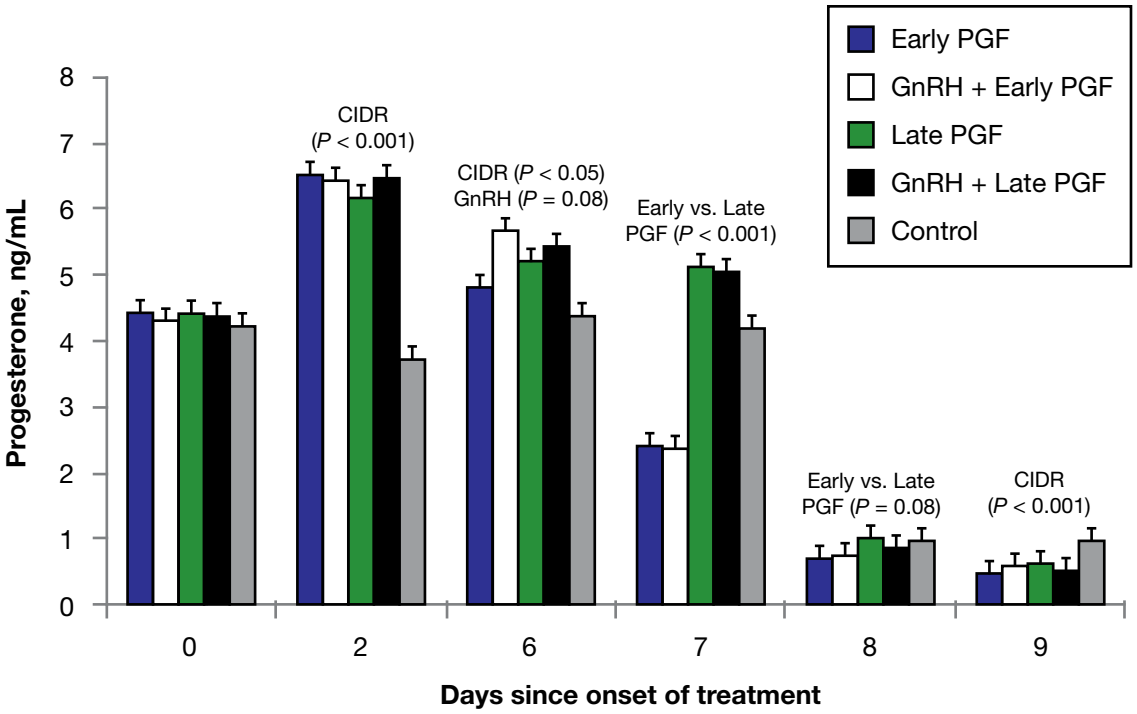



**Figure 2.** Treatment effects on concentrations of progesterone beginning at the onset of treatment (day 0) until 2 days after progesterone insert removal. All treatments except control included a 7-day insert with or without a concurrent injection of GnRH. An injection of $PGF_{2\alpha}$ (PGF) was given either at insert removal or 24 hours earlier. Control heifers received GnRH followed in 7 days by $PGF_{2\alpha}$. Five treatments were (1) early PGF (n = 56), (2) GnRH + early PGF (n = 56), (3) late PGF (n = 55), (4) GnRH + late PGF (n = 60), and (5) control (n = 55). Contrasts are progesterone insert (CIDR) vs. control, GnRH vs. no GnRH (progesterone insert treatments only), and early vs. late PGF.

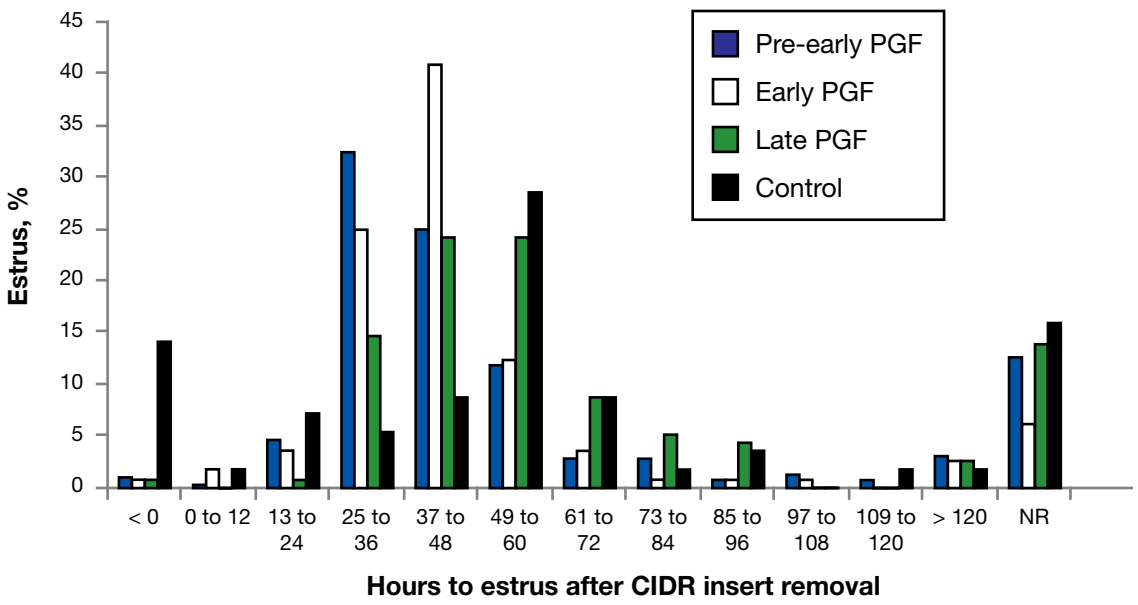



**Figure 3.** Pattern of post-treatment estrus. Distribution of estrus after either early administration of $PGF_{2\alpha}$ (PGF; 24 hours before a 7-day progesterone insert was removed from all heifers during pretreatment synchronization of estrus; n = 247), early $PGF_{2\alpha}$ (24 hours before insert removal) during treatment (n = 105), late $PGF_{2\alpha}$ concurrent with insert removal (n = 99), or in controls (GnRH 7 days before $PGF_{2\alpha}$; n = 47).

# Resynchronized Pregnancy Rates in Dairy Cattle: Timing of Gonadotropin-Releasing Hormone Injection before Timed Artificial Insemination

*J. S. Stevenson and C. A. Martel*

## Summary

Lactating dairy cows and replacement virgin heifers of unknown pregnancy status were treated with either gonadotropin-releasing hormone (GnRH) or saline to initiate a resynchronization program that was continued 7 days later when a not-pregnant diagnosis was determined. Non-pregnant cattle were administered prostaglandin $F_{2\alpha}$ and then either injected with GnRH 56 hours later and artificially inseminated (AI) by appointment at 72 hours or injected and inseminated concurrently at 72 hours. Injection of GnRH at 56 hours produced more pregnancies than injection of GnRH at 72 hours when AI was administered at 72 hours in both treatments (30.9 vs. 15.2%). Further, starting the resynchronization with GnRH was beneficial to resulting pregnancy rates but was timing dependent. When a not-pregnant status was determined between day 30 and 36 after AI, upfront GnRH injection (7 days before pregnancy diagnosis) may not be necessary because stage of cycle is 1 to 7 days (days 3 to 4 in 71% of cattle) and resulting pregnancy rates after GnRH or saline did not differ (27.5 vs. 26.6 %, respectively). In contrast, when pregnancy status was determined after day 36 (days 37 to 43; cycle days 10 to 11 in 71% of cattle), upfront GnRH as part of the resynchronization protocol nearly doubled the number of pregnancies compared with saline (31.0 vs. 15.1%).

## Introduction

Achieving acceptable pregnancy rates in previously inseminated dairy cows after a not-pregnant diagnosis is a challenge. Most dairy producers find that first-service timed artificial insemination (**TAI**) pregnancy rates are much greater than those achieved in open cows reinseminated after a not-pregnant diagnosis. A number of factors determine the success of such reinseminations including precise follicular maturation and its synchronization with the demise (luteolysis) of the corpus luteum or corpora lutea (**CL**). Good follicular synchronization usually occurs when the resynchronization protocol is initiated with GnRH 7 days before prostaglandin $F_{2\alpha}$ (**$PGF_{2\alpha}$**) is administered to the open female at a not-pregnant diagnosis. Administering GnRH causes ovulation in more than 60% of dairy cows and reinitiates new follicular growth and a new dominant follicle after 4 to 5 days. Timing of pregnancy diagnosis relative to the stage of the estrous cycle in nonpregnant females may not require the upfront GnRH injection for those that are early in the estrous cycle at initiation of the resynchronization protocol.

Our first objective was to determine whether gonadotropin-releasing hormone (**GnRH**) is necessary to achieve acceptable pregnancy rates when the not-pregnant diagnosis occurs earlier (days 30 to 36) post-insemination rather than later (days 37 to 43). The earlier diagnosis corresponds to when transrectal ultrasonography is generally used, whereas the later diagnosis corresponds to when transrectal palpation is applied for diagnosing pregnancy in dairy cows and heifers.

Our second objective was to determine whether timing of the standard second GnRH injection would improve pregnancy rates if administered at 56 vs. 72 hours after $PGF_{2\alpha}$. The earlier timing at 56 hours would more closely align with the standard Ovsynch protocol (injection of GnRH at 7 days and 48 hours after $PGF_{2\alpha}$ with TAI occurring 16 hours after the second GnRH injection) but requires another cow handling event before the TAI.

## Experimental Procedures

The experiment was conducted between October 2006 and July 2008 at the Kansas State University Dairy Teaching and Research Center (Manhattan, KS). Lactating dairy cows (n = 704) and 125 replacement heifers (12 to 16 months of age) previously inseminated and of unknown pregnancy status were assigned randomly but unequally to a 2 × 2 factorial experiment consisting of 4 treatments 7 days before pregnancy status was determined by transrectal ultrasonography (5.0 MHz linear-array transducer, Aloka 500V; Corometrics Medical Systems, Inc., Wallingford, CT). Pregnancy status was determined every 2 weeks.

Main effects were upfront injection of GnRH (100 µg; 2 mL Fertagyl, Intervet, Millsboro, NJ) or saline 7 days before a not-pregnant status (30 to 43 days after last AI) and timing of GnRH injection (56 vs. 72 hours) after $PGF_{2\alpha}$. Therefore, the 4 treatments were (1) saline + Ovsynch-56, (2) saline + Cosynch-72, (3) GnRH + Ovsynch-56, and (4) GnRH + Cosynch-72 (Figure 1). The treatments represented either a standard Ovsynch or Cosynch program with 1 TAI administered 72 hours after $PGF_{2\alpha}$, with the exception of replacing the standard upfront GnRH injection with saline. One AI technician performed 90.3% of all inseminations, and multiple sires were used. Pregnancy status was determined 32 to 39 days after TAI.

Results were analyzed by logistic regression (procedures LOGISITIC and GLM, SAS Institute, Inc., Cary, NC). The model to determine pregnancy rate included upfront injection (GnRH vs. saline), time of GnRH injection (56 vs. 72 hours), interaction of GnRH and time, season, and lactation number (0 1, 2, and 3+).

## Results and Discussion

Pregnancy rates resulting from treatments are summarized in Table 1. Initiating the resynchronization program with GnRH increased ($P < 0.01$) TAI pregnancy rates from 21.1 to 30.2%. Initiating a resynchronized ovulation program by injecting GnRH to cause ovulation of the dominant follicle, however, was timing dependent. When GnRH or saline was administered between 23 and 30 days after the last AI and pregnancy diagnosis then occurred 7 days later (days 30 to 36), the resulting TAI pregnancy rates did not differ from one another (Table 2; GnRH = 27.5% and saline = 26.6%). In contrast, when the program was initiated between days 30 and 37 and pregnancy diagnosis occurred 7 days later (days 37 to 43), pregnancy rates were doubled ($P = 0.044$) when GnRH (31%) was used rather than saline (15.2%).

Because TAI is used rather extensively in our herd, more than 70% of inseminations are closely synchronized. For cows diagnosed not pregnant at the earlier interval (days 30 to 36), 71.2% of the diagnoses were made on days 32 or 33 since last AI. If we assume that the estrous cycle averages 22 days in duration, these cattle were likely on days 3 or 4 of the estrous cycle when GnRH or saline was injected. We would not expect a large proportion of cows to ovulate in response to GnRH at this stage of follicular growth, early in the estrous cycle. In fact, the proportion of cattle having 2 or more CL at the not-pregnant diagnosis for this earlier interval was similar (saline = 23.9%, n = 46 vs. 22.6%, n =115). Thus, no benefit in resulting TAI pregnancy rates was ac-

crued from administering the GnRH injection in these cattle receiving GnRH before the earlier not-pregnant diagnosis.

In contrast, for cattle diagnosed at the later interval (days 37 to 43), 71.8% of the diagnoses were made on days 39 or 40 since last AI. These cattle were likely on days 10 or 11 of the estrous cycle when GnRH or saline was injected. The GnRH injection was beneficial to the resulting pregnancy rates because of greater GnRH-induced ovulation to initiate the resynchronized ovulation program. The proportion of cattle having 2 or more CL at the not-pregnant diagnosis for this later interval tended ($P = 0.12$) to favor the GnRH treatment (34.5%, n = 58) compared with saline (15.8%, n = 19). Thus, the improvement in pregnancy rates likely occurred because of greater follicular synchrony in those cattle receiving GnRH to initiate the resynchronization program at the later post-AI interval. This trend for a difference in CL proportions among treatments is validated by differences in concentrations of progesterone in blood serum of cattle having 1 or 2+ CL at the not-pregnant diagnosis (7 days post-treatment; Figure 2). Serum progesterone did not differ among GnRH- and saline-treated cattle having only 1 CL, but among those having 2+ CL, GnRH treatment increased ($P < 0.05$) concentrations of progesterone.

As expected, the resynchronized TAI pregnancy rates tended ($P = 0.058$) to be greater in replacement heifers (44.8%, n = 29) than in the lactating cows: first lactation (26.7%, n = 359), second lactation (24.7%, n = 162), or third and greater lactation numbers (24.6%, n = 126).

When ultrasound is used to diagnose pregnancies at earlier post-AI intervals (days 30 to 36), reinitiating a resynchronized ovulation program with a GnRH injection in cows of unknown pregnancy status 7 days before a not-pregnant diagnosis is contraindicated because resulting pregnancy rates were not improved. In contrast, for herds in which pregnancy diagnosis is made at a later post-AI interval (days 37 to 43), either by transrectal ultrasound or palpation, initiating the resynchronization program requires GnRH to improve resulting TAI pregnancy rates. Further work to improve resynchronization treatments and resulting TAI pregnancy rates is warranted.

**Table 1.** Pregnancy rates in dairy cattle in response to resynchronized ovulation initiated with either saline or gonadotropin-releasing hormone (GnRH) and subsequent timing of GnRH before timed artificial insemination (TAI)

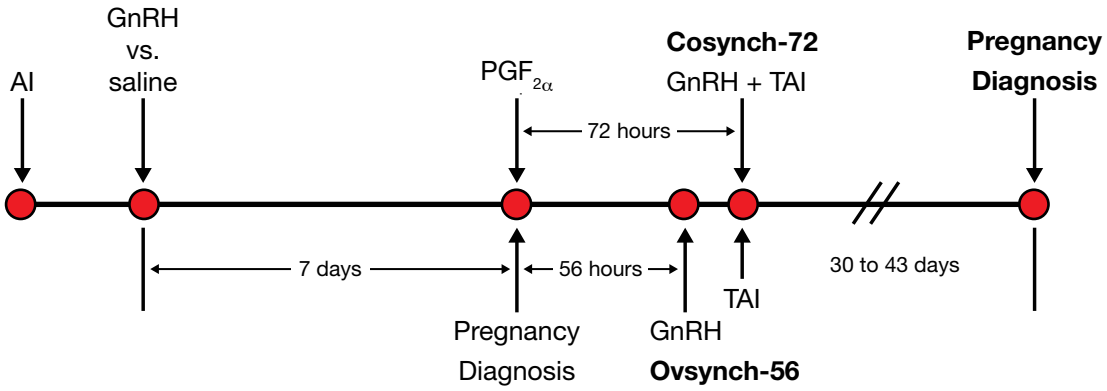
| | Time of GnRH before TAI, hours | | |
|---|---|---|---|
| Item | 56 | 72 | Total |
| Upfront treatment | | ---------- % (no./no.) ---------- | |
| GnRH | 34.1 (107/314) | 17.5 (17/97) | 30.2[x] (124/411) |
| Saline | 25.3 (45/178) | 12.6 (11/87) | 21.1[y] (56/265) |
| Total | 30.9[a] (152/492) | 15.2[b] (28/184) | 26.6 (180/676) |

[a-b] Means having different superscript letters differ ($P < 0.05$).
[x-y] Means having different superscript letters differ ($P < 0.001$).

**Table 2.** Pregnancy rates in dairy cattle are affected by the timing of resynchronization program whether initiated with either saline or gonadotropin-releasing hormone (GnRH)

| | Timing of upfront treatment, days since last AI | |
|---|---|---|
| Item | 23 to 30 | 30 to 37 |
| Upfront treatment | ---------- % (no./no.) ---------- | |
| GnRH | 27.5[a,b] (57/207) | 31.0[a] (54/174) |
| Saline | 26.6[a,b] (33/124) | 15.1[b] (16/106) |
| Total | 27.2 (90/331) | 25.0 (70/280) |

[a-b] Interaction of timing of upfront treatment and type of upfront treatment ($P = 0.044$).




2 × 2 factorial with 4 treatments:
Saline + Ovsynch-56
Saline + Cosynch-72
GnRH + Ovsynch-56
GnRH + Cosynch-72

**Figure 1.** Experimental design of treatments for previously inseminated dairy cattle of unknown pregnancy status treated 7 days before a not-pregnant diagnosis conducted at 30 to 43 days post-insemination. AI = artificial insemination; TAI = timed artificial insemination; GnRH = gonadotropin-releasing hormone; $PGF_{2\alpha}$ = prostaglandin $F_{2\alpha}$.

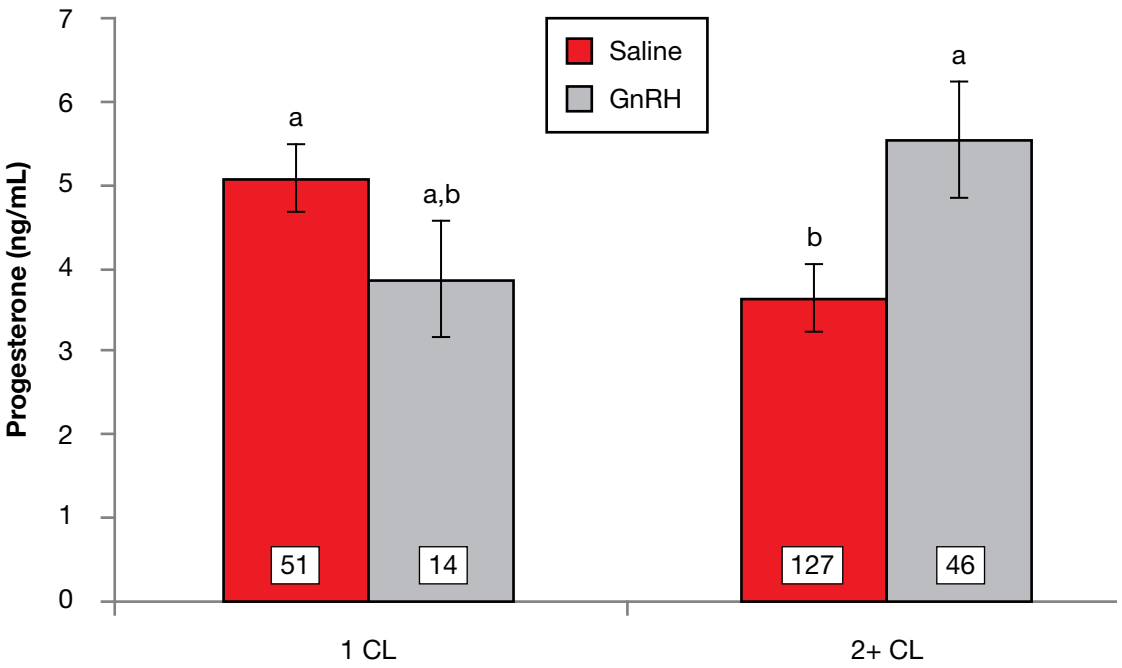



**Figure 2.** Concentrations of progesterone in blood serum at the time of pregnancy diagnosis (7 days post-treatment) and number of corpora lutea (CL) identified at not-pregnant diagnosis. Numbers of observations are shown for each bar. [a-b] Means with different letters differ ($P < 0.05$).

# Estimating Optimal Operation Time of Korral Kools on Dairy Cows in a Desert Environment

*X. A. Ortiz, J. F. Smith, B. J. Bradford, J. P. Harner, and A. Oddy*

## Summary

Developing management strategies for Korral Kools will help producers provide cooling in the housing area while minimizing the operational cost of the Korral Kools system. Two experiments were conducted at a dairy in Saudi Arabia to evaluate operational time of Korral Kools for multiparous and primiparous dairy cows. For multiparous cows, running time per day of Korral Kools should be continuous, but for primiparous cows, no difference in performance was detected between 21 and 24 hours. However, producers need to be careful when reducing daily operation time of Korral Kools for primiparous cows because elevated core body temperatures were observed in both treatments.

## Introduction

An efficient indicator for assessing the physiological response to heat stress is elevated core body temperatures (**CBT**). The average normal CBT is 101.5°F for dairy cows. Producers use the Korral Kools (**KK**) cooling system to increase wind speed and decrease the temperature of the air surrounding the cow. Two experiments were conducted at a dairy in Saudi Arabia to determine daily operational time of KK for multiparous and primiparous dairy cows.

## Experimental Procedures

### Experiment 1

Korral Kools systems were operated for 18 (18 h), 21 (21 h), and 24 (24 h) hours per day while CBT of 63 multiparous (average milk production = 97 ± 37 lb/day and 120 ± 85 days in milk) Holstein dairy cows were monitored. All treatments started at 0600 hours, and systems were turned off at 0000 and 0300 hours for the 18 h and 21 h treatments, respectively. The animals were housed in 7 different pens that were randomly assigned to the treatment sequence in a 3 × 3 Latin square design.

### Experiment 2

Twenty-one multiparous (average milk production = 79 ± 37 lb/day and 144 ± 56 days in milk) and 21 primiparous cows (average milk production = 79 ± 35 lb/day and 94 ± 38 days in milk) were housed in 6 different pens. Pens were randomly assigned to a sequence of 2 treatments, 21 (21 h) or 24 (24 h) hours per day, in a switchback design. All treatments started at 0600 hours, and KK were turned off at 0300 hours for the 21 h treatment.

In both experiments, CBT measurements were obtained at 5-minute intervals by using data loggers (HOBO U12, Onset Computer Corporation, Bourne, MA) attached to intravaginal inserts. Each experiment lasted 6 days, with 3 periods of 2 days each. Cows had 1 day to acclimate to each treatment, and the second day was used to determine CBT.

## Results and Discussion

### Experiment 1

During the experiment, average ambient temperature was 99 °F and average relative humidity was 24% (Figure 1). Cows had lower ($P < 0.05$) average CBT in the 24 h treatment than in the 18 h and 21 h treatments (102.15 °F, 102.35 °F, and 102.27 °F, respectively, Figure 2). A significant treatment × time interaction ($P < 0.001$) was detected, with greatest treatment effects occurring at 0600 hours. Temperature means at 0600 hours were 102.99 °F, 102.86 °F, and 101.99 °F for 18 h, 21 h, and 24 h treatments, respectively (Figure 3). These results demonstrate that reducing running time of KK cooling systems for 3 or more hours per day may lead to an increased CBT.

### Experiment 2

During the experiment, average ambient temperature was 96 °F and average relative humidity was 49% (Figure 4). A significant parity × treatment interaction was observed; multiparous cows on the 24 h treatment had a lower ($P = 0.008$) average CBT than multiparous cows on the 21 h treatment (102.63 °F vs. 103.02 °F, respectively), but treatment had no effect on average CBT of primiparous cows (103.11 °F vs. 103.34 °F for 21 h and 24 h, respectively). A treatment × time interaction ($P < 0.001$) was detected, with greatest treatment effects occurring at 0500 hours. Treatment means at this time were 103.24 °F, 102.62 °F, 103.81 °F, and 102.28 °F for 21 h primiparous, 24 h primiparous, 21 h multiparous, and 24 h multiparous cows, respectively (Figure 6). These results demonstrate that multiparous and primiparous cows respond differently when running time of KK cooling systems decreases from 24 to 21 hours.

## Conclusions

On the basis of these results, we conclude that for multiparous dairy cows in desert climate conditions, it is advisable to operate the KK system continuously to decrease heat stress, whereas KK operating time could potentially be reduced from 24 to 21 hours for primiparous cows. Reducing operation time should be done carefully, however, because CBT was elevated in all treatments.

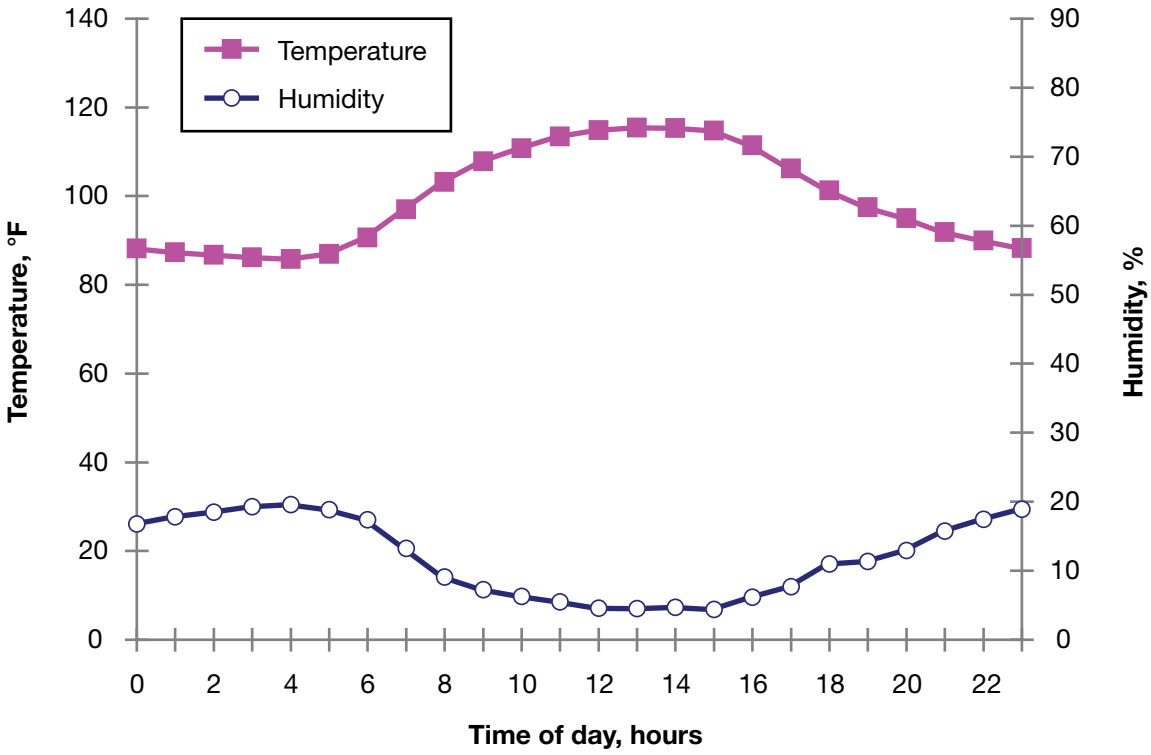



**Figure 1.** Average ambient temperature and relative humidity (Exp. 1).

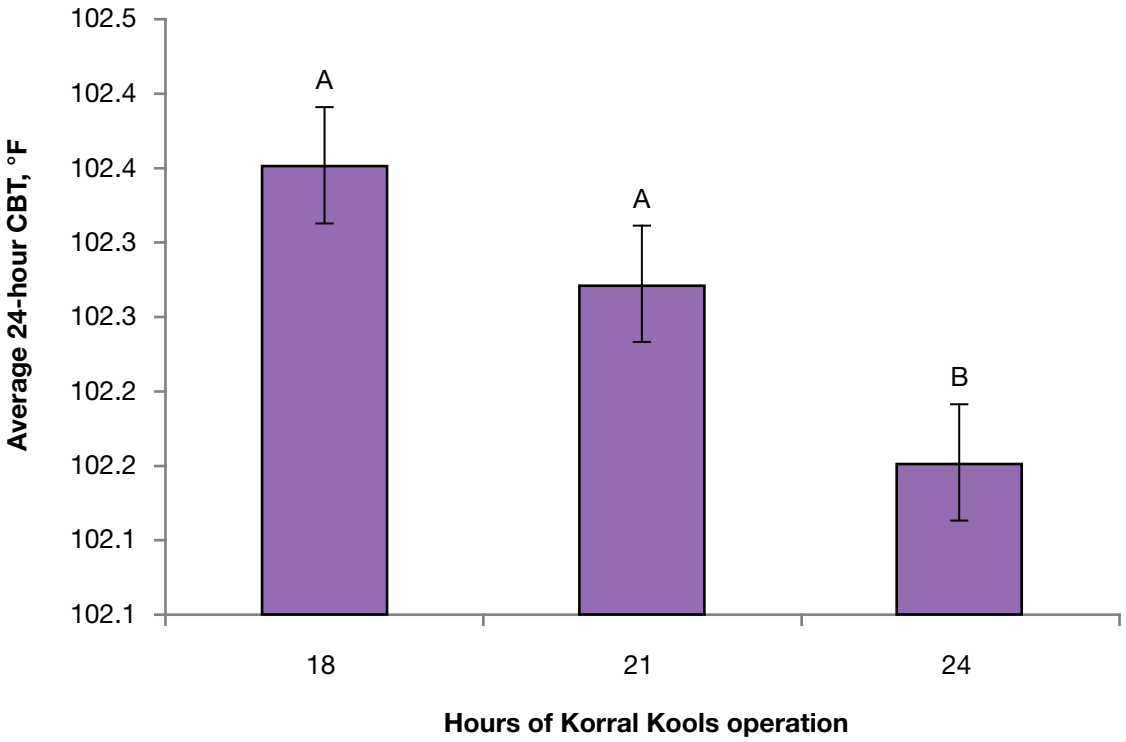



**Figure 2.** Average core body temperature (CBT) of multiparous cows with Korral Kools operated for 18, 21, and 24 hours per day (Exp. 1). $^{A\text{-}B}$Values with different letters differ ($P < 0.05$).

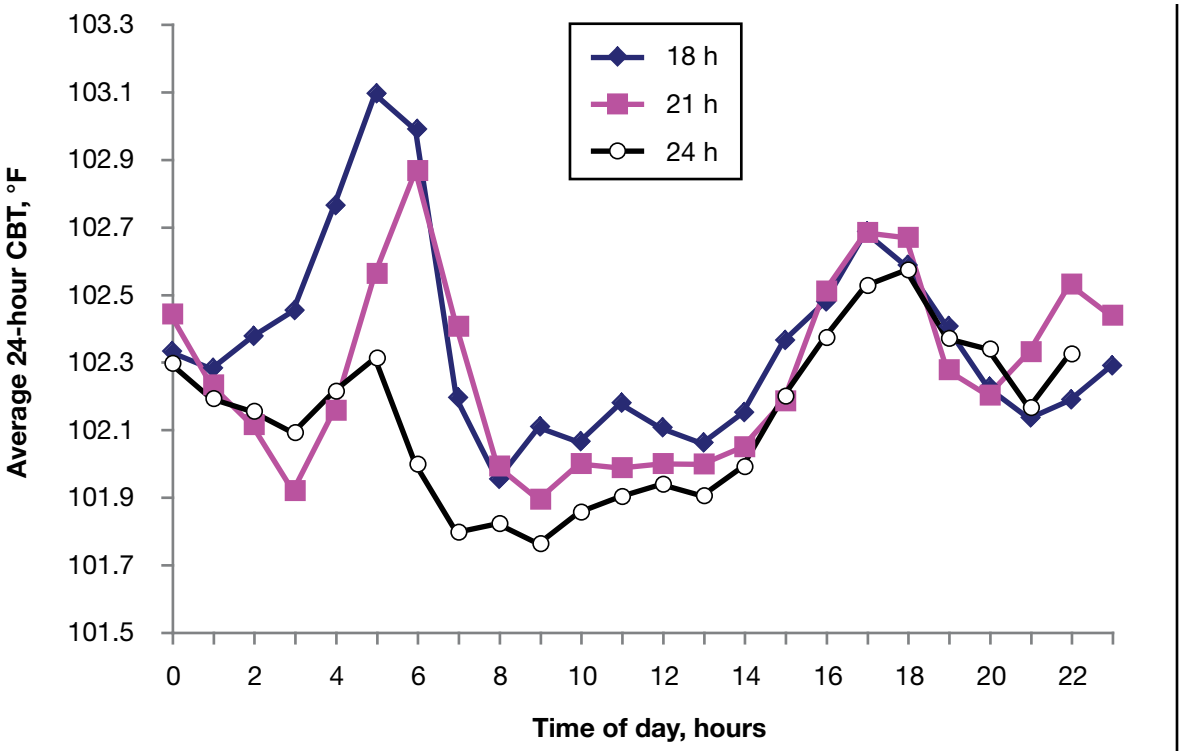



**Figure 3.** Running core body temperature (CBT) of multiparous cows with Korral Kools operated for 18, 21, and 24 hours per day. Treatment × time interaction ($P < 0.001$; Exp. 1).

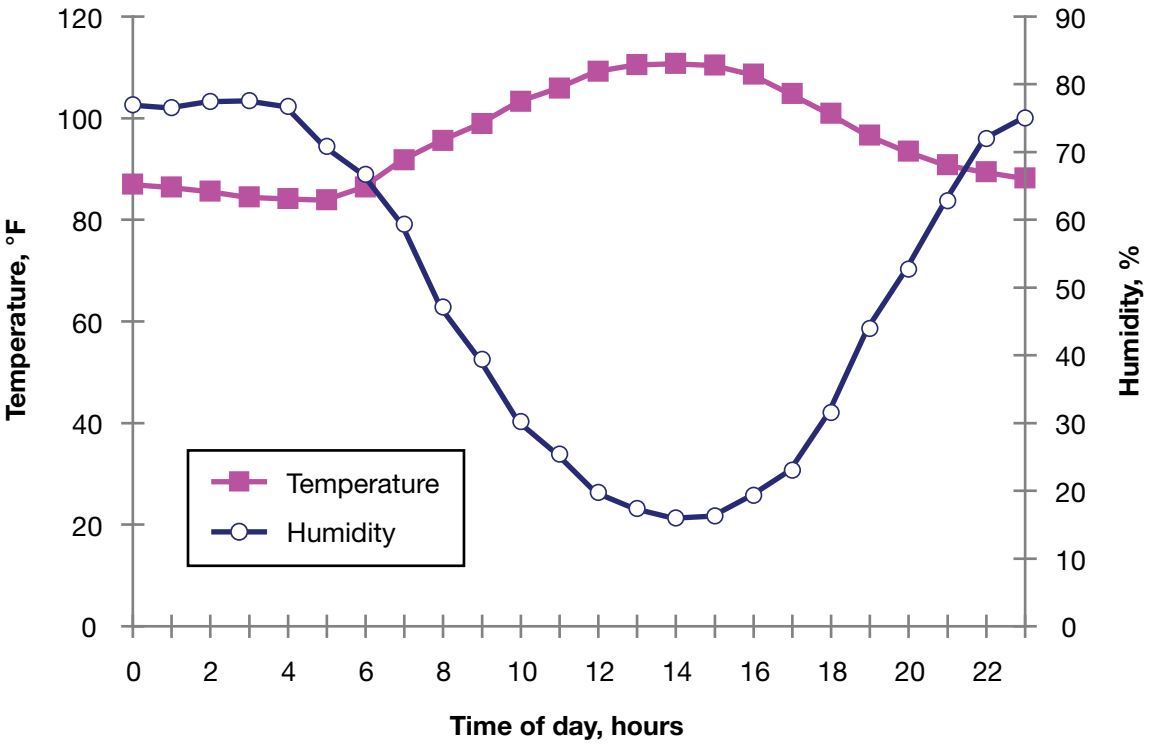



**Figure 4.** Average ambient temperature and relative humidity (Exp. 2).

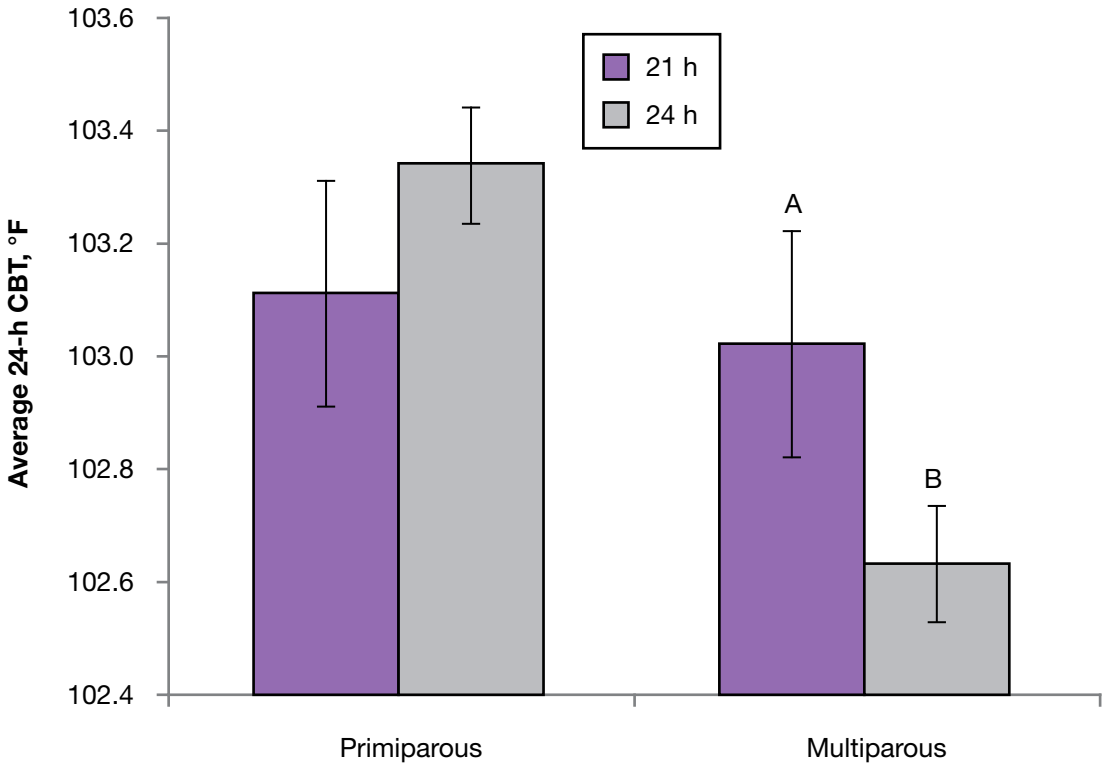



**Figure 5.** Average core body temperature (CBT) of multiparous and primiparous cows with Korral Kools operated for 21 and 24 hours per day (Exp. 2). [A-B]Values with different letters differ ($P = 0.008$).

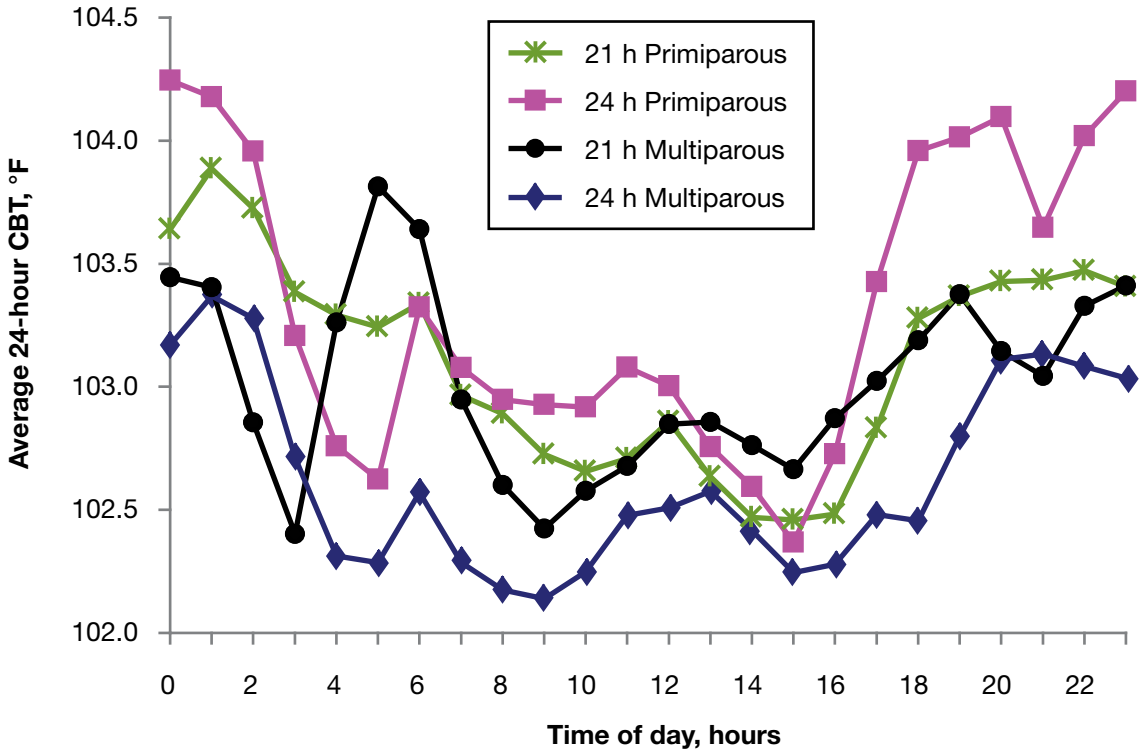



**Figure 6.** Running core body temperature (CBT) of primiparous and multiparous cows with KK operated for 21 and 24 hours per day. Treatment × time interaction ($P < 0.001$; Exp. 2).

# Opportunities with Low Profile Cross Ventilated Freestall Facilities

*J. F. Smith, J. P. Harner, B. J. Bradford, and M. W. Overton* [1]

## Summary

Low profile cross ventilated freestall buildings are one option for dairy cattle housing. These facilities allow producers to control the cows' environment during all seasons of the year. As a result, an environment similar to the thermoneutral zone of a dairy cow is maintained during both summer and winter, resulting in more stable core body temperatures. Low profile cross ventilated facilities allow buildings to be placed closer to the parlor, thus reducing the time cows are away from feed and water. Other advantages include a smaller overall site footprint than naturally ventilated facilities and less critical orientation because naturally ventilated facilities should be orientated east to west to keep cows in the shade. Other benefits of controlling the cows' environment include increased milk production and income over feed cost, improved feed efficiency and reproductive performance, reduced lameness and fly control costs, and the ability to control lighting.

## Characteristics of Low Profile Cross Ventilated Facilities

The "low profile" results from the roof slope being changed from a 3/12 or 4/12 pitch common in naturally ventilated buildings to a 0.5/12 pitch. Figure 1 shows the difference in ridge height between 4-row naturally ventilated buildings and an 8-row low profile cross ventilated (**LPCV**) building. Contractors are able to use conventional warehouse structures with the LPCV building and reduce the cost of the exterior shell of the building, but the interior components and space per cow for resting, socializing, and feeding in an LPCV building are similar to a 4-row building. Differences in land space requirements between the 4-row naturally ventilated freestall buildings and an 8-row LPCV building are also shown in Figure 1.

Figure 2 shows an end view of an 8-row LPCV building. An evaporative cooling system is located along one side of the building, and fans are placed on the opposite side. More space is available for fan placement, and the cooling system is parallel to the ridge rather than perpendicular because the equipment doors are located in the end walls.

Figure 3 shows a layout of an 8-row LPCV building with tail to tail freestalls. From a top view, this design simply places two, 4-row freestall buildings side by side and eliminates the space between the buildings that is necessary for natural ventilation. One potential advantage of the LPCV, or tunnel ventilated, buildings is that cows are exposed to near-constant wind speeds. The air velocity, or wind speed, inside the building is normally less than 8 miles/hour during peak airflow. Ventilation rate is reduced during cold weather, with wind speed decreasing to less than 2 miles/hour.

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## Providing a Consistent Environment

Constructing a cross ventilated facility ensures the ability to provide a consistent environment year-round, resulting in improved cow performance. These buildings provide a better environment than other freestall housing buildings during all seasons of the year because of the use of an evaporative cooling system.

Ability to lower air temperature by evaporative cooling depends upon ambient temperature and relative humidity. As relative humidity increases, cooling potential decreases (Figure 4). Cooling potential is the maximum temperature drop possible, assuming the evaporative cooling system is 100% efficient. As relative humidity increases, the ability to lower air temperature decreases, regardless of temperature. The cooling potential is greater as air temperature increases and relative humidity decreases. Figure 4 also shows that evaporative cooling systems perform better as the humidity decreases below 50%.

## Effect of LPVC Facilities on Core Body Temperature

One of the major benefits of LPCV facilities is the ability to stabilize a cow's core body temperature. A heat stress audit was conducted at a North Dakota dairy to evaluate the effect of a changing environment on the core body temperature of cows. Vaginal temperatures were collected from 8 cows located in the LPCV facility and 8 cows located in a naturally ventilated freestall facility with soakers and fans. Data were recorded every 5 minutes for 72 hours by using data loggers (HOBO U12, Onset Computer Corporation, Bourne, MA) attached to an intravaginal insert. Environmental temperature and humidity data were collected on individual dairies by using logging devices that collected information at 15-minute intervals. Environmental conditions and vaginal temperatures during the evaluation period are presented in Figures 5 and 6. Vaginal temperatures were acceptable in both facilities, but temperatures of cows housed in the LPCV facility were more consistent. Feedline soakers in naturally ventilated buildings effectively cool cows, but cows must walk the feedline to be soaked. On the other hand, cows in an LPCV facility already experience temperatures that are considerably lower than the ambient temperature. Reducing fluctuations in core body temperature has a dramatic effect on production, reproduction, and health of a dairy cow.

## Environmental Effect on Nutrient Requirements and Efficiency

Dairy cows housed in an environment beyond their thermoneutral zone alter their behavior and physiology in order to adapt. These adaptations are necessary to maintain a stable core body temperature but affect nutrient utilization and profitability on dairy farms.

The upper critical temperature, or upper limit, of the thermoneutral zone for lactating dairy cattle is estimated to be approximately 70°F to 80°F. When temperatures exceed that range, cows begin to combat heat stress by reducing feed intake, sweating, and panting. These mechanisms increase cows' energy costs, resulting in up to 35% more feed necessary for maintenance. When dry matter intake decreases during heat stress, milk production also decreases. A dairy cow in a 100°F environment decreases productivity by 50% or more relative to thermoneutral conditions.

Compared with research on the effect of heat stress, little attention has been given to cold stress in lactating dairy cattle. The high metabolic rate of dairy cows makes them more susceptible to

heat stress in U.S. climates, so the lower critical temperature of lactating dairy cattle is not well established. Estimates range from as high as 50°F to as low as −100°F. Regardless, evidence exists that performance of lactating cows decreases at temperatures below 20°F. One clear effect of cold stress is an increase in feed intake. Although increased feed intake often results in greater milk production, cold-induced feed intake is caused by increased rate of digesta passage through the gastrointestinal tract. An increased passage rate limits the digestion time and results in less digestion as the temperature drops. In cold temperatures, cows also maintain body temperature by using nutrients for shivering or metabolic uncoupling, both of which increase maintenance energy costs. These mechanisms decrease milk production by more than 20% in extreme cold stress. However, even when cold stress does not negatively affect productivity, decreased feed efficiency can hurt dairy profitability.

To assess the effects of environmental stress on feed efficiency and profitability, a model was constructed to incorporate temperature effects on dry matter intake, diet digestibility, maintenance requirements, and milk production. Expected responses of a cow producing 80 lb of milk per day in a thermoneutral environment with total mixed ration costs of $0.12/lb of dry matter and milk value of $18/hundred weight (cwt) of milk are shown in Figure 7. The model was altered to assess responses to cold stress if milk production is not decreased. In this situation, the decrease in diet digestibility results in an 8% decrease in income over feed cost as temperatures drop to −10°F ($6.94/cow vs. $7.52/cow per day).

Given these research results, cost benefits can be estimated for environmental control of LPCV facilities. Benefits of avoiding extreme temperatures can be evaluated by comparing returns at ambient temperatures with temperatures expected inside LPCV barns. For example, the model predicts that income over feed cost can be improved by nearly $2/cow per day if the ambient temperature is 95°F and barn temperatures are maintained at 85°F. Likewise, if ambient temperature is 5°F and the temperature inside the barn is 15°F, income over feed cost is expected to increase by $1.15/cow per day.

Besides effects on feed costs and productivity, heat stress also has negative effects on reproduction, immunity, and metabolic health. These factors represent huge potential costs to a dairy operation. Although responses to cold stress are not typically dramatic, increased manure production is a resulting factor. In this model, increased feed intake and decreased digestibility during cold stress also increased manure output by as much as 34%. Manure is a significant cost factor on many farms, requiring increased manure storage capacity and more acres for manure application.

## Environmental Effect on Reproduction

Even though cold stress has little effect on reproduction, heat stress can reduce libido, fertility, and embryonic survival in dairy cattle. Environmental conditions above a dairy cow's thermoneutral zone decrease the cow's ability to dissipate heat, resulting in increased core body temperature. Elevated body temperatures negatively affect reproduction in both cows and bulls.

Effects of heat stress can be categorized by the effects of acute heat stress (short-term increases in body temperature above 103°F) or chronic heat stress (cumulative effects of prolonged exposure to heat throughout the summer). In acute heat stress, even short-term rises in body temperature can result in a 25 to 40% drop in conception rate. An increase of 0.9°F in body temperature causes a decline in conception rate of 13%. The effect of heat stress on reproduction is more

dramatic as milk production increases, a result of greater internal heat load produced because of more feed intake.

Regardless whether the decline in pregnancy rates is voluntary, fewer cows becoming pregnant create holes in the calving patterns. Often, there is a rebound in the number of cows that become pregnant in the fall. Nine months later, a large number of pregnant cows puts additional pressures on the transition facilities when an above-average group of cows moves through the close-up and fresh cow pens. Overcrowding these facilities leads to increases in post-calving health issues, decreased milk production, and impaired future reproduction.

Table 1 examines the economic effect of heat stress by describing the reproductive performance for a hypothetical 3,200-cow Holstein dairy. As shown in Table 1, the herd has above-average reproductive performance during much of the year (insemination rate of 57%, conception rate of 30%, and pregnancy rate of 17%). During summer and throughout the month of September, both insemination rate and conception rate decline, resulting in pregnancy rates that are well below average. As a consequence of these periods of poor reproductive performance, the herd's annual pregnancy rate is 15%. On the basis of economic models that evaluate the value of changes in reproductive performance, this subpar performance during the five 21-day periods costs the dairy approximately $115,000.

Although this simple spreadsheet illustrates how heat stress adversely affects reproductive performance, it does not capture the total cost of the issues created by heat stress. Consideration of the increased number of abortions commonly seen during heat stress; the effect of transition facility overcrowding; and the negative effect on cow health, early lactation milk production, and future reproduction leads to estimated losses well beyond $135,000/year, or at least $42/cow per year, using a milk price of $0.18/lb and a feed cost of $0.12/lb.

## Environmental Effect on Milk Production

Although the effect of cold stress on milk production is minimal, the effect of heat stress on milk production can be very dramatic. Numerous studies have been completed to evaluate the economic effect of heat stress on milk production, but because so many approaches are used to manage heat stress, standard evaluations are difficult. Heat stress not only affects milk production during summer but also reduces the potential for future milk production of cows during early lactation. For every pound of peak milk production lost, an additional 250 lb of production will be lost over the entire lactation.

A simple sensitivity analysis was conducted to observe the effect of heat stress on gross income. A net milk price of $18/cwt was used for this analysis. The milk production effect of 90 to 150 days of heat stress on gross income per cow is presented in Table 2. When daily milk production is reduced 2 to 12 lb/cow per day, the gross income loss related to heat stress ranges from $32.40/cow to $324.00/cow.

The effect of heat stress on future milk production is evaluated in Table 3. Gross income per cow per lactation is increased from $90/cow to $540/cow per lactation as peak milk production is increased from 2 to 12 lb/cow per day during periods of heat stress.

## Lighting

Light is an important environmental characteristic in dairy facilities. Proper lighting can improve cow performance and provide a safer and more pleasant work environment. Meeting the lighting requirement of both dry and lactating cows in an LPCV facility can be challenging because lactating and dry dairy cattle have different lighting requirements. Dry cows need only 8 hours of light (8 L) and 16 hours of darkness per day, whereas lactating dairy cows exposed to 16 hours of light (16 L) per day increase milk production from 5 to 16% (8% being typical), increase feed intake about 6%, and maintain reproductive performance. It is important to note, though, that 16 L does not immediately increase milk production. A positive response can take 2 to 4 weeks to develop, assuming that nutrition and other management conditions are acceptable. Cows exposed to 8 L vs. 16 L during the dry period produce 7 lb more milk per day in the following lactation.

Enhanced lighting for the milking herd is profitable. Cows move more easily through uniformly lit entrances and exits, and producers, herdsmen, veterinarians, and other animal care workers report easier and better cow observation and care. Workers also note that a well-lit area is a more pleasant work environment. Increased cow performance and well-being plus better working conditions make lighting an important environmental characteristic in a dairy facility.

## Conclusions

Low profile cross ventilated facilities are capable of providing a consistent environment for dairy cows throughout the year. Changing the environment to reflect the thermoneutral zone of a dairy cow minimizes the effect of seasonal changes on milk production, reproduction, feed efficiency, and income over feed cost. The key is to reduce variation in the core body temperature of the cows by providing a stable environment.

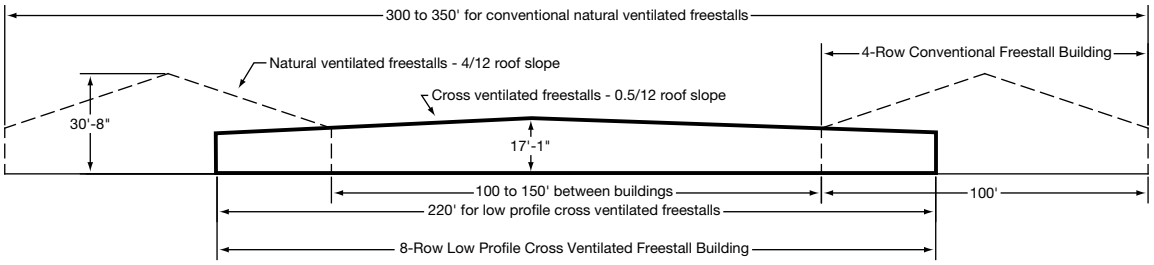


**Figure 1.** End views of 8-row naturally ventilated freestall buildings and an 8-row low profile cross ventilated freestall building.

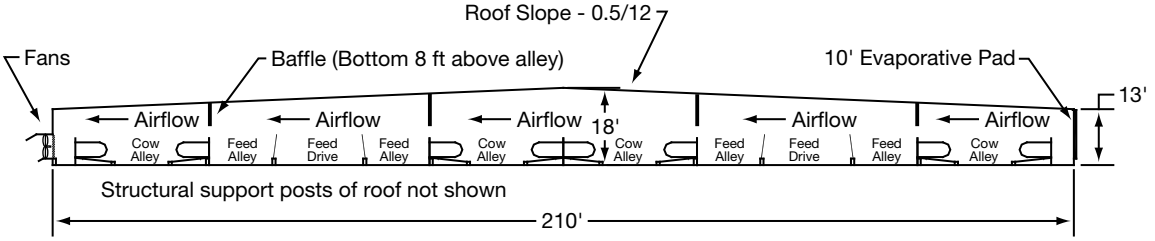


**Figure 2.** End view of an 8-row low profile cross ventilated freestall building.

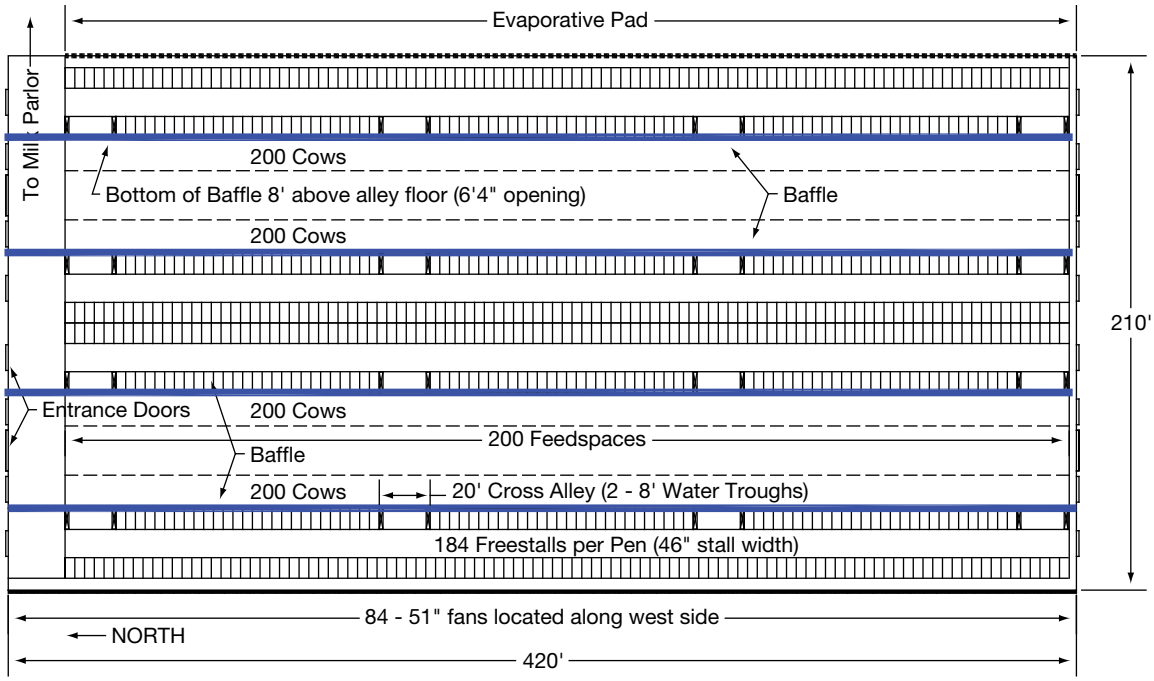


**Figure 3.** Top view of an 8-row low profile cross ventilated building (adjustable building length based on cow numbers).

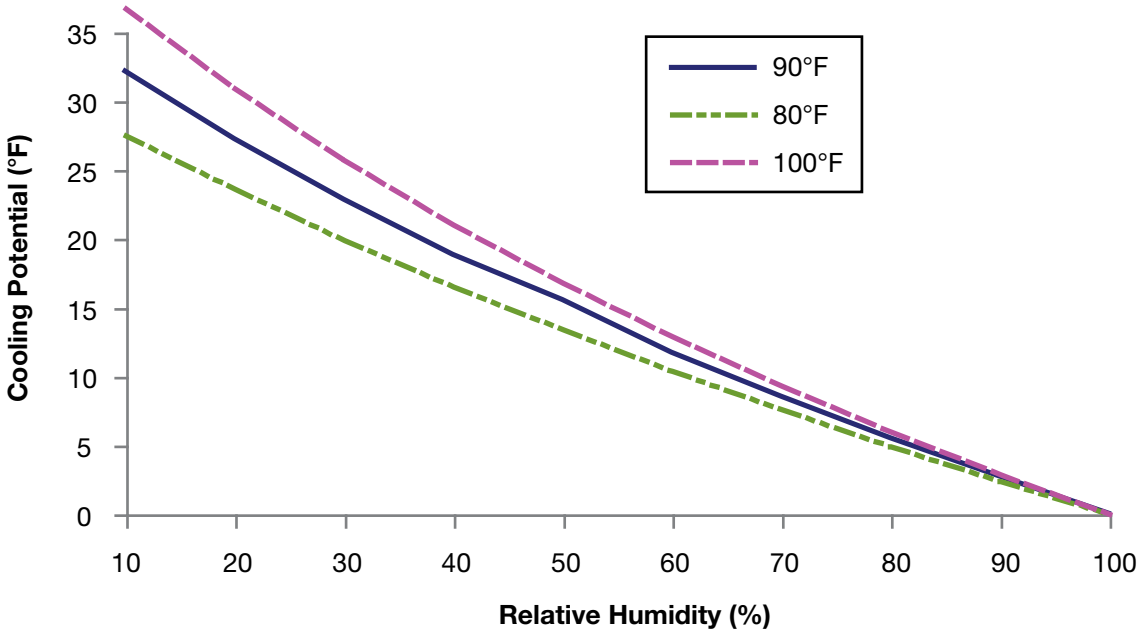


**Figure 4.** Effect of relative humidity and temperature on cooling potential when using an evaporative cooling system.

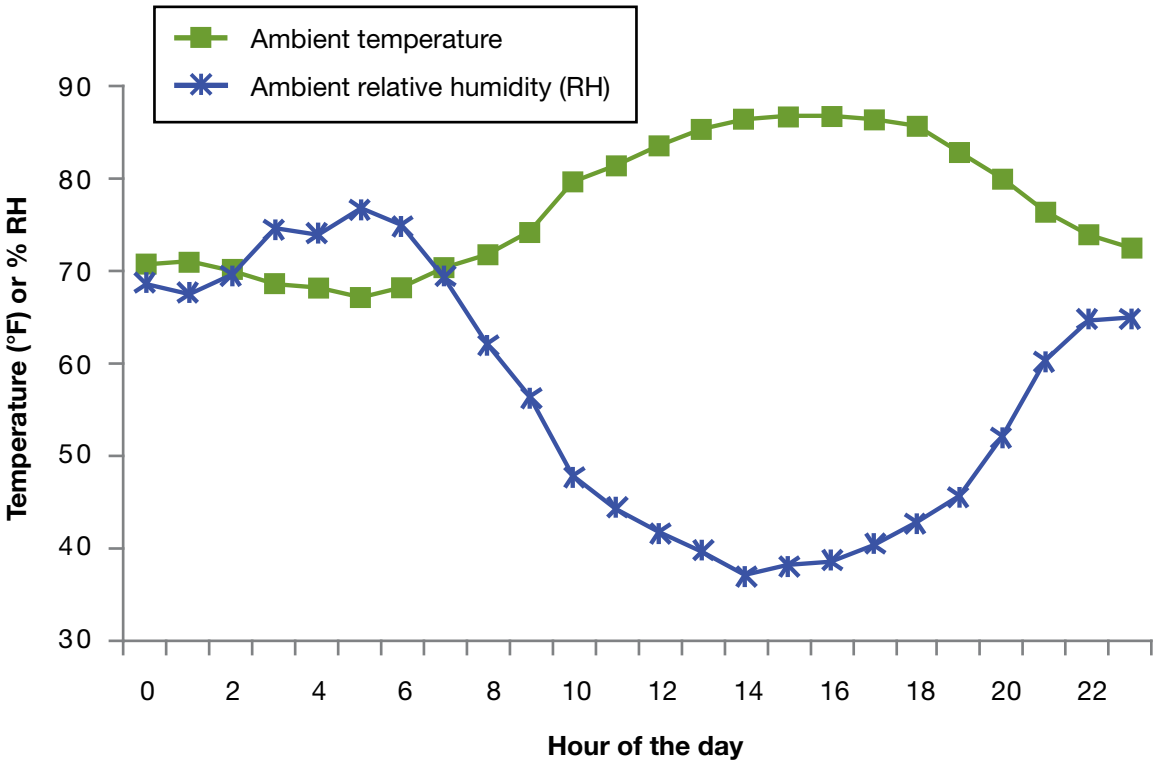


**Figure 5.** Ambient temperature and percentage relative humidity for Milnor, ND (July 6 to 9, 2006).

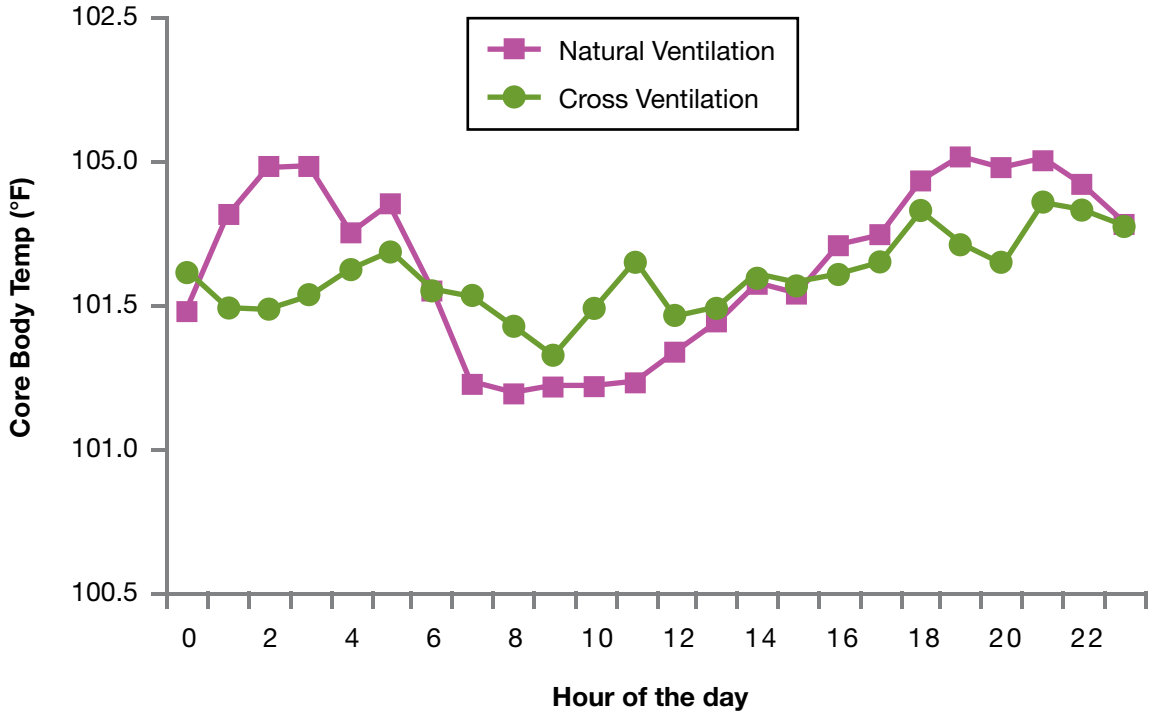


**Figure 6.** Core body temperature of cows housed in naturally ventilated (fans and soakers) and low profile cross ventilated freestalls (evaporative pads).

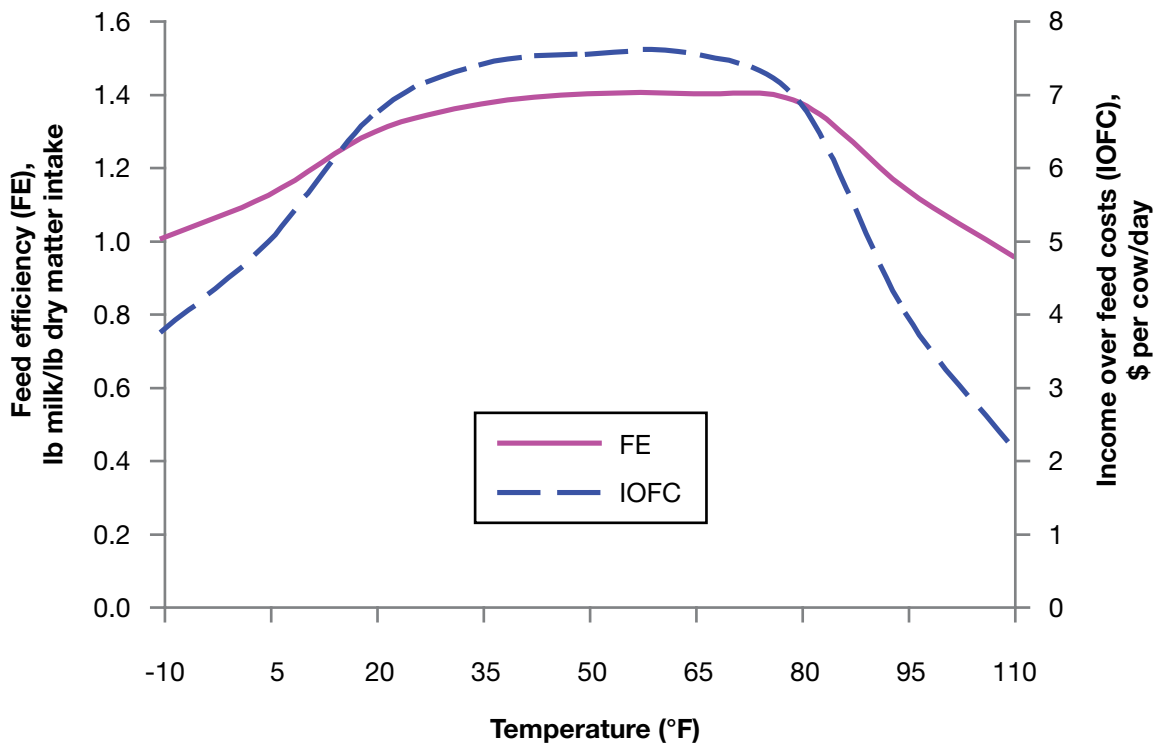


**Figure 7.** Responses to environmental stress (thermoneutral production of 80 lb/day, total mixed ration cost of $0.12/lb of dry matter, and milk value of $18/cwt).

**Table 1.** Historical reproductive performance for a hypothetical 3,200-cow Holstein dairy

| Date | Eligible (n) | Insemination rate (%) | Bred (n) | Conception rate (%) | Pregnant (n) | Pregnancy rate (%) |
|---|---|---|---|---|---|---|
| 1-Jan | 932 | 57 | 531 | 30 | 159 | 17 |
| 22-Jan | 905 | 57 | 516 | 30 | 155 | 17 |
| 12-Feb | 884 | 57 | 504 | 30 | 151 | 17 |
| 5-Mar | 868 | 57 | 495 | 30 | 149 | 17 |
| 26-Mar | 855 | 57 | 487 | 30 | 146 | 17 |
| 16-Apr | 845 | 57 | 481 | 30 | 144 | 17 |
| 7-May | 833 | 57 | 475 | 30 | 142 | 17 |
| 28-May | 831 | 57 | 473 | 30 | 142 | 17 |
| 18-Jun | 825 | 46 | 376 | 21 | 79 | 10 |
| 9-Jul | 883 | 46 | 402 | 21 | 85 | 10 |
| 30-Jul | 930 | 46 | 424 | 21 | 89 | 10 |
| 20-Aug | 983 | 46 | 448 | 21 | 94 | 10 |
| 10-Sep | 1041 | 49 | 514 | 24 | 123 | 12 |
| 1-Oct | 1078 | 54 | 582 | 30 | 175 | 16 |
| 22-Oct | 1049 | 57 | 598 | 30 | 179 | 17 |
| 12-Nov | 1014 | 57 | 578 | 30 | 173 | 17 |
| 3-Dec | 965 | 57 | 550 | 30 | 165 | 17 |
| 24-Dec | 945 | 57 | 539 | 30 | 162 | 17 |
| Total or avg. | 16,664 | 54 | 8,974 | 28 | 2,513 | 15 |

**Table 2.** Potential loss of gross income for different periods of heat stress

| Reduction of milk production (lb/cow per day) | 90 days of lost production (lb) | 120 days of lost production (lb) | 150 days of lost production (lb) | Lost income 90 days ($0.18/lb) | Lost income 120 days ($0.18/lb) | Lost income 150 days ($0.18/lb) |
|---|---|---|---|---|---|---|
| 2 | 180 | 240 | 300 | 32.40 | 43.20 | 54.00 |
| 4 | 360 | 480 | 600 | 64.80 | 86.40 | 108.00 |
| 6 | 540 | 720 | 900 | 97.20 | 129.60 | 162.00 |
| 8 | 720 | 960 | 1,200 | 129.60 | 172.80 | 216.00 |
| 10 | 900 | 1,200 | 1,500 | 162.00 | 216.00 | 270.00 |
| 12 | 1,080 | 1,440 | 1,800 | 194.40 | 259.20 | 324.00 |

**Table 3.** Effect of increasing peak milk during heat stress on future milk production and gross income

| Increase in peak milk production (lb/cow per day) | Additional milk production (lb/lactation) | Additional gross income per lactation ($0.18/lb) |
|---|---|---|
| 2 | 500 | 90.00 |
| 4 | 1,000 | 180.00 |
| 6 | 1,500 | 270.00 |
| 8 | 2,000 | 360.00 |
| 10 | 2,500 | 450.00 |
| 12 | 3,000 | 540.00 |

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