Kansas State University

Agricultural Experiment Station
and Cooperative Extension Service

DAIRY DAY
2002

Report of Progress 898

FOREWORD

Members of the Dairy Commodity Group of the Department of Animal Sciences and Industry are pleased to present this Report of Progress, 2002. Dairying continues to be a viable business and contributes significantly to the agricultural economy of Kansas. In 2001, dairy farms accounted for 2.2% of all farm receipts, ranking 7th overall among all Kansas farm commodities. Wide variation exists in the productivity per cow as indicated by the production testing program (Heart of America Dairy Herd Improvement Association [DHIA]). The Heart of America DHIA opened for business on January 1, 1995, by combining three labs into one. More than 115,392 cows were enrolled in the DHI program from Kansas, Nebraska, Oklahoma, Arkansas, North Dakota, and South Dakota beginning January 1, 2002. A comparison of Kansas DHIA cows with all those in the Heart of America DHIA program for the year 2001 is illustrated in the table below.

Comparison of Heart of America Cows with Kansas Cows - 2001

Item	HOA	KS
No. of herds	948	308
No. of cows/herd	122	114
Milk, lb	19,191	19,774
Fat, lb	712	739
Protein, lb	597	615
IOFC*, $	1,701	1,582

*IOFC = income over feed costs.

Most of this success occurs because of better management of 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, use of superior, proven sires in artificial insemination (AI) programs shows average predicted transmitting ability (PTA) for milk of all 299 Holstein AI bulls in service (August, 2001) to be +1,479 lb (range of +449 to +2,740 lb). Emphasis on use of superior genetics through more use of AI sires is warranted.

The excellent functioning of the Dairy Teaching and Research Center (DTRC) is due to the dedication of our staff. It has served us well since 1977. Our milk production with 207 cows has improved considerably according to our last test day in August (85.5 lb). Our rolling herd average for milk was 26,273 lb, with 966 lb of fat, and 812 lb of protein.

We acknowledge our current DTRC staff for their dedication: Michael V. Scheffel (Manager); Donald L. Thiemann; Daniel J. Umsheid; William P. Jackson; Charlotte Boger; Lesa Reves; and Robert Reves. Special thanks are given to Cheryl K. Armendariz and a host of graduate and undergraduate students for their technical assistance in our laboratories and at the DTRC.

Each dollar spent for research yields a 30 to 50% return in practical application. Research is not only tedious and painstakingly slow but expensive. Those interested in supporting dairy research are encouraged to consider participation in the Livestock and Meat Industry Foundation (LMIF), a philanthropic organization dedicated to furthering academic and research pursuits by the Department of Animal Sciences and Industry (more details about the LMIF are found at the end of this publication).

J. S. Stevenson, Editor
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Dairy Day 2002

EFFECT OF TUNNEL VENTILATION AND EVAPORATIVE COOLING ON THE BARN ENVIRONMENT AND COW COMFORT IN MIDWEST DAIRY FACILITIES

***M. J. Brouk, J. F. Smith, and J. P. Harner, III*[1]**

Summary

During the summer of 2001 six tunnel ventilated tie stall barns in northeastern Missouri and southeastern Iowa were evaluated. Three of the barns were equipped with cellulose evaporative pads and three were not. Temperature and relative humidity were recorded continuously for 11 weeks from July 1 to September 15, 2001. Cattle housed in tie stall barns equipped with evaporative cooling had lower average respiration rates (65.7 vs 70.3 breaths/min) than those housed in barns without evaporative cooling. However, rates observed in the morning and at night were not different, only the afternoon rates differed significantly. Average rectal temperatures were also lower for the cows housed in evaporative cooled barns. Similar to respiration rates, the greatest differences existed during the afternoon. Skin temperatures followed respiration rates and rectal temperatures and were significantly lower for the cattle housed in the barns equipped with evaporative cooling with the greatest differences observed during the afternoon.

Barns equipped with evaporative cooling pads were up to 8.25ºF cooler during the afternoon hours than those without. However, relative humidity increased up to 30% and THI decreased up to 3.25 units over ambient conditions. As compared to the barns with only tunnel ventilation, barns with evaporative cooling had a greater percentage of July and August hours at a THI level below 70 and eliminated the hours in the 85-90 THI level during the hours of 1:00 PM and 8:00 PM. Evaporative cooling reduced the heat stress during the afternoon hours without increasing the stress during the evening and night hours as compared to the tunnel ventilated barns. This study showed significant advantages for the evaporative cooled and tunnel ventilated barns in terms of respiration rates, rectal temperatures and barn environment.

(Key Words: Heat Abatement, Facilities, Stress.)

Introduction

Heat stress during the summer months reduces milk production and reproductive efficiency. Cows are beginning to be stressed when the temperature humidity index (THI) exceeds 72. Dairy cattle produce large amounts of heat from both ruminal fermentation and metabolic processes. As production increases, the total amount of heat produced increases. In order to maintain body temperature within the normal range, cows must exchange this heat with the environment.

There are two general approaches to cooling dairy cattle. One must either modify the

[1]Department of Biological and Agricultural Engineering.

environment to prevent heat stress or utilize methods that increase heat dissipation from the skin of cattle. Air conditioning is the ultimate method to modify a warm environment. It reduces air temperature and relative humidity, greatly lowering the THI of the environment. On a commercial basis, this is not an economical choice for modifying the environment of dairy cattle. A more economical method to reduce air temperature is by evaporative cooling. When water evaporates it absorbs heat, reducing the temperature. When water evaporates it also increases the relative humidity due to the increased level of water vapor present.

The combination of tunnel ventilation with evaporative cooling systems has been used in swine and poultry operations for many years to cool the environment. Recently, these systems have been installed in some Midwest dairy facilities. Evaporative cooling has been used very successfully to cool dairy cattle in hot arid climates. Under arid conditions and high environmental temperatures, there is a great potential to reduce temperature and THI (Figures 1 and 2). However, as relative humidity increases and or temperature decreases, the potential of evaporative cooling to modify the environment decreases. Data presented in Figures 1 and 2 are based on a 100% efficiency of evaporation to 90% relative humidity. The efficiency of evaporative cooling equipment ranges between 50 and 80% reducing the effect of the systems. In the Midwest, high relative humidity reduces the potential of evaporative cooling. As relative humidity increases above 70%, the potential reduction in THI is less than 10%.

Recent Studies

As dairy producers have adopted evaporative cooling systems, the K-State Dairy Team has had the opportunity to monitor several systems beginning in the summer of 1999. The two barns evaluated in 1999 were both modified systems utilizing roof peak ventilation fans. Air was drawn through the sidewall with either cellulose evaporation pads or a narrow slit equipped with a high-pressure mist system. Temperature and relative humidity were monitored and recorded every 15 minutes at various points in the building from late July until early September. In addition, naturally ventilated freestall barns located in the area were also monitored. Respiration rates of cattle under heat stress were evaluated and recorded in each of the barns. As compared to the ambient conditions, evaporative cooled barns were cooler in the afternoon hours but warmer during the late evening and early morning hours. When the data were averaged by day average temperature was less than 2ºF different than ambient conditions. Average THI were actually higher than ambient conditions. Cattle housed in the evaporative cooled barns had greater morning respiration rates as compared to cattle housed in a naturally ventilated freestall barn, indicating a greater level of environmental stress associated with greater THI in those barns. The system designs did not effectively alter the environmental conditions enough to reduce heat stress. It should be noted that both of these systems utilized roof exit fans and were not tunnel ventilated but rather roof ventilated.

During the summer of 2000, two barns with tunnel ventilation and evaporative pads were evaluated (Figures 3 and 4). The level of THI was reduced during the afternoon hours as compared to ambient conditions. However, the degree of reduction was greater for one barn than the other. Data presented in Figure 4 indicates that the evaporative cooled tie stall barn was cooler than either the two-row or four-row naturally ventilated freestall barn. This was due to differences in ambient conditions and barn design. This tie stall had an excellent design and provided an airflow of 500-600 ft/sec and a small cross-sectional area. The other barn (Figure 4) was much larger and reductions during the afternoon hours were less than the smaller barn and offset by increases during the evening and night hours. It was also noted that air temperature increased and relative humidity decreased at greater distances from the air intake at the evaporative pads. The effects of barn and system design are important factors in determining the efficiency of evaporative cooling on Midwest dairy facilities.

Data from the 1999 and 2000 studies were summarized by hours above and below a THI of 75 (Table 1). The reduction in hours above a THI of 75 ranges from –10.3 to +3.5%. Factors critical to the correct design of the system include airflow, air turnover, cross-sectional area, and evaporation potential. When using evaporative cooling systems, one is trying to reduce the environmental stress level. Evaporative cooling is only effective if the THI is actually lowered relative to ambient conditions. It is important to recognize that as air temperature is lowered due to water evaporation the potential to evaporate moisture from the skin of cattle is also reduced. The net effect of evaporative cooling of air must be greater than the loss of cooling from moisture evaporation from the skin of cattle or cattle stress will increase rather than decrease under heat stress conditions. As a result of questionable system design, some evaporative cooled barns may be more stressful than conventional freestall barns that are naturally ventilated as was observed in the 1999 studies.

During the summer of 2001 six tunnel ventilated tie stall barns in northeastern Missouri and southeastern Iowa were evaluated. Three of the barns were equipped with cellulose evaporative pads and three were not. Temperature and relative humidity were recorded continuously for 11 weeks from July 1 to September 15, 2001. On three consecutive days under stress conditions, respiration rates, rectal temperature, and skin temperature of 20 cows at each of the sites were evaluated (Table 2). Cattle housed in tie stall barns equipped with evaporative cooling had lower average respiration rates (65.7 vs 70.3 breaths/min) than those housed in barns without evaporative cooling. However, rates observed in the morning and at night were not different, only the afternoon rates differed significantly. Average rectal temperatures were also lower for the cows housed in evaporative cooled barns. Similar to respiration rates, the greatest differences existed during the afternoon. Skin temperatures followed respiration rates and rectal temperatures and were significantly lower for the cattle housed in the barns equipped with evaporative cooling with the greatest differences observed during the afternoon.

Changes in barn environment for evaporative cooled and tunnel ventilated barns are shown in Figures 5, 6 and 7. Greatest changes from ambient conditions are noted during the 1:00 PM to 8:00 PM period. During this period temperature decreased up to 8.25ºF, relative humidity increased up to 30% and THI decreased up to 3.25 units as compared to the ambient conditions. There is considerable variation in the response over the 11 wk trial. During the period from 9:00 PM to 4:00 AM and the period from 5:00 AM to 12:00 PM, the evaporative pads were not utilized due to the ambient humidity level reaching about 85%. Thus the systems had little effect upon the barn environment during these periods.

As compared to the barns with only tunnel ventilation, barns with evaporative cooling had a greater percentage of July and August hours at a THI level below 70 and eliminated the hours in the 85-90 THI category (Figure 8) during the hours of 1:00 pm and 8:00 pm. Evaporative cooling reduced the heat stress during the afternoon hours without increasing the stress during the evening and night hours as compared to the tunnel ventilated barns. This study showed significant advantages for the evaporative cooled and tunnel ventilated barns in terms of respiration rates, rectal temperatures and barn environment.

Data presented in Figure 9 suggests that micro-environments are present in large tunnel ventilated and evaporative cooled freestall barns. The coolest and highest relative humidity air was present near the inlet. As the distance from the inlet increased temperature increased and relative humidity decreased. Depending upon the time period of the day, a 3-5ºF increase in temperature was observed from the inlet to the exhaust. In large tunnel ventilated and evaporative cooled barns, there may be an advantage to having higher producing animals in the pens closest to the inlet and evaporative pads.

Conclusions

Can evaporative cooling be utilized in combination with tunnel ventilation to reduce heat stress of dairy cattle housed in the Midwest? It depends upon several factors. First, what is the temperature and evaporation potential of the environment? In many locations, the afternoon relative humidity may be too great to take advantaged of evaporative cooling. In the 2001 study area, nighttime relative humidity was near the saturation point, limiting the systems. However, afternoon relative humidity dropped to a level that allowed for evaporation potential making the systems effective in reducing the severity of the stress. In hot, arid conditions, the system would work well. However, in high humidity locations its effectiveness would be limited by evaporation potential.

If the environment will allow for evaporation potential, one should then consider barn design. The barns studied in 2001 were well designed and had a small cross-sectional area. This allowed for high levels of air exchanged with minimal fan horsepower. These barns were also less than 300 ft in length and approximately 40 ft wide with ceiling heights of less than 9 ft. All barns also had a correct pad area. These systems were utilized during the afternoon hours and were shut down during the high humidity evening and night hours. The net effect was a reduction in animal stress as compared to tunnel ventilation only. When sound design criteria are not followed, problems arise as was noted in the 1999 study. Based on the 2000 data, there may be some advantages of the evaporative system in smaller barns as compared to large freestall barns. Smaller barns (tie stall) have a much smaller cross-sectional area than a large freestall barn. If one builds a barn with 12 ft side-walls and a 4/12 roof pitch, over 25% of the cross-sectional area is the rafter area. One approach is to utilize a ceiling or false ceiling along underside of the rafters to reduce the cross-sectional area that is tunnel ventilated and evaporative cooled. It would also be possible to lower the sidewall height and roof pitch. This results in a structure that must always be mechanically ventilated. This approach has been taken in the swine industry. Trying to mix natural and mechanical ventilation systems has had limited success in the swine industry and the same is likely in the dairy industry. To work effectively, evaporative cooling and tunnel ventilation systems must be correctly designed.

The third thing to consider is the effectiveness of evaporative cooling with other heat abatement methods. Work at KSU has shown the effectiveness of soaking cattle and then evaporating the water from skin. This has been shown to be highly effective in reducing respiration rates and skin temperatures. However, to date no study has evaluated in a head-to-head comparison the effect of evaporative cooling verses soaking and evaporation from the skin surface. It would be more efficient to dissipate heat from the skin via evaporation rather than exchange via convection. However additional research is needed to determine the effects of tunnel and evaporative cooling systems on milk production as compared to conventional methods of cow cooling.

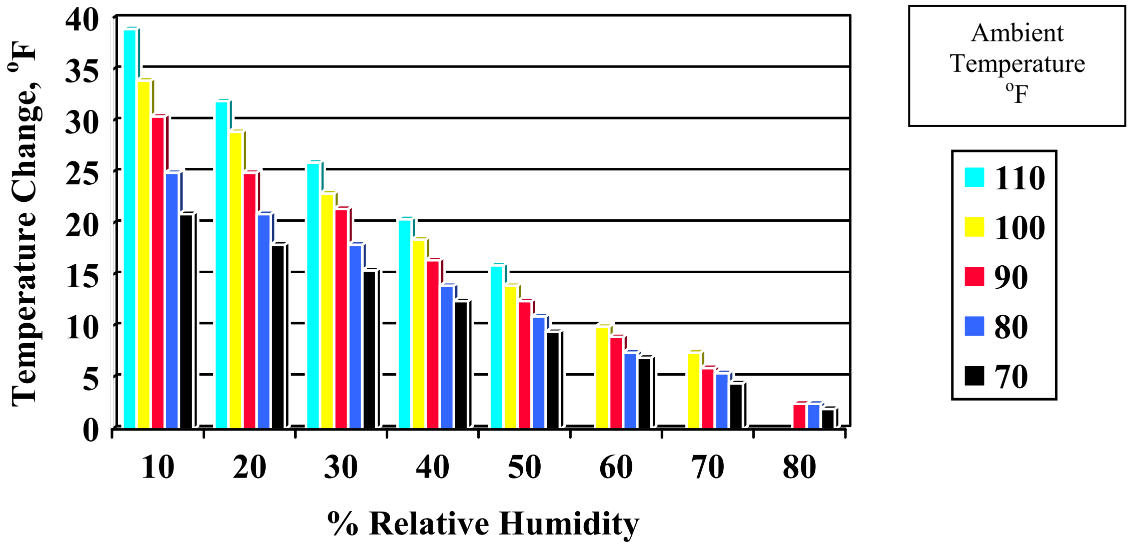

Figure 1. Potential Air Temperature Change Due to Evaporative Cooling at Various Levels of Ambient Air Temperatures and Relative Humidity.

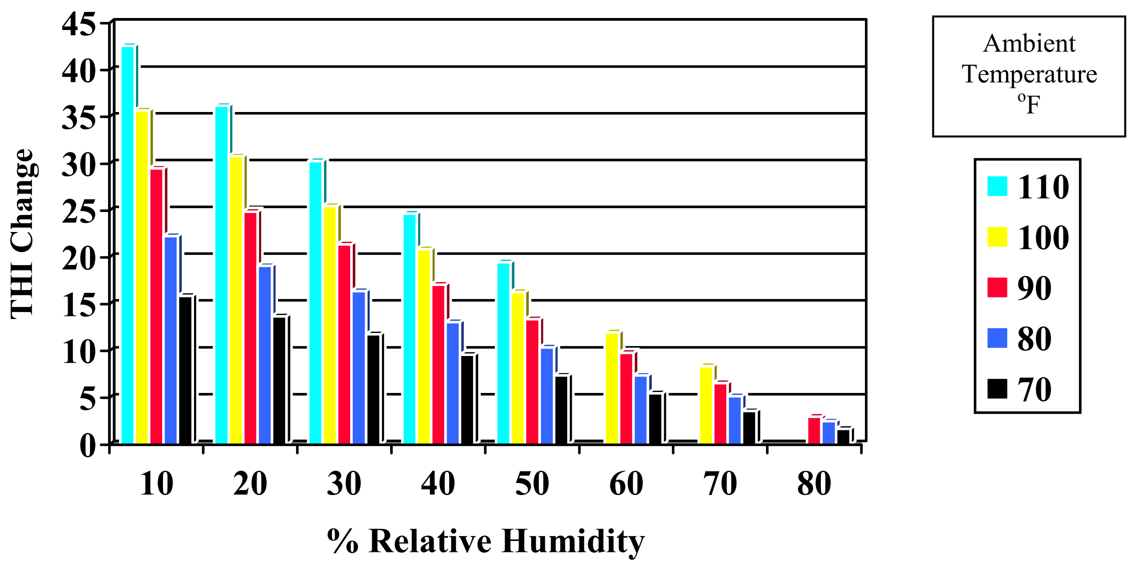

Figure 2. Potential Temperature-Humidity Index Change Due to Evaporative Cooling at Various Levels of Ambient Air Temperature and Relative Humidity.

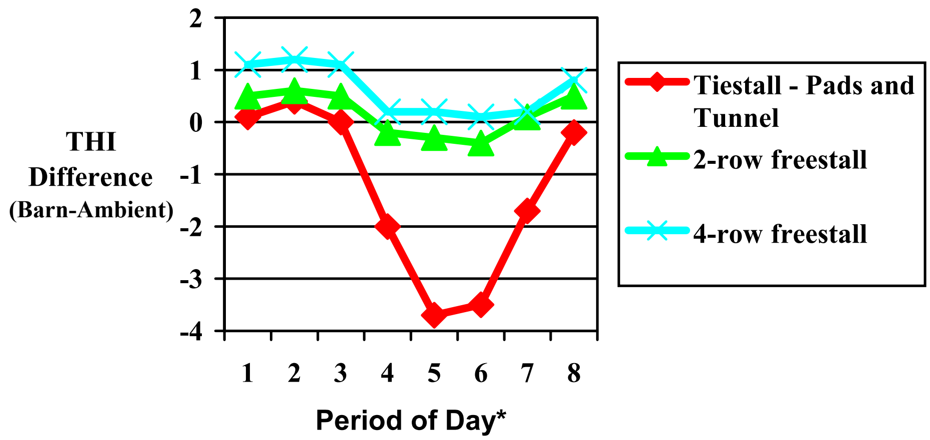

Figure 3. Effect of Cooling System and Barn Style of the Difference Between Barn and Ambient THI at Different Periods* of the Day during Summer Heat Stress.**

*Period 1=12:00 AM -3:00 AM, 2=3:00-6:00 AM, 3=6:00 AM-9:00 AM, 4=9:00 AM-12:00 PM, 5=12:00 PM -3:00 PM, 6=3:00 PM – 6:00 PM, 7=6:00 PM – 9:00 PM, 8= 9:00 PM – 12:00 AM. **July 6 – September 6, 2000.

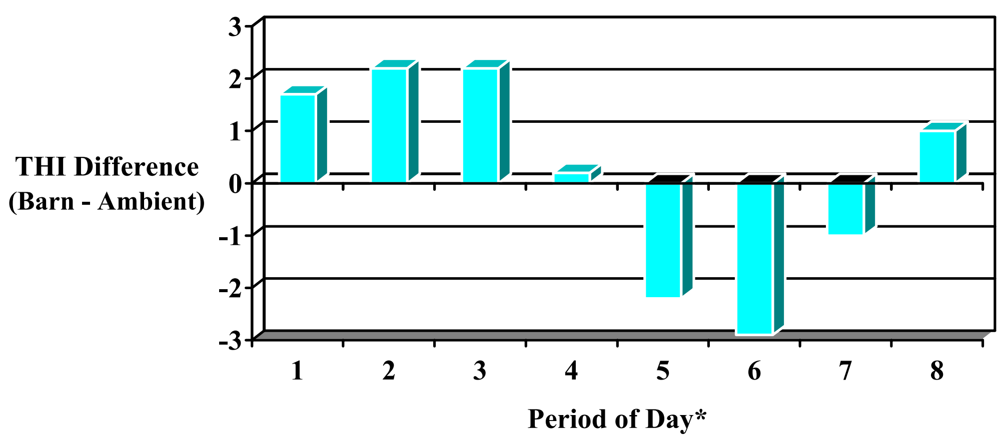

Figure 4. Difference Between Barn and Ambient Conditions at Different Periods of the Day of a Tunnel Ventilated and Evaporative Cooled Freestall Barn during Summer Heat Stress.**

*Period 1=12:00 AM -3:00 AM, 2=3:00-6:00 AM, 3=6:00 AM-9:00 AM, 4=9:00 AM-12:00 PM, 5=12:00 PM -3:00 PM, 6=3:00 PM – 6:00 PM, 7=6:00 PM – 9:00 PM, 8= 9:00 PM – 12:00 AM. **July 11 – September 11, 2000.

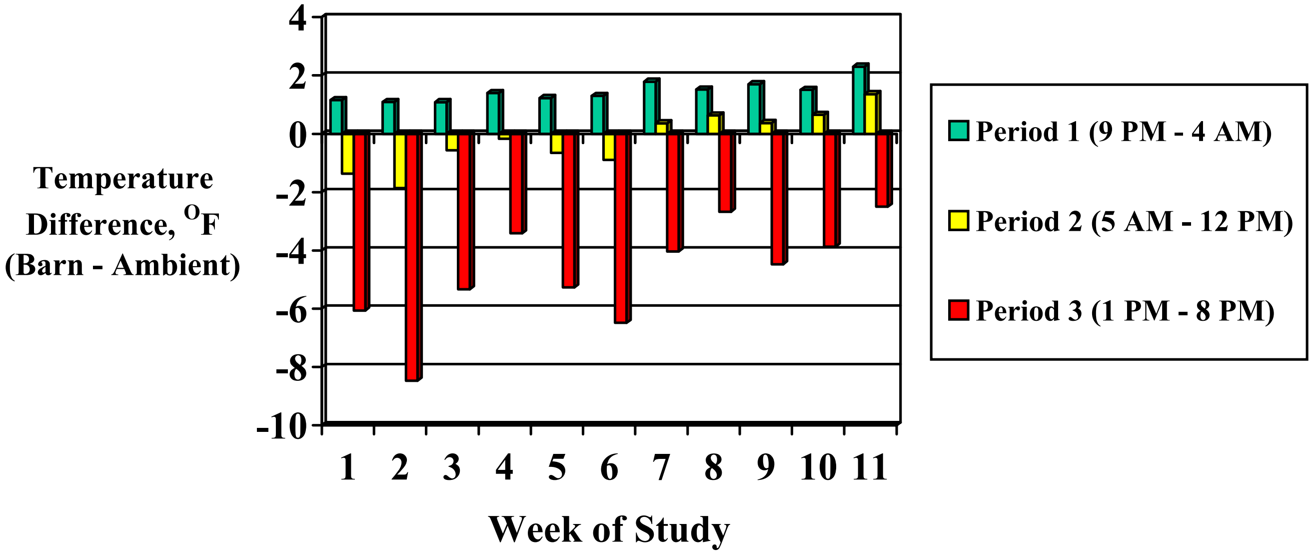

Figure 5. **Effect of Evaporative Cooling on Temperature Difference (barn-ambient) during Three Different Periods of the Day in Tie Stall Barns during the Summer of 2001.**

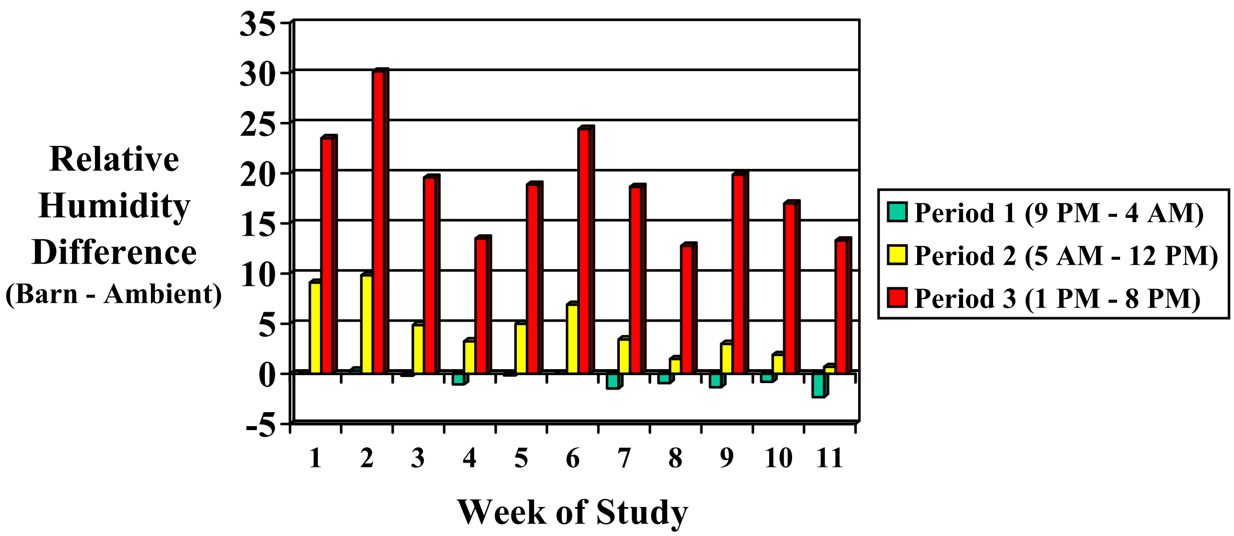

Figure 6. **Effect of Evaporative Cooling on Relative Humidity Difference (barn-ambient) during Three Different Periods of the Day in Tie Stall Barns during the Summer of 2001.**

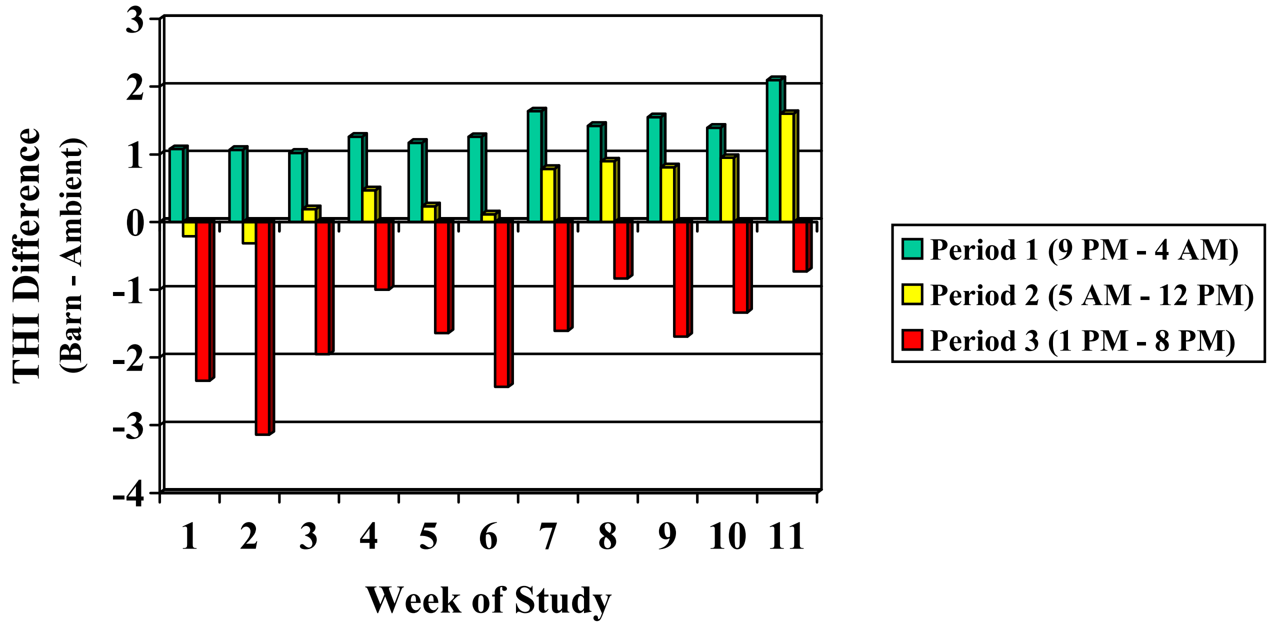

Figure 7. Effect of Evaporative Cooling on Temperature-Humidity Index Difference (barn-ambient) during Three Different Period of the Day in Tie Stall Barns during the Summer of 2001.

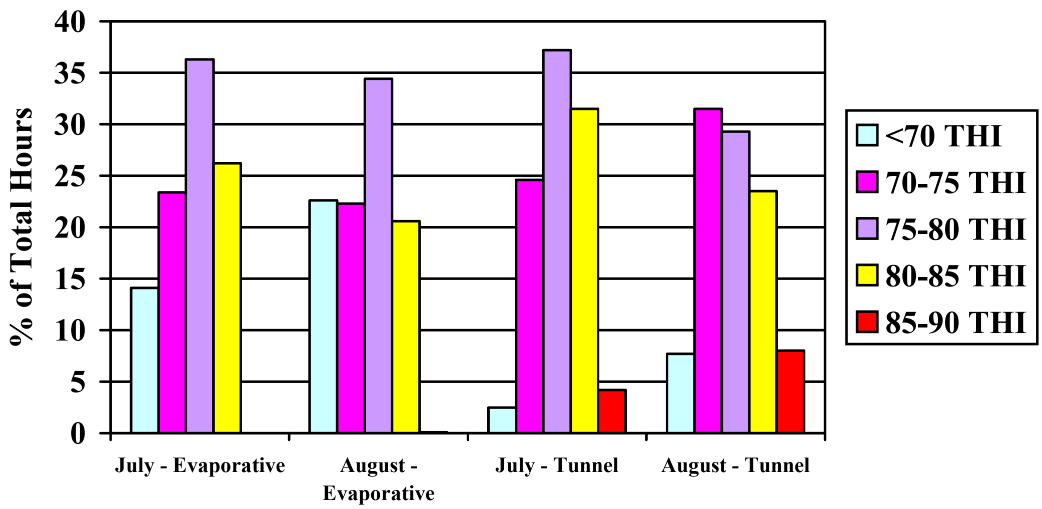

Figure 8. Percentage of Hours at Different Levels of Temperature-Humidity Index of Tunnel Ventilated Tie Stall Barns with and without Evaporative Cooling during the Hours of 1:00 PM to 8:00 PM during July and August of 2001.

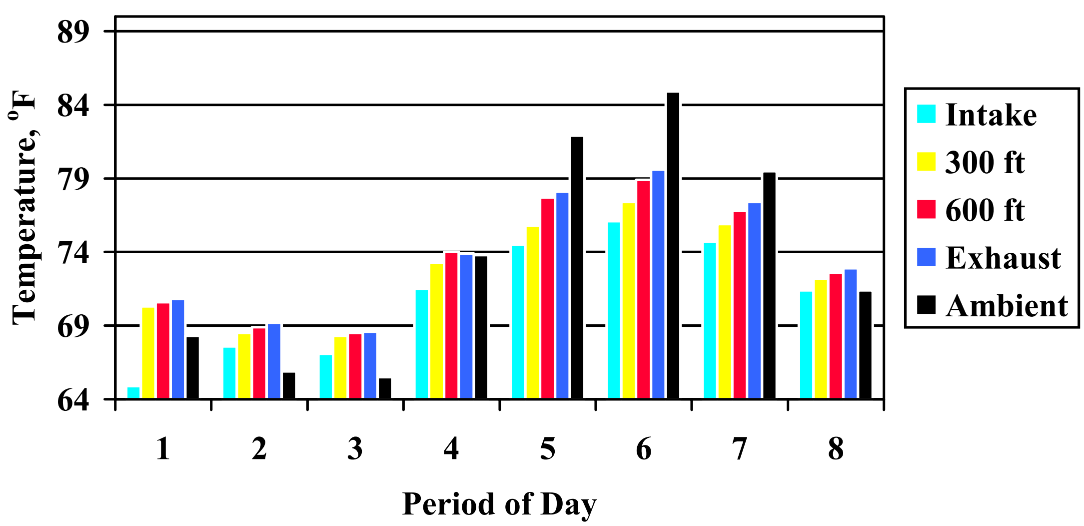

Figure 9. Effect of Location on Temperature in a Tunnel Ventilated and Evaporative Cooled Dairy Freestall Barn.

Data collected from July 11 to September 11, 2000.
Period = 3 hour blocks of time starting at midnight.

Table 1. Effect of Evaporative Cooling on the Percent of Summer Hours Below and Above Temperature-Humidity Index (THI) of 75 in Four Midwest Dairy Facilities

Barn	Summer	System	Location	Percentage of Hours: THI <75	Percentage of Hours: THI =>75
A	2000	Pads/Tunnel	Barn	67.5	34.3
			Ambient	55.4	44.6
			Change	-10.3	
B	1999	Pads/Roof Exit	Barn	79.2	20.8
			Ambient	75.7	24.3
			Change	-3.5	
C	1999	High Pressure/Roof	Barn	73.3	26.7
			Ambient	76.9	23.1
			Change	3.6	
D	2000	Pads/Tunnel	Barn	76.5	23.5
			Ambient	70.5	29.5
			Change	-6.0	
Average Change				-4.05	

Table 2. Effect of Tunnel Ventilation With and Without Evaporative Cooling on the Average Respiration Rate, Rectal Temperature and Skin Temperatures of Lactating Holstein Cows at Three Different Time Periods of the Day

Measurement	Barn	Period of Day: Morning	Period of Day: Afternoon	Period of Day: Night	Average of Day	Cooling System Effect
Respiration rate, breaths/min	Tunnel + Evap	55.0	73.5a	68.7	65.7a	*P*<.01
	Tunnel	56.5	83.8b	70.6	70.3b	
Rectal Temperature, ºF	Tunnel + Evap	101.4	102.3a	102.5	102.1a	*P*<.01
	Tunnel	101.6	103.0b	102.7	102.4b	
Thurl Skin Temperature, ºF	Tunnel + Evap	90.0	93.2a	93.4a	92.2a	*P*<.01
	Tunnel	91.8	97.5b	94.6b	94.6b	
Rear Udder Skin Temperature, ºF	Tunnel + Evap	92.4	95.4a	95.0	94.3a	*P*<.01
	Tunnel	92.5	98.3b	95.4	95.4b	
Ear Skin Temperature, ºF	Tunnel + Evap	90.3	93.3a	93.2	92.2a	*P*<.01
	Tunnel	90.4	06.3b	93.2	93.3b	

EVALUATION OF THE CALIFORNIA MASTITIS TEST TO DETERMINE UDDER HEALTH STATUS OF EARLY LACTATION DAIRY COWS

R. T. Dingwell [1], K. E. Leslie [2], J. M. Sargeant [3], Y. H. Schukken [4], L. L. Timms [5], and J. E. Shirley

Summary

Quarter milk bacteriology results of samples collected within the first week of calving were used to calculate the test characteristics of the California Mastitis Test (CMT) that estimate the udder health status of fresh dairy cows. Over 1,200 quarters were both cultured and had a CMT performed. The overall sensitivity and specificity of the CMT was 68.8% and 71.5%, respectively. Using a cutpoint of any CMT reaction as a positive test and examining the results by various days in milk, the highest sensitivity and specificity occurred at day four (82.4% and 80.6%, respectively). The CMT has the potential to be a useful tool for monitoring udder health in fresh cows.

(Key Words: CMT, Udder Health, Fresh Cow.)

Introduction

The dry period is a good time in the lactation cycle to eliminate existing and prevent new intramammary infections (IMI). A major goal of dry cow management programs is to have as few quarters infected with mastitis-causing pathogens as possible at the next calving. Increased interest has recently occurred in novel dry cow management strategies such as external and internal teat sealers that would help prevent new IMI from occurring in the dry period. These new strategies offer promise in helping to reduce the rate of new IMI above what can be achieved by conventional dry cow antibiotic therapy alone. Dry cow antibiotic therapy generally does not persist into the late dry period and is ineffective against gram-negative organisms. However, whatever dry cow udder health management program is used, new IMI are still likely to occur in the dry period. Thus, emphasis should be placed on identifying infected cows early after calving as part of mastitis control in dairy herds.

Identifying and eliminating IMI in early lactation may have significant economic benefits. Preventing clinical mastitis in early lactation, decreasing the amount of discarded milk, and reducing bulk milk somatic cell count are some of the benefits. Bacteriological culture of milk samples is the standard method for identifying subclinical IMI. However, the logistic and financial considerations involved with sampling all fresh cows have precluded this technique from being widely adopted. The California Mastitis Test (CMT) is arguably the only reliable cowside screening test for subclinical mastitis that can easily be applied.

[1]Department of Clinical Sciences.
[2]University of Guelph, Guelph, Ontario, Canada.
[3]Department of Diagnostic Medicine/Pathobiology.
[4]Cornell University, Ithaca, NY.
[5]Iowa State University, Ames, IA.

Most recent studies evaluating the CMT have looked at identifying IMI in the first 10 days of lactation, and also describing changes in somatic cell counts (SCC) during that same time. It was determined that the optimal strategy to select infected quarters for bacteriological culture was 3 days post-calving. Similar work in the Netherlands has supported those findings. These studies also have demonstrated that individual cow SCC declines more rapidly than the previously suggested 2 weeks. Furthermore, other studies have begun to evaluate specific diagnostic and treatment protocols for early fresh cows based on the results of a CMT. It seems that the CMT has the potential to be a rapid and cost-effective cowside test for fresh cows. Thus, the purpose of this study was to evaluate the ability of the CMT to determine the udder health status of dairy cows within the first week of calving, using a large number of cows in various herds.

Procedures

Research herds associated with Kansas State University, Iowa State University, the State University of New York in Cobleskill, and the University of Guelph in Ontario Canada, participated in this study for a period of just over 1 year. Data were collected from 325 cows that were all starting their second or greater lactation. Upon calving, all cows had a CMT performed on each functional quarter, and an aseptic quarter milk sample was collected immediately thereafter. The CMT and culture were performed only once on each cow, and were done as close to calving as possible. However, for any given cow, these tests may have been performed on days 1 to 7 in milk.

Milk samples were sent to the microbiology laboratory associated with each university. Each laboratory had Standard Operating Procedures in place for handling samples, culture techniques, and interpretation of results consistent with recommended procedures of the National Mastitis Council. Culture results were interpreted without prior knowledge of the infection of each cow status before the dry period. Therefore, new versus persistent dry period infections were not known. All levels of growth of coagulase-negative staphylococci and *Corynebacterium bovis* were considered minor pathogens. An IMI was defined as the presence of a major mastitis organism including: *Staphylococcus aureus*, *Streptococcus uberis*, *Streptococcus dysgalactiae,* non-speciated streptococci, *Escherichia coli*, Klebsiella, Mannheimia, *Arcanobacterium pyogenes*, Pseudomonas, Yeast, Serratia, other coliforms, Enterococcus, Proteus, and Prototheca. Contaminated samples, defined as growth of three or more pathogens from the same sample, were excluded.

The CMT was performed, results interpreted and recorded by one trained technician in each herd. The CMT reaction of each quarter was recorded for an ordered scale as either zero, one, two, or three. A score of zero indicated no reaction and one indicated a trace reaction. Various cutpoints of the CMT scores were used to define a positive CMT in the analysis.

All data were sent to the University of Guelph and stored in a database. Calculations of diagnostic test characteristics were performed using the milk bacteriological culture result as a gold standard control. The sensitivity, specificity, and the predictive values of the CMT results, compared to culture results, were calculated using standard two-by-two contingency tables. A 95% confidence interval was calculated for the sensitivity and specificity of the CMT on various days in milk.

Results and Discussion

A total of 1,283 quarter CMT and bacteriology results were available for analysis. Overall, the prevalence of IMI in early lactation was 10% of quarters. The predominant major mastitis-causing organisms isolated were environmental streptococci spp. and *E. coli*. The proportion of specific pathogens cultured of *Strep. uberis*, *Strep. dysgalactiae*, *E. coli*, Klebsiella, *Staph. aureus*, and all other major pathogens were 10.2%, 3.9% 15.6%, 8.6%, 14.8%, and 17.9%, respectively.

When any level of a positive CMT was defined to be an IMI, the sensitivity and specificity were 68.8% and 71.5%, respectively (Table 1). By increasing the cutpoint at which a CMT was considered positive to those reactions that were greater than a score of one, the sensitivity decreased (55.0%) and the specificity increased (86.5%). Based on the prevalence of IMI in these data, and using the same cutpoint of CMT reaction of greater than one, the positive predictive value of the CMT increased, and the negative predictive value decreased (Table 1). Stratifying the sensitivity and specificity of the CMT on the day in milk in which it was performed, a general increase of the sensitivity occurred up to day 4. The highest specificity was also on day 4.

The sensitivity of the CMT reflects its ability to detect an IMI. It is the proportion of quarters testing positive for the CMT in which an IMI was detected. The specificity of the CMT is its ability to detect quarters that did not have an IMI. It is calculated as the proportion of noninfected quarters that had a negative CMT. In combination, these two test characteristics describe how well the CMT can discriminate between infected and noninfected quarters. The predictive values of the CMT reflect the way that the test results are used in the field. The positive predictive value indicates the likelihood that a quarter with a positive CMT is indeed infected. Conversely, the negative predictive value indicates the likelihood that a quarter with a negative CMT is not infected. It is not appropriate to select a test based on predictive values, as the predictive value of any test is influenced by both the sensitivity and specificity, but also by the prevalence of disease in a population. For example, the predictive value of a CMT at a given sensitivity/specificity would be different in a herd with a very low number of new IMI at calving compared to a herd with many cows with infected quarters.

As a screening test to detect IMI in early lactating cows, a high sensitivity would be ideal. This would enable the CMT to detect the majority of quarters that had an IMI, and then these quarters could be sampled further for bacteriology. However, it is also desirable to limit the amount of false-positive reactions by having a high specificity to the CMT, or else the test would be no better than sampling all fresh cows anyway. With a calculated sensitivity and specificity of 82% and 80%, respectively, it would appear that the CMT may be a useful test to use on the fourth day of lactation. This finding is consistent with previous reports. With a relatively high and consistent negative predictive value, when a CMT was scored as having no reaction, there was a high likelihood that no IMI was present. An important consideration of this study is that all CMT reactions were scored by technicians in research dairy herds. The performance of the CMT may be very different when used on commercial dairy farms.

A valuable addition to a fresh cow program would be a rapid, cost-effective cow-side test that would identify IMI. Identifying and treating IMI before the milk becomes colostrum-free and saleable, and before the cow reaches high production, could have great economic benefits for the producer. Furthermore, identifying infected quarters and cows for further attention or to enroll them in the herd's udder health protocol immediately following calving would be beneficial to decrease the overall herd bulk milk somatic cell count.

The results of the current study confirm conclusions made from other trials that the CMT has the potential to be a rapid and accurate test for fresh cows. A definite need exists for a cow-side test that would identify those specific pathogens in CMT positive quarters.

Table 1. Calculated Test Characteristics of the California Mastitis Test within the First Week of Calving to Determine the Udder Health Status of Dairy Cows. Bacteriological cultures made from the same 1,283 quarters were used as the gold standard control.

CMT cutpoint[1]	No. of quarters	Prevalence[2] (%)	Sensitivity % (95% CI)	Specificity % (95% CI)	Positive predictive value	Negative predictive value
> Zero	1283	10.0	68.8 (60-76)	71.5 (70-72)	21.1	95.4
> One	1283		55.0 (47-63)	86.5 (85-87)	31.4	94.6
> Zero						
Days in milk						
1	311	9.6	73.3 (55-87)	66.5 (64-68)	23.2	94.8
2	348	8.6	76.7 (58-89)	70.8 (69-72)	19.8	96.8
3	244	7.4	77.8 (53-93)	62.4 (60-64)	14.1	97.2
4	115	15.6	82.4 (58-95)	80.6 (76-83)	32.6	96.3
5	100	7	71.0 (31-95)	79.6 (76-81)	20.8	97.4

[1]CMT scored as: zero (no reaction), one (trace reaction), two, or three.
[2]Prevalence of intramammary infection defined as growth of a major mastitis-causing pathogen.

ASSOCIATION OF COW AND QUARTER-LEVEL FACTORS AT DRY OFF AND NEW INTRAMAMMARY INFECTIONS IN THE DRY PERIOD

R. T. Dingwell [1], K. E. Leslie [2], J. M. Sargeant [3], Y. H. Schukken [4], L. L. Timms [5], and J. E. Shirley

Summary

Data from 300 cows and 1,178 quarters were analyzed to determine factors associated with new intramammary infections (IMI). Teat-ends that were cracked and teats that did not close during the dry period were 1.7 and 1.8 times more likely to develop new IMI, respectively. The level of milk production on the last day of lactation significantly influenced new IMI and teat canal closure. More ($P<0.05$) cows (36%) producing ≥21 kg of milk developed new IMI than cows (18%) producing less. When milk production was 21 kg or higher, teat canals were 1.8 times more likely to remain open.

(Key Words: Dry Off, Mastitis, Teat Ends.)

Introduction

The importance of the dry period with respect to udder health management and the increased rate of new intramammary infections (IMI) that occur during this time have been recognized for quite some time. For the first few weeks after the beginning of the dry period, and then again immediately before calving, cows are at an increased risk of developing IMI. Research supports that this susceptibility is related to variations in the teat streak canal and inherent biochemical and cellular changes occurring in the udder during this period. The time in which the udder is most resistant to new infections in the dry period is when the udder has become fully involuted, and a natural teat canal keratin plug has formed, which acts as a physical barrier in each teat.

Risk factors affecting susceptibility to new IMI can be categorized as occurring at the quarter, the cow, and the herd level. At the level of the individual quarter, bacterial populations present at the teat end, the integrity of the teat end, and timely formation of the teat canal keratin plug are very important. Due to this recognized importance, a standardized classification system for teat-end integrity was proposed. A method to assess closure of the teat streak canal during the dry period has been docu mented.

Cow level risk factors have been studied previously as well. The influence of age and the level of milk production of a cow at the time of dry off have been investigated, in addition to various approaches to enhance the process of involution. Debate over the relative importance of milk production at dry off continues to evolve, especially as the genetic potential for milk production of cows continues to increase.

[1]Department of Clinical Sciences.
[2]University of Guelph, Guelph, Ontario, Canada.
[3]Department of Diagnostic Medicine/Pathobiology.
[4]Cornell University, Ithaca, NY.
[5]Iowa State University, Ames, IA.

A need exists to determine the importance of milk production at drying. In addition, the most effective strategies currently being employed by dairy producers to dry off cows need to be identified. No specific recommendations are given to producers on how to manage a cow from the 2 weeks before the dry period until early in that period.

In the current study, cows were evaluated from 2 weeks before dry off through to the next lactation, to describe the influence of specific cow and quarter factors on the rate of new dry period IMI. The variables of interest were daily milk production, teat-end integrity, and closure of the teat streak canal during the dry period. Information on the breed, parity, days in milk and the season of dry off were also recorded. The underlying hypothesis was that with an enhanced understanding of drying-off management, and the influence of various factors on the development of new IMI, future recommendations on the process of dry off could be made.

Procedures

Research herds associated with Kansas State University, Iowa State University, the State University of New York in Cobleskill, and the University of Guelph in Ontario Canada, participated in this study for a period of just over one year. Dairy cows ending their first or subsequent lactation were enrolled in this study at 2 weeks before the scheduled dry period. The majority of cows were ending their first or second lactations at enrollment, and were Holsteins. Other breeds in this study included Ayrshires, Jerseys, Guernseys, Milking Shorthorns and Brown Swiss. The routine dry cow management program, including the administration of dry cow antibiotic therapy at the end of lactation, was not altered in any herd. At the time of enrollment prior to dry off (day -14), aseptic quarter milk samples were collected from all cows for bacteriological culture, days in milk of each cow was recorded, and each of the four quarters were scored for teat-end lesions. Daily milk weights were recorded from this time up until dry off (day 0). All cows were milked just once on the day of dry off, and following that milking, quarter milk samples were obtained prior to administration of a dry cow antibiotic, and teat-ends were scored again. Once a week for the first 6 weeks of the dry period, research technicians evaluated each cow for teat-end scores and formation of the teat canal keratin plug. Weekly dry period examinations ended when all four quarters of a cow were determined to be closed, or at 6 weeks after dry off, whichever came first. Within the first week after calving (day 1), a final quarter milk sample was obtained for culture, and teat ends were scored one final time. Teat ends were aseptically prepared prior to milk sample collection and samples were sent to a laboratory at each participating site. Each laboratory had Standard Operating Procedures in place for handling samples, culture techniques, and interpretation of results consistent with recommended procedures of the National Mastitis Council. Quarters were defined to harbor a new infection when a mastitis-causing pathogen was isolated on the sample post-calving, and that pathogen was not present in the same quarter prior to dry off.

A uniform teat-end score classification guide was created by the authors. The specific classification used was adapted from a similar teat-end callosity classification recently published. Scores from one to five with 0.5 increments were used that incorporated both smooth and rough callosity as well as the degree of callosity. A score of 1 described a teat with no ring (callosity) or roughness (cracking). Scores of 1.5 to 3 represented teats with a smooth callosity ring (no roughness/cracking). By comparison, scores from 3.5 to 5 represented teats with a rough callosity ring and cracking.

Descriptive statistics were generated using the univariate and frequency procedures. Estimates of mean values, and differences among means across various strata (herd, milk production, season) were calculated with a least squares mean procedures. A Chi-square test was used to test the significance of a single factor on the proportion of new IMI. Generalized estimation equations were used to model the probability of both an individual cow and quarter to develop a new IMI.

Results and Discussion

Complete data from 300 cows and 1,178 quarters were available for analyses. Descriptive statistics of the cows used in this trial are presented in Table 1. The average duration of the dry period was 65 days and varied significantly in duration among the five herds. Although this trial was conducted for a period of just over one full year, over 60% of the cows were dried off in the summer and fall months. One herd had a seasonal calving pattern.

Bacteriological results from the quarter milk samples revealed that 11.1% of quarters developed a new IMI during the dry period. An individual cow was considered newly infected if she had at least one quarter develop a new IMI. Using that definition, 20.7% of cows developed new infections. Significant differences were detected in both the quarter and cow rate of new IMI among herds (Table 2). The majority of these new infections were caused by environmental organisms. The proportion of new IMI caused by environmental streptococci sp, *E. coli*, and *Staphylococcus aureus* were 22.9%, 14.5% and 10.7%, respectively. A total of 66% and 2.7% of the 1,178 quarter samples yielded no growth and nonsignificant bacterial growth, respectively. The predominance of environmental organisms causing new dry period IMI was not surprising. However, the finding of 10% new *S. aureus* IMI may be a result of the sampling schedule used. It is plausible that these infections were not detected before the dry period, and indeed were not initiated during the dry period.

A total of 24.5% of teats scored were classified to be cracked teat ends at some time during the study. The specific time at which most teats were observed to be cracked was on the actual day of dry off. The individual teat-end scores were pooled to quantify the occurrence of cracked teats in cows. In total, 24.7% of cows had at least one cracked teat during the study. This finding, relative to the overall number of individual cracked teats, indicated that cows tended to have multiple cracked teat ends. As the dry period progressed, there was a general improvement in teat end scores, which is consistent with other studies that have shown improvements in teat end callosity when the mechanical forces of machine milking are reduced or absent (dry period).

A marked decline occurred in the percentage of open teats early in the dry period, with over 50% of teats closing in the first week. However, after 6 weeks of observation, 23.4% of teats remained open. Significant differences in the closure of teats were detected among herds as well. After all four teats were closed per cow, 63.3% of cows met that criteria within 6 weeks of the dry period. Teat closure at the cow level varied among herds from 18.5% to 89.8% (Table 3).

The relative importance of teat-end integrity and teat canal closure on new IMI was evident from the univariate association of these factors on that outcome (Table 2). This importance was evident at both the level of the individual quarter and the cow. Overall, 14% of teats that took longer ($P<0.05$) than 3 weeks to close developed new IMI, compared to only 9.7% of teats that closed in the first 3 weeks. Teats that were cracked developed more ($P<0.05$) new IMI than teats that were not cracked (14.8% and 9.8%, respectively). Similarly, cows that had at least one teat cracked developed more ($P<0.05$) new IMI than cows that did not have any teats cracked (31.1% and 17.3%, respectively).

Also, only 12.8% of cows that had all four teats close in the first 3 weeks of the dry period developed a new IMI, compared to 28.5% of cows that took longer (*P*<0.01) than three weeks for all teats to close.

A general but variable decline in the level of milk production occurred among herds from the time of enrollment until the day of dry off. On the day prior to dry off, which was the last time when two milkings occurred, the average milk production was 12.9 ± 0.4 kg. Level of milk production among herds at this time varied between 8.3 and 18.8 kg (Table 3). In total, more (*P*<0.05) cows (35.6%) that were producing greater than 21 kg on the day prior to dry off developed new IMI during the dry period, than cows (18%) producing less than that amount of milk. An interesting finding from this study was the association between the level of milk production prior to dry off and the rate of teat canal closure. Using the same cutpoint of 21 kg of milk yield on the day prior to dry off when cows were producing above that level, teat canal closure took longer (*P*<0.05) to occur than when milk production was less than 21 kg (Figure 1). The final proportional hazards model revealed that when milk production was greater than 21 kg, the hazard ratio (HR) for a teat to close was reduced (HR=0.56), which implies that a teat remained open longer (*P*<0.01).

In the final logistic models, which controlled for breed, parity, dry period duration and season, it was determined that teat-end integrity, teat canal closure and milk production all remained significantly associated with the development of new IMI. Quarters that remained open were 1.8 times more (*P*<0.05) likely to develop a new IMI than quarters that were closed via formation of a natural keratin plug. Quarters that were defined to have a cracked teat end were 1.7 times more (*P*<0.05) likely to develop infections, than quarters that were never defined to be cracked. The final logistic model for a cow to develop a new IMI found that cows that had all four teat ends close within the first 3 weeks of the dry period were 75% less (*P*<0.01) likely to develop new IMI than cows that had at least one teat remain open for longer than 3 weeks. Cows that had at least one teat with a cracked teat end were 2.5 times more (*P*<0.05) likely to develop new dry period infections than cows that had no cracked teats.

In summary, this observational study followed 300 cows from 2 weeks prior to scheduled dry off, until after the dry period. By classifying teat-end integrity, assessing teat canal closure and recording daily milk production, several new findings were reported, and the association of various factors were reemphasized. Although teat end integrity has often been implicated in clinical mastitis during lactation, little information exists about the integrity of teats during the dry period. This study has shown the strong influence of teat end integrity both at the quarter and at the cow level to be a risk factor for new dry period IMI.

Closure of the teat canal during the dry period, by means of a naturally occurring keratin plug, has been proven an important defense mechanism. This study has not only reemphasized how important timely closure is, but also that natural closure may not occur in a very high percentage of teats. Furthermore, the level of milk production prior to dry off may determine teat canal closure. This indirect effect of milk production and its impact of teat canal closure should be explored in much more detail.

It would appear that management strategies aimed at improving teat-end integrity as well as enhancing teat canal closure during the dry period would be of benefit to decreasing new dry period IMI. Further elucidation of the impact of milk production on teat canal closure, coupled with a recognition of important quarter-level factors may allow for future management recommendations.

Table 1. Descriptive Statistics of 300 Cows and Herds Enrolled in Study From Five Participating Sites

Variable		No. (%)	Mean	S. D.	95% CI
Parity	1	131 (43.7)			
	2	88 (29.3)			
	3	39 (13.0)			
	4+	42 (14.0)			
Breed	Holstein	256 (85.3)			
	Other	44 (14.7)			
Dry period (days)	Overall		65.2	13.4	
	Herd 1		74.9^{b}		71.9 - 77.9
	Herd 2		75.1^{b}		71.4 - 78.7
	Herd 3		60.8^{a}		57.9 - 63.6
	Herd 4		66.2^{b}		62.7 - 69.6
	Herd 5		58.4^{a}		56.2 - 60.8
Season of dry off	Spring		63 (21.0)		
	Summer		91 (30.3)		
	Fall		107 (35.7)		
	Winter		39 (13.0)		

^{a,b}Means with dissimilar superscript letters differ (P<0.05).

Table 2. Proportion of New Intramammary Infections During the Dry Period Across Various Factors and Herd and Cow Specific Rates of Teat Canal Closure

Item	Factor	Level	No.	% new IMI
Quarter	Herd	1	211	12.3^{a}
		2	151	11.9^{a}
		3	256	10.6^{a}
		4	176	17.6^{b}
		5	384	7.6^{a}
	Time until closed	< 3 weeks	803	9.7^{a}
		≥ 3 weeks	375	14.0^{b}
	Teat-end integrity	No crack	791	9.8^{a}
		Cracked	275	14.8^{b}
Cow	Herd	1	55	16.4^{a}
		2	38	21.1^{a}
		3	65	29.2^{ab}
		4	44	36.4^{bc}
		5	98	10.2^{a}
	All teats closed	< 3 weeks		12.8^{a}
		≥ 3 weeks		28.5^{b}
	Teat end integrity	>one teat cracked		31.1^{a}
		No teats cracked		17.3^{b}
	Milk production	≥ 21 kg		35.6^{a}
		< 21 kg		18.0^{b}

^{a,b,c}Percentages within column, and within the same level of a factor, not sharing a similar superscript are significantly different at P<0.05.

Table 3. Summary Statistics of Teat Canal Closure, Teat-end Integrity and Milk Production by Participating Herd

			Week						
Factor	Herd	Dry off	1	2	3	4	5	6	Total
% Open teats	Overall		46.8%	37.5%	31.8%	28.5%	24.8%	23.4%	23.4%
	1		42.2%	35.1%	27.9%	21.3%	16.1%	16.1%	
	2		51.7%	40.4%	35.8%	31.1%	26.5%	26.5%	
	3		83.2%	78.9%	75.0%	73.1%	69.5%	63.3%	
	4		23.9%	15.9%	11.9%	8.5%	7.4%	7.4%	
	5		33.6%	20.1%	12.8%	10.9%	7.0%	7.0%	
% Cracked teats	Overall	20.9%	6.0%	6.6%	9.4%	2.3%	2.1%	1.8%	
Milk production (kg)	Overall	12.9							
	1	12.7							
	2	12.1							
	3	18.8							
	4	15.9							
	5	8.3							

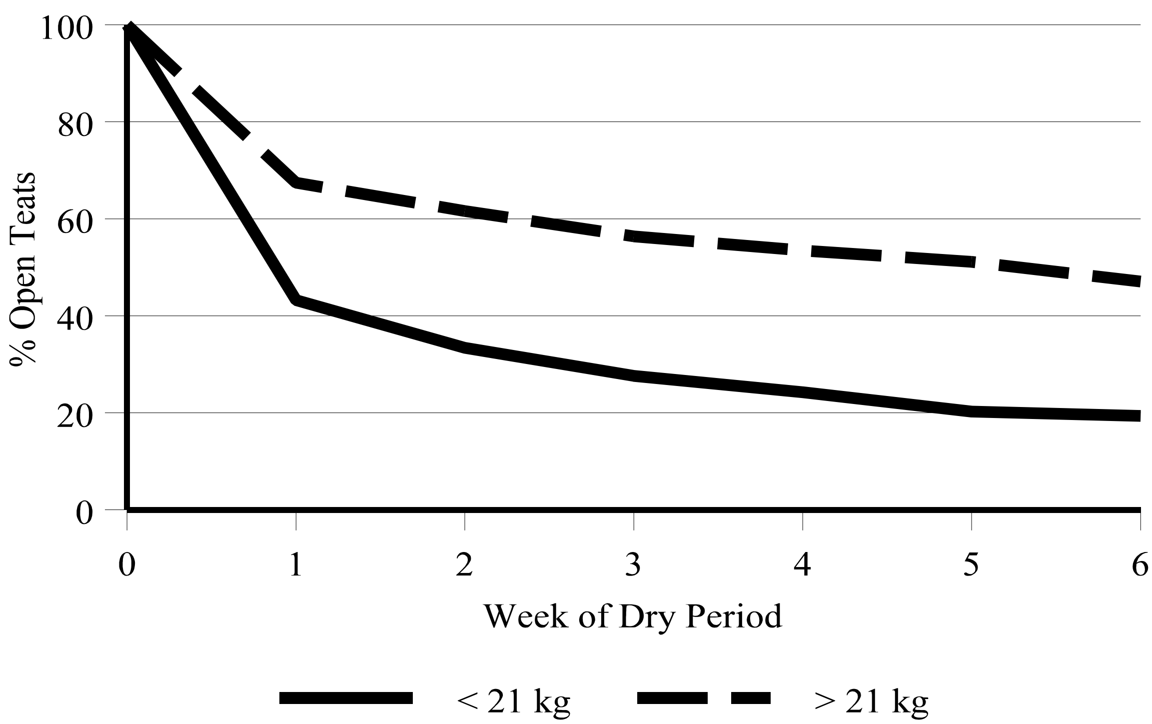

Figure 1. Proportion of Teats Classified as Open at Each of Six Weeks During the Dry Period, by the Level of Milk Production Prior to Dry Off.

METABOLIC CHANGES DURING THE TRANSITION PERIOD

A. F. Park, J. E. Shirley, E. C. Titgemeyer, R. C. Cochran, J. M. DeFrain, E. E. Ferdinand, and D. E. Johnson [1]

Summary

We used four ruminally fistulated, multiparous, pregnant Holstein cows to measure changes in concentrations of plasma metabolite as the dairy cow transitions from one lactation to the next. Diets consisted of typical far-off and close-up diets, a late lactation diet containing wet corn gluten feed (20% DM), and an alfalfa hay-corn silage based early lactation diet. Calculated NE_L (Mcal/lb), measured crude protein (%), and diet digestibilities (%; based on steers fed at 2% of BW) were 0.78, 18.7, 74.1; 0.70, 11.5, 66.2; 0.74, 15.6, 71.0; 0.73, 18.4, 70.7 for late lactation, far-off dry, close-up dry, and early lactation diets, respectively. Blood samples were obtained on day 79 prior to calving and weekly thereafter until calving and on days 1, 3, 5, 7, 15, 20, 25, 30, 60, and 90 after calving. Cows gained body weight and condition during the dry period, peaked just prior to calving, and lost weight and condition steadily through the first 11 weeks of lactation. Calculated energy balance was negative during the first 3 weeks of lactation. Plasma concentrations of non-esterified fatty acids (NEFA), glucose, and insulin to glucagon ratio remained fairly stable during the dry period. Plasma glucose increased just before calving, decreased markedly during early lactation, then increased and stabilized by day 30 of lactation. Plasma NEFA concentrations increased at calving and were elevated during early lactation, then returned to prepartum concentrations by day 30 of lactation. The insulin to glucagon ratio decreased just prior to calving, continued to decrease until day 7 of lactation, and then remained stable until the end of the trial. Changes in diet and intake affected plasma urea nitrogen, which decreased as dietary protein decreased during the far-off period, decreased with intake during the close-up period, and increased after calving consistent with the higher dietary protein and increase in dry matter intake. Most of the observed metabolic adaptations reflected the energy status of the cow with large shifts occurring around parturition. Certainly, some of the hormones associated with calving can initiate metabolic events favorable to lactation, but the changes in energy balance and nutrient supply support the continued diversion of nutrients to the mammary gland. These data support the concept that dairy cows experience a period of increased tissue mobilization from approximately 2 days prior to calving until 30 days after calving. In conclusion, a number of metabolic adaptations occur in transition dairy cows that provide clues to improve feeding and management guidelines.

(Key Words: Transition, Dairy Cow, Plasma.)

Introduction

As dairy cows transition from one lactation through the dry period to the next lactation their metabolism changes to accommodate the shift in nutrient and physiological requirements. The requirements of the developing fetus and maintenance of body tissues dictate the requirements of the far-off dry cow. Cows entering the dry period with a body condition score

[1]Department of Statistics.

(BCS; 1 = thin and 5 = fat) of less than 3 require additional nutrients to increase body stores, and young cows require additional nutrients for growth. The requirements of close-up cows are greater than those of the far-off cow because the fetus is in a rapid growth phase and mammary gland function (lactogenesis) is initiated in preparation for lactation. Typically, feed intake decreases sharply (20 to 30%) during the last week before calving followed by a shift in adipose tissue metabolism from deposition to mobilization of fat. Several hormones associated with parturition stimulate and/or depress body metabolic activities in order to deliver the calf and support the lactating mammary gland. Several studies have described metabolic activities during the periparturient period, but none describe the metabolic transitions from one lactation through the dry period and into the first third of the next lactation. Thus, our objective was to characterize the metabolic adaptations that occur when dairy cows transition from one lactation through the first 13 weeks of the next lactation.

Procedures

We used four ruminally fistulated, multiparous, pregnant Holstein cows fed total mixed rations (TMR) twice daily. Typical dairy diets were used for late lactation, far-off, close-up, and lactation (Tables 1 and 2). Plasma samples were collected prior to calving on days 79, 72, 65 (late lactation); days 58, 51, 44, 37, 30 (far-off); days 23, 16, 9, 2 (close-up); and then days 1, 3, 5, 7, 15, 20, 25, 30, 60, and 90 days after calving. Samples were collected from the coccygeal vein between 2 to 3 hours after the AM feeding. Plasma was harvested and stored frozen until analyzed for concentrations of insulin, glucagon, glucose, NEFA, and urea nitrogen. Body weights and BCS were measured weekly to estimate energy balance. Energy balance was defined as net energy of lactation intake minus net energy used for maintenance plus either fetal growth or lactation.

Results and Discussion

All cows calved within an 8-day period, and none experienced health disorders. Thus, metabolic profiles reflect normal cows transitioning from one lactation to the next. All cows received a diet consistent with their state of lactation or gestation (Tables 1 and 2).

Cows gained body weight and condition from dry off to calving with increases in body weight from 1295 lb to 1446 lb and body condition from 2.7 to 2.9 (Figure 1). Prepartum gains in body weight and condition correlated well with calculated energy balance (Figure 2). However, postpartum losses in body weight and condition do not correlate well with calculated energy balance likely due to an overestimation of the net energy of lactation value of the diet consumed.

The insulin to glucagon ratio began to decrease by day 2 prior to calving, continued to decrease until day 5 after calving, then remaining low, but stable, for the remainder of the trial (Figure 3). Plasma glucose concentration increased sharply on day 2 prior to calving, reflective of the declining insulin to glucagon ratio, then decreased across calving before rebounding with intake by day 30 after calving (Figure 4). Concentrations of NEFA's, reflecting fat mobilization from adipose tissue, began to increase 2 days prior to calving, peaked on day 15 postpartum, and returned to prepartum concentrations by day 30 after calving (Figure 5). Plasma urea nitrogen concentration decreased during the far-off period and increased initially when cows were fed the close-up diet (Figure 6) containing 15.6% CP. Likely the decrease in PUN concentrations during the far-off period were due to a lower dietary protein content (11.5% CP). Plasma urea nitrogen concentrations decreased during the close-up period and then increased dramatically after calving. Decreasing PUN concentrations during the close-up period mirrored the decrease in feed intake during this time. Concentrations increased sharply after calving with an increase in dietary protein, dry matter intake, and tissue mobilization to support lactation.

The majority of observed metabolic adaptations reflected the energy status of the cow with the major shifts associated with parturition and onset of lactation. Certainly, some of the hormones associated with calving can initiate metabolic events favorable to lactation, but the changes in energy balance and nutrient supply support the continued diversion of nutrients to the mammary gland. These data support the concept that dairy cows experience a period of increased tissue mobilization from approximately 2 days prior to calving until 30 days after calving. In conclusion, a number of metabolic adaptations occur in the transition dairy cow, and they could provide clues that will improve feeding and management guidelines.

Table 1. Experimental Diets

	Diets (% of DM)			
Ingredient	Late Lactation	Far-off	Close-up	Lactation
Alfalfa hay	20.0	–	15.0	30.0
Prairie hay	–	48.4	20.0	–
Corn silage	10.1	19.8	30.0	15.0
Corn grain	27.7	22.4	18.7	32.0
Whole cottonseed	9.3	–	–	9.3
Fishmeal	1.3	–	–	1.3
Expeller soybean meal	7.7	–	9.4	3.3
48% soybean meal	–	8.4	4.4	4.4
Wet corn gluten feed	19.6	–	–	–
Molasses	1.3	–	–	1.0
Limestone	1.38	0.06	0.60	1.36
Dicalcium phosphate	0.05	0.40	0.74	0.88
Sodium bicarbonate	0.68	–	–	0.75
Trace mineral salt[1]	0.29	0.34	0.50	0.32
Magnesium oxide	0.20	–	0.50	0.21
Vitamin A,D,E[2]	0.12	0.11	0.12	0.13
Sodium selenite premix[3]	0.08	0.02	0.04	0.01

[1]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, and 0.004% Co.

[2]Contributed 4,912 IU vitamin A, 2,358 IU vitamin D, and 24 IU vitamin E per kg diet DM.

[3]Contributed 0.06 mg Se per kg diet DM.

Table 2. Chemical Characteristics of Experimental Diets

	Diets (% DM)			
Nutrient	Late Lactation	Far-off	Close-up	Lactation
Dry matter, %	75.3	82.5	76.9	82.5
Crude protein, %	18.7	11.5	15.6	18.4
Soluble protein, % of CP[1]	31.3	25.2	25.2	31.3
RDP, % of CP	62.1	63.4	65.8	63.4
ADF, %	17.5	25.2	22.0	18.2
NDF, %	29.9	42.9	34.4	27.0
Non-fiber carbohydrate, %	37.8	35.2	39.1	40.4
TDN, %	73.2	67.0	69.1	72.3
NE_L , Mcal/kg[2]	0.78	0.70	0.74	0.73
Crude fat, %	5.75	3.76	3.49	5.60
Ash, %	7.70	6.72	7.40	8.43
Calcium, %	1.07	0.52	0.81	1.51
Phosphorus, %	0.66	0.36	0.49	0.71
Magnesium, %	0.34	0.20	0.35	0.33
Potassium, %	1.41	1.15	1.49	1.48
Sodium, %	0.37	0.11	0.17	0.33
Sulfur, %	0.25	0.13	0.17	0.21

[1]Based on feed analysis from Dairy Herd Improvement Forage Testing Laboratory (Ithaca, NY).

[2]Calculated based on NRC (2001). Estimates of NE_L values from summation of individual ingredients (0.78, 0.66, 0.71, and 0.77 for the late lactation, far-off, close-up, and lactation diets, respectively).

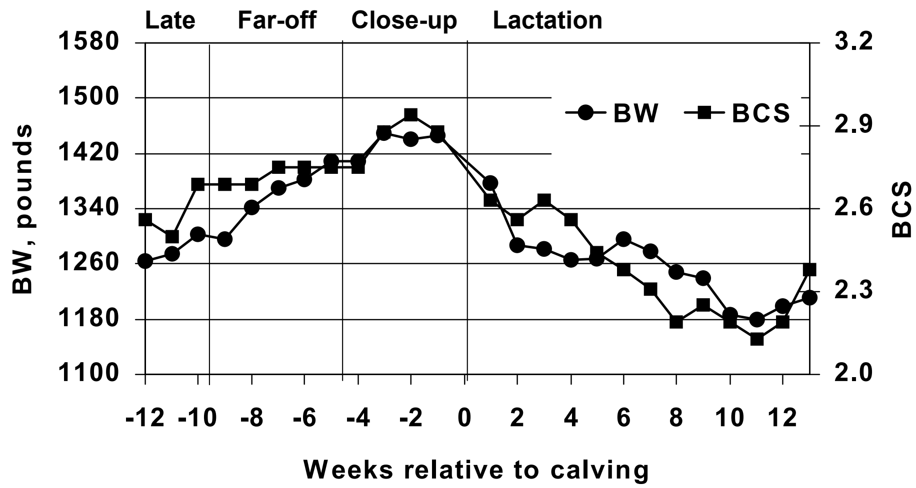

Figure 1. Body Weights and Body Condition Scores.

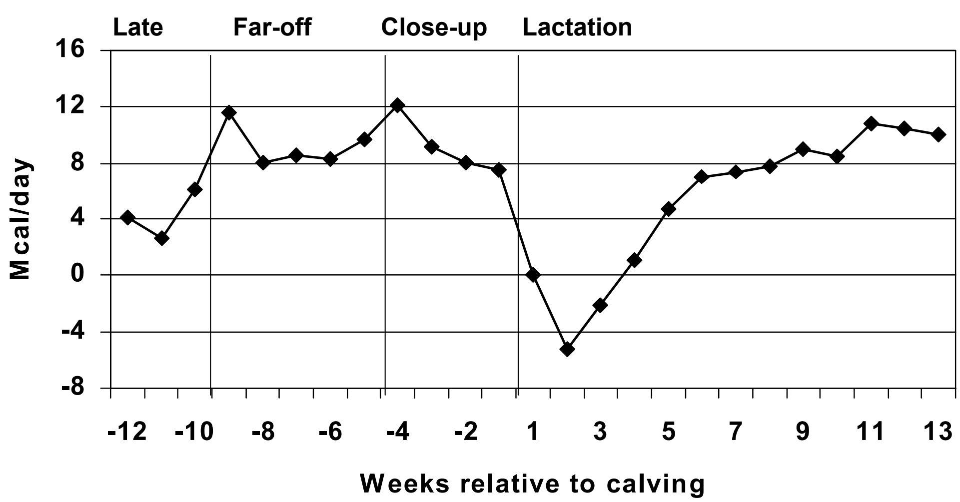

Figure 2. Calculated Energy Balance.

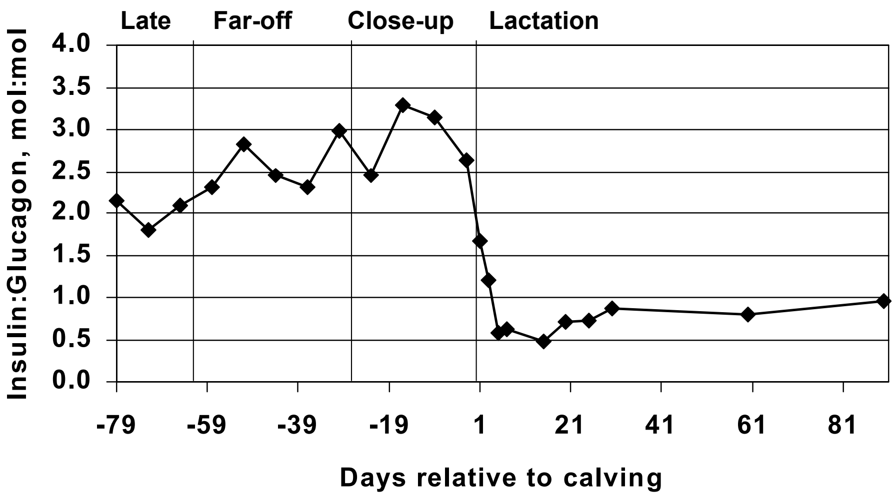

Figure 3. Molar Ratio of Insulin to Glucagon.

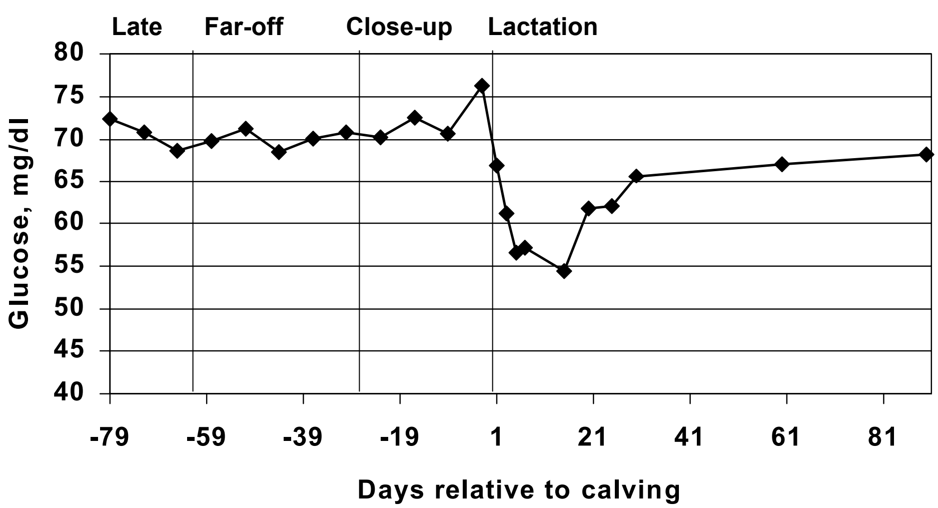

Figure 4. Concentrations of Plasma Glucose.

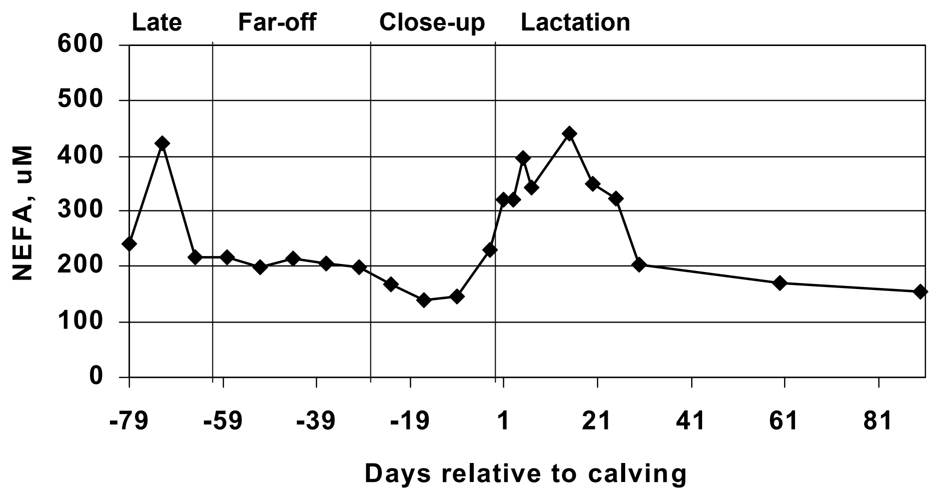

Figure 5. Concentrations of Plasma Nonesterified Fatty Acids (NEFA).

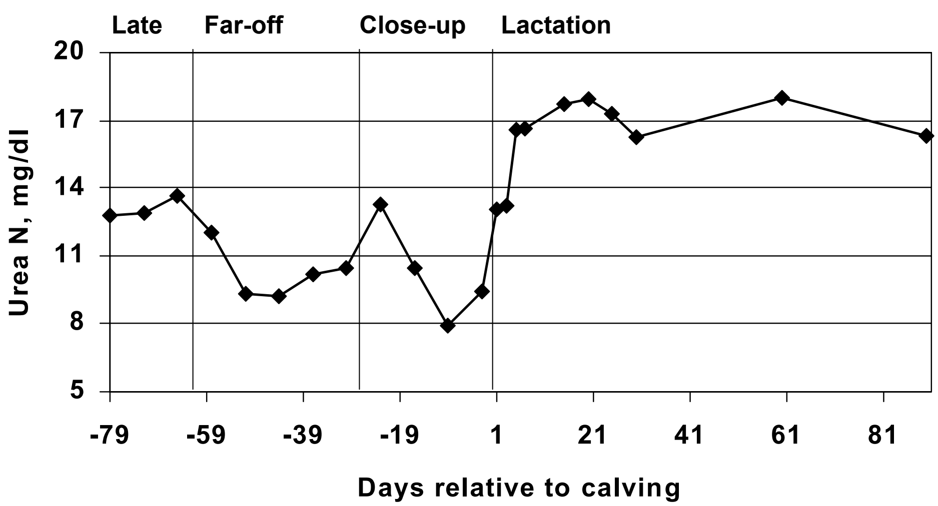

Figure 6. Concentrations of Plasma Urea Nitrogen (PUN).

CHARACTERISTIC CHANGES OF RUMINAL FERMENTATION IN TRANSITION DAIRY COWS

A. F. Park, J. E. Shirley, E. C. Titgemeyer, R. C. Cochran, J. M. DeFrain, E. E. Ferdinand, T. G. Nagaraja[1], and D. E. Johnson[2]

Summary

Four-ruminally fistulated, multiparous, pregnant Holstein cows were used to delineate changes in ruminal fermentation in dairy cows as they experienced the transition from one lactation to the next. Diets consisted of typical far-off and close-up diets, a late lactation diet containing wet corn gluten feed (20% DM) and an alfalfa hay-corn silage based early lactation diet. Calculated NE_L (Mcal/lb), measured crude protein (%), and diet digestibilities (%; based on steers fed at 2% of BW) were: 0.78, 18.7, 74.1; 0.70, 11.5, 66.2; 0.74, 15.6, 71.0; 0.73, 18.4, 70.7 for late lactation, far-off dry, close-up dry, and early lactation diets, respectively. Ruminal measurements were taken on days 72 (late lactation), 51 (far-off), 23, and 9 (close-up dry) before calving and on days 6, 20, 34, 48, 62, 76, and 90 days after calving. Ruminal samples were collected at hours 0, 3, 6, 9, and 12 after feeding on each sampling date. Major shifts in ruminal fermentations occurred when the close-up diet was consumed before calving and in concert with an increase in DM intake during the first 48 days of lactation. Dry matter digestibility increased after cows were switched to the close-up diet and continued this trend through day 6 postpartum. Ruminal pH decreased and total volatile fatty acids, peptides, and free amino acids increased after cows were switched to the early lactation diet. These data support the concept that alterations in ruminal fermentation reflect changes in both diet and intake.

(Key Words: Transition, Dairy Cow, Rumen Fermentation.)

Introduction

Improving nutritional status of transition cows can help ensure a successful lactation by improving rumen function and reducing the incidence of metabolic diseases. Transition dairy cows face a number of nutritional challenges including diet changes, decreased dry matter intake (DMI), and increased nutrient requirements. The generally observed decrease in prepartum DMI followed by a major diet change immediately after parturition can lead to lactic acidosis, ketosis, milk fever, and displaced abomasal disorder. Recommended transition cow management dictates that dry cows are fed a close-up diet containing a portion of the feedstuffs included in the lactation diet beginning 21 days before the expected calving date. This practice is designed to begin adapting the ruminal microbial population to the lactation diet before it is introduced after parturition. The 21-day duration of the close-up period ensures that all cows are fed the close-up diet for at least 14 days. This program works reasonably well but little information exists regarding its impact on ru-

[1]Department of Diagnostic Medicine/Pathobiology.
[2]Department of Statistics.

men function. Thus, our objective was to characterize ruminal responses to dietary changes from one lactation through the first third of the next lactation in an effort to provide a basis for improving transition cow nutrition.

Procedures

We used four-ruminally fistulated, multiparous, pregnant Holstein cows fed twice daily typical dairy diets for late lactation, far-off and close-up dry, and early lactation. Sample collections were made on days 72 (late lactation), 51 (far-off), 23 and 9 (close-up) and on days 6, 20, 34, 48, 62, 76, and 90 postpartum. Total tract dry matter digestibility (DMD) and solid passage rate were measured using indigestible acid detergent fiber (IADF) as the marker. Calculations of DMD and solid passage rate required determination of IADF concentrations in diet, refusals, digesta, and fecal samples. Digesta and fecal sample collections utilized a total ruminal collection via cannula and fecal grab sampling scheme (every 6 hr for a day then advancing 2 hr until 12 samples were collected). Ruminal fermentative measurements included pH, total volatile fatty acids (TVFA), peptides, free amino acids, and ammonia.

Results and Discussion

Metabolic profiles (companion study) reflected a normal transitioning of cows from one lactation to the next with no health disorders observed during the experiment. All cows received a common diet consistent with their physiological state (Tables 1 and 2). Solid rate of passage increased steadily from late lactation to day 23 prior to calving, whereas DMD remained relatively unchanged (Figure 1). Changes occurred in DMD and solid rate of passage during the last 3 weeks of gestation as DMI decreased (Figure 2). Dry matter digestibility increased from 50.4% on day 23 prior to calving to 58.3% on day 6 postpartum, whereas solid rate of passage decreased substantially (6.47 to 3.27% per h). Total tract dry matter digestibility and solid rate of passage remained fairly stable between day 6 and day 62 after calving. Solids passage rate decreased from 4.0 to 3.0% per hr and DMD increased 52.1 to 64.1% after d 62 in lactation.

Ruminal pH (Figure 3) increased after cows were switched to the far-off diet and remained elevated until lactation began, likely due to an increase in fiber content of dry cow diets. Ruminal pH decreased (6.7 to 6.1) between day 9 before calving and day 20 after calving as a result of the increased amount of concentrate in the lactation diet and increased DMI. Ruminal pH is important because it influences the microbial population, ruminal digestion, and absorption. Total volatile fatty acid concentrations (Figure 4) remained relatively constant from late lactation to day 9 before calving, then increased until day 48 after calving (93.8 to 153.2 mM), then decreased through day 90. Ruminal TVFA concentrations are a function of production, absorption, and rate of passage. The increase in ruminal TVFA concentration between day 9 and day 48 postpartum mirrored increases in intake and was likely responsible for increased production. The decrease in ruminal TVFA concentrations after d 48 was partially attributed to increased absorption because intake was increasing and solid rate of passage was decreasing.

Ruminal concentrations of individual VFAs are influenced by the type and amount of feedstuffs in the diet. Concentrations of acetate are associated with dietary forages, whereas concentrations of propionate are associated with dietary concentrates. The increase in acetate to propionate ratio observed when cows consumed the far-off and close-up diets (Figure 5) reflects a decrease in propionate relative to acetate, whereas the decrease in acetate to propionate ratio after day 48 in lactation was due to a decrease in acetate relative to propionate.

Ruminal microbes work in concert to degrade dietary protein and non-protein nitrogen into peptides, free amino acids, and ammonia for incorporation into microbial crude protein. Ruminal peptide concentrations remained unchanged in the dry period but decreased from 2.5 mM on day 48 to 1.1 mM on day 62 postpartum (Figure 6) then remained unchanged. Ruminal free amino acid concentrations (Figure 7) decreased during far-off and close-up periods and increased after calving. Ruminal ammonia concentrations decreased during the close-up period and remained fairly stable during lactation (Figure 8), except for the sharp increase on day 6 postpartum.

The lower peptide concentration after day 48 of lactation (Figure 6) was attributed to increased microbial activity. Concentrations of free amino acids increased in lactation but were quite variable. The variability of ruminal free amino acids during early lactation possibly reflects microbial adjustments to increases in DMI. These data support the concept that ruminal fermentation is affected by both diet and intake.

Table 1. Experimental Diets

	Diets (% of DM)			
Ingredient	Late Lactation	Far-off	Close-up	Lactation
Alfalfa hay	20.0	–	15.0	30.0
Prairie hay	–	48.4	20.0	–
Corn silage	10.1	19.8	30.0	15.0
Corn grain	27.7	22.4	18.7	32.0
Whole cottonseed	9.3	–	–	9.3
Fishmeal	1.3	–	–	1.3
Expeller soybean meal	7.7	–	9.4	3.3
48% soybean meal	–	8.4	4.4	4.4
Wet corn gluten feed	19.6	–	–	–
Molasses	1.3	–	–	1.0
Limestone	1.38	0.06	0.60	1.36
Dicalcium phosphate	0.05	0.40	0.74	0.88
Sodium bicarbonate	0.68	0.00	–	0.75
Trace mineral salt[1]	0.29	0.34	0.50	0.32
Magnesium oxide	0.20	–	0.50	0.21
Vitamin A,D,E[2]	0.12	0.11	0.12	0.13
Sodium selenite premix[3]	0.08	0.02	0.04	0.01

[1]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, and 0.004% Co.

[2]Contributed 4912 IU vitamin A, 2358 IU vitamin D, and 24 IU vitamin E per kg diet DM.

[3]Contributed 0.06 mg Se per kg diet DM.

Table 2. Chemical Characteristics of Experimental Diets

	Diets (% DM)			
Nutrient	Late Lactation	Far-off	Close-up	Lactation
Dry matter, %	75.3	82.5	76.9	82.5
Crude protein, %	18.7	11.5	15.6	18.4
Soluble protein, % of CP[1]	31.3	25.2	25.2	31.3
RDP, % of CP	62.1	63.4	65.8	63.4
ADF, %	17.5	25.2	22.0	18.2
NDF, %	29.9	42.9	34.4	27.0
Non-fiber carbohydrate, %	37.8	35.2	39.1	40.4
TDN, %	73.2	67.0	69.1	72.3
NE_L , Mcal/lb[2]	0.78	0.70	0.74	0.73
Crude fat, %	5.75	3.76	3.49	5.60
Ash, %	7.70	6.72	7.40	8.43
Calcium, %	1.07	0.52	0.81	1.51
Phosphorus, %	0.66	0.36	0.49	0.71
Magnesium, %	0.34	0.20	0.35	0.33
Potassium, %	1.41	1.15	1.49	1.48
Sodium, %	0.37	0.11	0.17	0.33
Sulfur, %	0.25	0.13	0.17	0.21

[1]Based on feed analysis from Dairy Herd Improvement Forage Testing Laboratory (Ithaca, NY).

[2]Calculated based on NRC, 2001. Estimates of NE_L values from summation of individual ingredients (0.78, 0.66, 0.71, and 0.77 for the late lactation, far-off, close-up, and lactation diets, respectively).

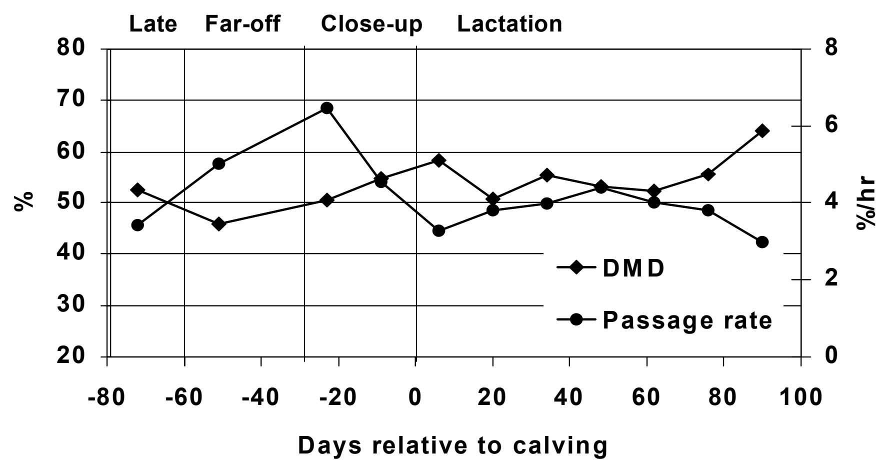

Figure 1. Dry Matter Digestibility and Rate of Passage.

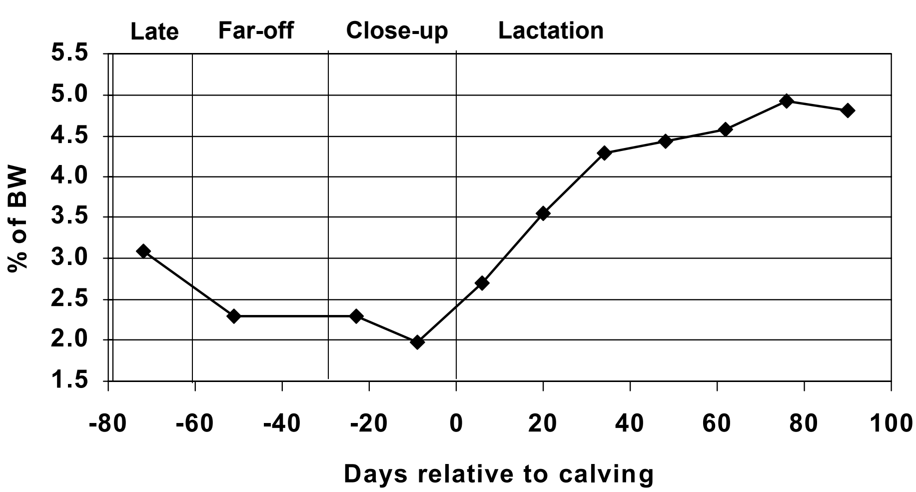

Figure 2. DMI as a Percentage of Body Weight (BW).

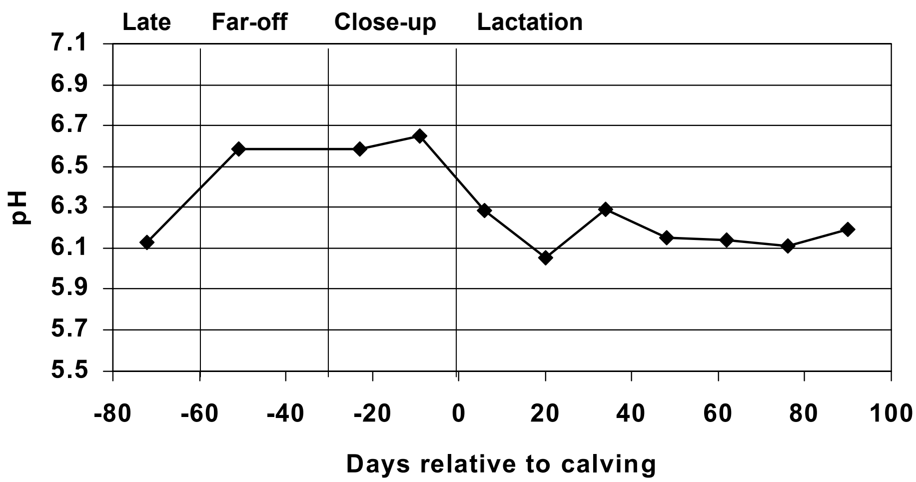

Figure 3. Ruminal pH.

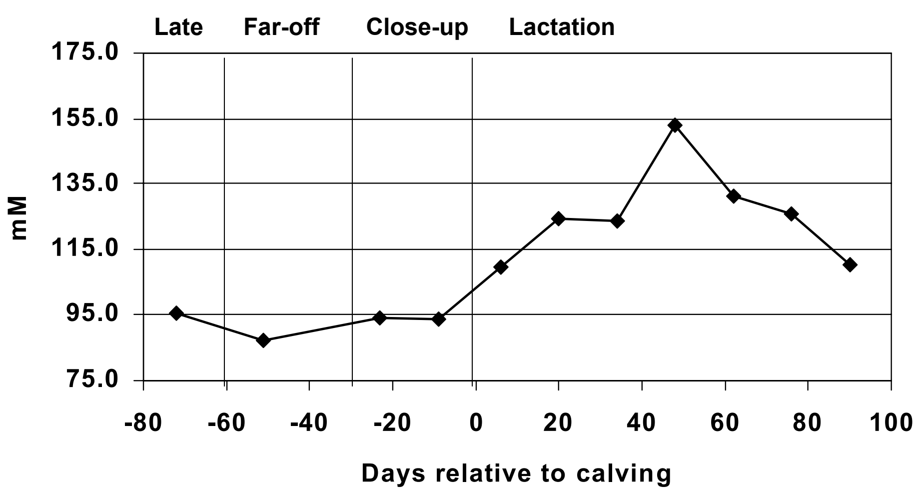

Figure 4. Total VFA.

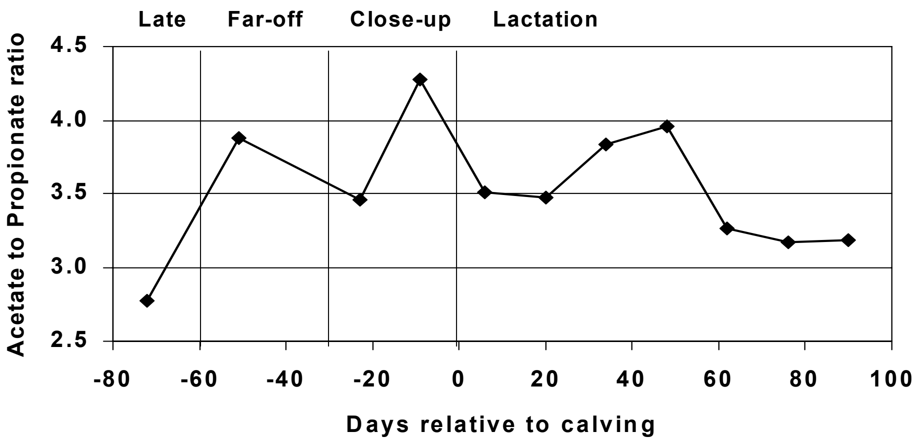

Figure 5. Ratio of Acetate to Propionate.

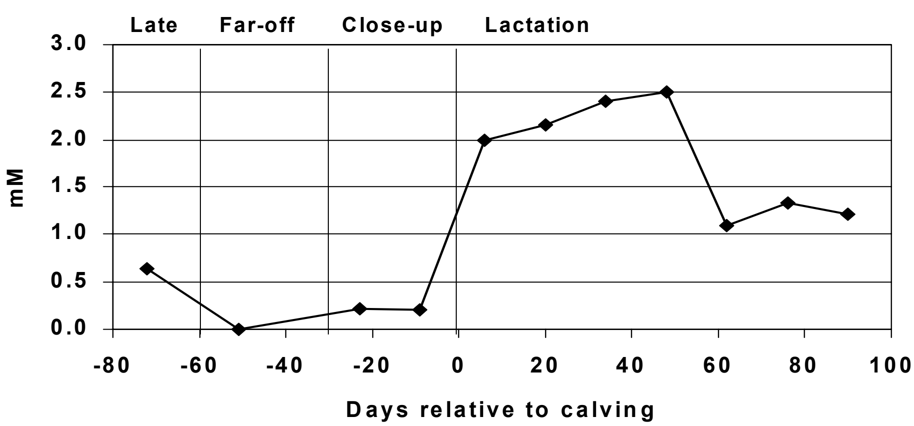

Figure 6. Ruminal Peptide Concentration.

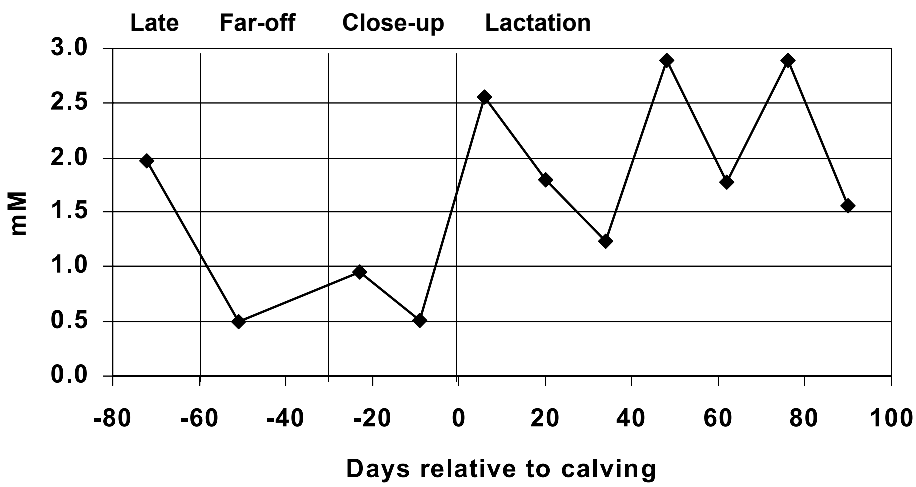

Figure 7. Ruminal Free Amino Acid Concentration.

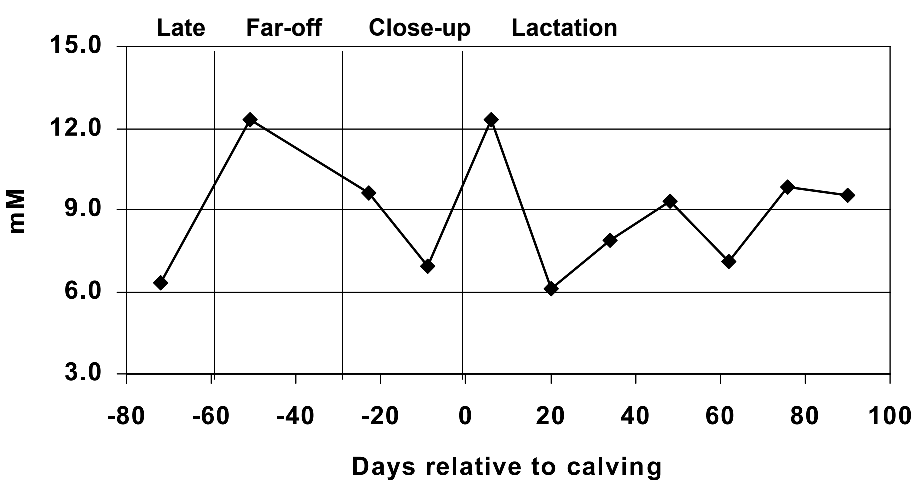

Figure 8. Ruminal Ammonia Concentration.

CHANGES IN RUMINAL MICROBIAL POPULATIONS IN TRANSITION DAIRY COWS

A. F. Park, J. E. Shirley, E. C. Titgemeyer, R .C. Cochran, J. M. DeFrain, E. E. Ferdinand, N. Wallace, T. G. Nagaraja[1], and D. E. Johnson[2]

Summary

We used four ruminally fistulated, multiparous, pregnant Holstein cows to delineate microbial adaptations in dairy cows as they experienced the transition from one lactation to the next. Diets consisted of typical far-off and close-up diets, a late lactation diet containing wet corn gluten feed (20% DM) and an alfalfa hay-corn silage based early lactation diet. Calculated NE_L (Mcal/lb), measured crude protein (%), and diet digestibilities (%; based on steers fed at 2% of BW) were: 0.78, 18.7, 74.1; 0.70, 11.5, 66.2; 0.74, 15.6, 71.0; 0.73, 18.4, 70.7 for late lactation, far-off dry, close-up dry, and early lactation, respectively. Microbial samples were obtained on days 72 (late lactation), 51 (far-off dry), 23, and 9 (close-up dry) prepartum and days 6, 20, 34, 48, 62, 76, and 90 postpartum. We analyzed ruminal samples for ciliated protozoa and viable counts of bacteria and fungi. Changing from a high forage to a high concentrate diet impacted bacterial counts less than ciliated protozoal and fungal counts. Switching diets from high concentrate to high forage increased ciliated protozoa and fungal counts, and counts decreased when diets were switched from high forage to high concentrate. Bacterial and ciliated protozoa counts increased in early lactation and decreased as cows approached peak dry matter intake. Dietary changes with the onset of lactation led to virtual disappearance of fungi from the rumen.

In general, ruminal microbial populations of dairy cows respond to changes in diet and intake. Changes in diet affected populations of protozoa and fungi, whereas changes in intake affected populations of bacteria, protozoa, and fungi.

(Key Words: Transition, Dairy Cow, Microbial.)

Introduction

Bacteria, protozoa, and fungi comprise the majority of the ruminal microbial population. Changes in diet and intake can affect each group of microbes differently. Bacteria possess the shortest generation time, thus changes in diet and intake should impact their populations less than protozoa or fungi. Protozoa have the longest generation time, so changes in diet and intake can greatly affect their population in the rumen. Protozoa usually attach themselves to larger feed particles or the ruminal wall to overcome the long generation time, thus maintaining populations in the face of diet and intake changes. In addition, protozoa can use bacteria and fungi as a source of nutrients to maintain populations during periods of low intake or low quality diets. Fungi attach and feed on fiber particles

[1]Department of Diagnostic Medicine/Pathobiology.
[2]Department of Statistics.

then release fungal spores upon maturation; thus, diet and intake changes may drastically affect their population.

The two-tiered feeding system (far-off and close-up diets) for dry cows is structured to allow time for ruminal microbial populations to adjust to dietary changes and potentially reduce the incidences of ruminal and metabolic disorders after calving. Ruminal microbes also must respond to changes in intake as the cow makes the transition from late gestation into early lactation. Changes in intake include about a 20 to 30% reduction during the 3 weeks prior to parturition and an increase in intake during early lactation. Limited information exists on changes in ruminal microbial populations in dairy cows associated with diet and feed intake changes during late gestation and early lactation. Thus, our objective was to characterize ruminal microbial changes as the dairy cow makes the transition from a non-lactational to a lactational state.

Procedures

We used four-ruminally fistulated, multiparous, pregnant Holstein cows fed typical dairy diets for late lactation, far-off dry, close-up dry, and early lactation. Diets were offered as a total mixed ration twice daily in amounts sufficient to ensure ad libitum intake. Ruminal content samples were collected from the rumen on days 72 (late lactation), 51 (far-off), 23 and 9 (close-up); then on days 6, 20, 34, 48, 62, 76, and 90 postpartum. Samples for microbial enumeration were obtained from the rumen prior to the morning feeding on each sampling date. Measurements included counts of total bacteria and fungi, cellulolytic bacteria and fungi, and total ciliated protozoa. Bacterial and fungal counts were enumerated by the Most Probable Number (MPN) method. Ciliated protozoa were counted under a microscope using a counting chamber.

Results and Discussion

None of the cows experienced health disorders during the experimental period, thus microbial counts likely reflect a normal transition from one lactation to the next. All cows received total mixed rations (TMR) consistent with stage of lactation or gestation (Table 1).

The cows consumed about 3.1% of their body weight on a dry matter basis prior to dry-off and their dry matter intake (DMI) dropped to about 2.3% of their body weight during the far-off period. This decrease in DMI was attributed to cessation of lactation (less demand for nutrients) and switching from a high energy, low fiber to a low energy, high fiber diet. Total ciliated protozoa (Figure 1) and total fungi (Figure 2) increased as cows moved into the far-off period, cellulolytic fungi (Figure 3) decreased during this change, and cellulolytic (Figure 4) and total bacteria (Figure 5) exhibited little or no response, respectively, by day 8 after the diet change. Dry matter digestibility was lower during the far-off period than during late lactation, and this likely was due to the increase in prairie hay in the diet at the expense of more digestible components, corn grain and soybean meal.

The cows were switched to a close-up diet 28 days before expected calving to partially adjust the rumen to the lactation diet. The cows calved later than expected, so the close-up diet was introduced on average 32 days before calving. The increase in energy and protein concentrations of the close-up diet compared with the far-off dry diet was achieved by partially replacing prairie hay with alfalfa hay, corn silage, and expeller soybean meal. These changes increased dry matter digestibility of the diet but did not change DMI. Total ciliated protozoa and total fungal counts were lower, cellulolytic fungal and total bacterial counts were unchanged, whereas cellulolytic bacteria were elevated 5 days after the switch to the close-up diet compared to their populations in samples collected during the far-off period. It is conceivable that the increase in cellulolytic bacteria and the decrease in total ciliated protozoa and total fungi could have occurred prior to the close-up sampling date because we did not evaluate a sample at the end of the far-off period. However, because the rumen had been exposed to the close-up diet for about 5 days prior to sampling it is assumed that the changes observed were associated with the diet change. The lack of change in total ciliated protozoa and total fungi between the first and second close-up period samples supports this assumption, but not the sharp decrease in cellulolytic bacterial counts between the two sampling dates. We theorize that the cellulolytic bacteria responded positively to the higher CP content in the close-up diet than the far-off diet at the first sampling date, but negatively to the decrease in DMI that occurred by the second sampling date. This theory is supported by the observed rebound in cellulolytic bacterial counts by day 6 after calving following the change to the lactation diet (higher CP content than the close-up diet) and an increase in DMI. The subsequent decrease in cellulolytic bacteria during lactation appears to be consistent with their accepted response to an increase in starch intake.

In addition to the aforementioned changes in cellulolytic bacteria, total bacterial counts on day 6 postpartum were similar to those on day 9 prepartum but increased by day 20 postpartum, likely due to an increase in starch fermenters. Total ciliated protozoa followed a pattern similar to total bacteria when the cows were switched from the close-up to the lactation diet. Total and cellulolytic fungal counts were low during the close-up and early lactation periods except for an increase in total fungi on day 6 postpartum.

In summary, ruminal microbial populations of dairy cows responded to changes in diet and intake. Changes in diet affected populations of protozoa and fungi, whereas changes in intake affected populations of bacteria, protozoa, and fungi. Focusing future research efforts on nutritional modulation to improve microbial populations during the transition period is warranted.

Table 1. Experimental Diets

	Diets (% of DM)			
Item	Late Lactation	Far-off	Close-up	Lactation
Ingredient				
Alfalfa hay	20.0	–	15.0	30.0
Prairie hay	–	48.4	20.0	–
Corn silage	10.1	19.8	30.0	15.0
Corn grain	27.7	22.4	18.7	32.0
Whole cottonseed	9.3	–	–	9.3
Fishmeal	1.3	–	–	1.3
Expeller soybean meal	7.7	–	9.4	3.3
48% soybean meal	–	8.4	4.4	4.4
Wet corn gluten feed	19.6	–	–	–
Molasses	1.3	–	–	1.0
Limestone	1.38	0.06	0.60	1.36
Dicalcium phosphate	0.05	0.40	0.74	0.88
Sodium bicarbonate	0.68	0.00	–	0.75
Trace mineral salt[1]	0.29	0.34	0.50	0.32
Magnesium oxide	0.20	–	0.50	0.21
Vitamin A,D,E[2]	0.12	0.11	0.12	0.13
Sodium selenite premix[3]	0.08	0.02	0.04	0.01
Nutrients				
Crude protein, %	18.7	11.5	15.6	18.4
RDP, %	11.6	7.3	10.3	11.7
ADF, %	17.5	25.2	22.0	18.2
NDF, %	29.9	42.9	34.4	27.0
Non-fiber carbohydrate, %	37.8	35.2	39.1	40.4
NE_L , Mcal/lb[4]	0.78	0.70	0.74	0.73
Crude fat, %	5.75	3.76	3.49	5.60

[1]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, and 0.004% Co.

[2]Contributed 4912 IU vitamin A, 2358 IU vitamin D, and 24 IU vitamin E per kg diet DM.

[3]Contributed 0.06 mg Se per kg diet DM.

[4]Calculated based on NRC, 2001. Estimates of NE_L values from summation of individual ingredients (0.78, 0.66, 0.71, 0.77 for the late lactation, far-off, close-up, and lactation diets, respectively).

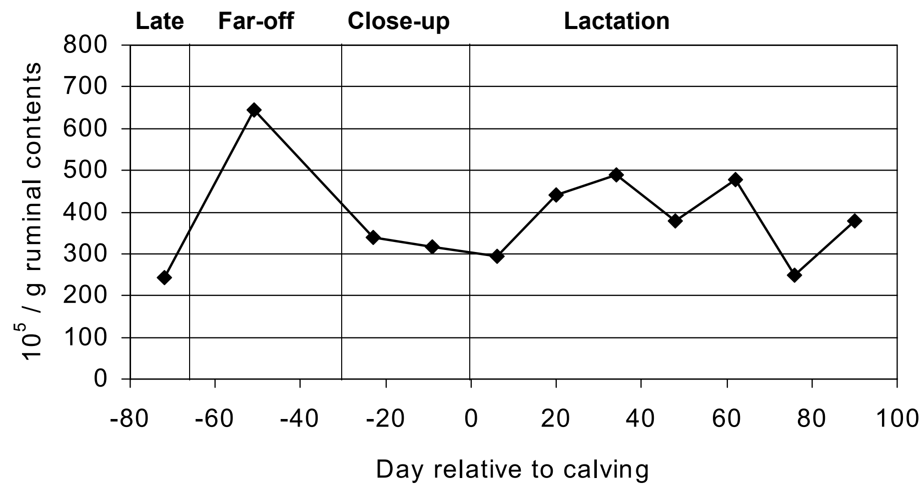

Figure 1. Total Ciliated Protozoal Counts.

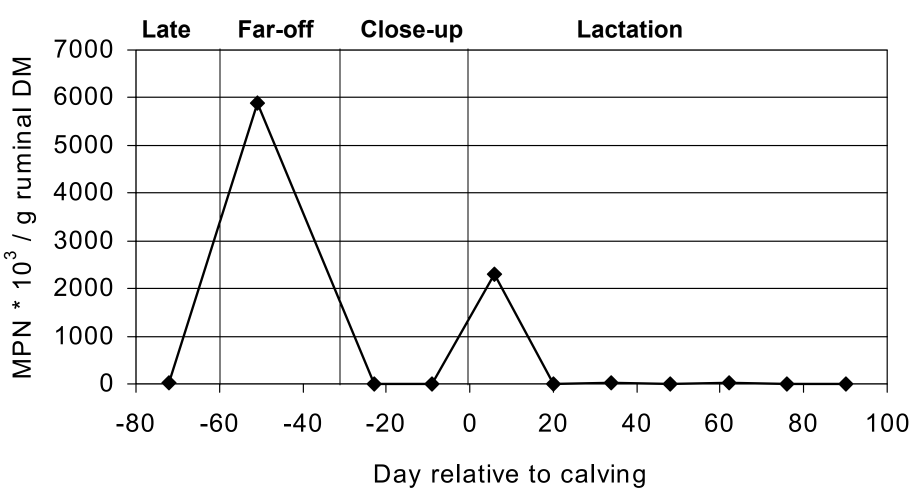

Figure 2. Total Fungal Counts.

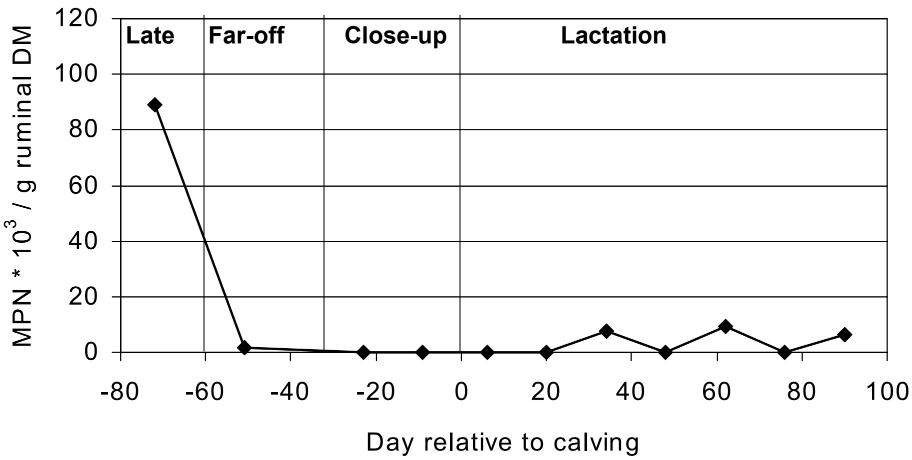

Figure 3. Cellulolytic Fungal Counts.

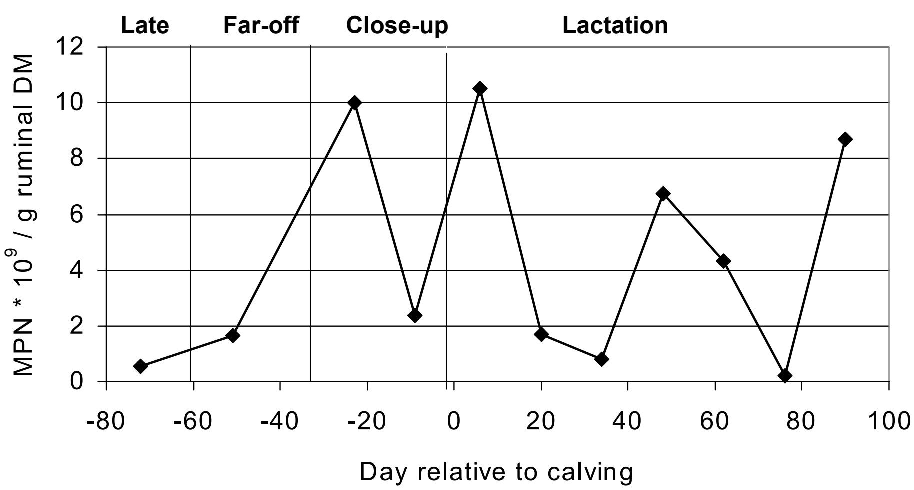

Figure 4. Cellulolytic Bacterial Counts.

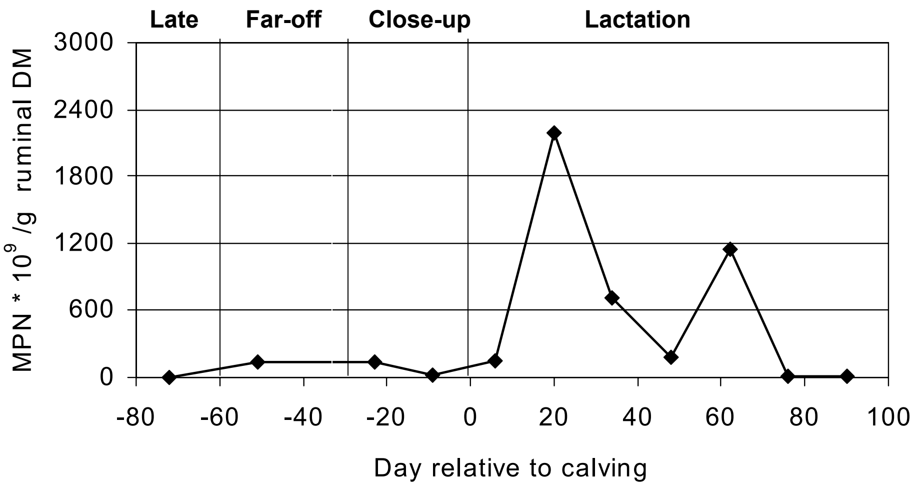

Figure 5. Total Bacterial Counts.

DIET DIGESTIBILITY AND RUMEN TRAITS IN RESPONSE TO FEEDING WET CORN GLUTEN FEED AND A PELLET CONSISTING OF RAW SOYBEAN HULLS AND CORN STEEP LIQUOR

E. E. Ferdinand, J. E. Shirley, E. C. Titgemeyer, J .M. DeFrain, A. F. Park, D. E. Johnson[1], R. T. Ethington[2]

Summary

Four ruminally cannulated and two intact multiparous Holstein cows were used in a 3 × 3 replicated Latin square design to evaluate digestibility and rumen traits in lactating dairy cows in response to feeding wet corn gluten feed and a novel product containing raw soybean hulls and corn steep liquor. Three dietary treatments were fed in the experiment. The control contained (DM basis) 30% alfalfa hay, 15% corn silage, 32% corn, 9.3% whole cottonseed, 4.4% solvent soybean meal (SBM), 3.3% expeller SBM, 1.3% fish meal, 1% wet molasses, and 3.7% vitamins/minerals. Wet corn gluten feed replaced 10% alfalfa hay, 5% corn silage, 5% corn grain, and expeller SBM replaced solvent SBM to maintain diet rumen undegradable protein. The novel product replaced 10% alfalfa hay, 5% corn silage, 3% solvent SBM, and 2% corn. Diets were analyzed to have dietary crude protein percentage and energy density values (Mcal/lb, NE_L) of 18.7, 0.75; 18.7, 0.77; 18.7, 0.74; for control, wet corn gluten feed, and the novel product, respectively. Experimental periods were 14 days (10 days adaptation and 4 days collection). Acid insoluble ash was used to estimate fecal output. Dry matter intake averaged 37.9 lb/day and total tract digestibilities of dry matter (DM), organic matter, neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein did not differ among diets: 71.7%, 73.2%, 63.1%, 58.5% and 73.0%, respectively. Diets affected liquid dilution rate, ruminal pH, and ruminal concentrations of total volatile fatty acids and ammonia similarly. The molar ratio of acetate to propionate was greater ($P<0.05$) for control (3.38) than for wet corn gluten feed (2.79) and the novel product (2.89). Inclusion of wet corn gluten feed and the novel product at 20% of dietary DM as a partial replacement for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported lactational performance similar to the control diet. Additionally, combining wet corn gluten feed or the novel product with corn silage and alfalfa hay maintained milk fat yields and ruminal pH, thereby demonstrating that wet corn gluten feed and the novel product can serve as an effective source of fiber when fed at 20% of dietary DM. These results indicate that wet corn gluten feed and the novel product tested can serve as alternative feedstuffs in lactating dairy cattle diets.

(Key Words: Wet Corn Gluten Feed, Soybean Hulls, Corn Steep Liquor, By-product).

[1]Department of Statistics.
[2]Minnesota Corn Processors, Inc., Marshall, MN.

Introduction

By-product feedstuffs such as wet corn gluten feed (WCGF) and soybean hulls have been successfully fed to lactating dairy cows and provide a highly digestible source of fibrous carbohydrates without increasing ruminal acidity. Previous research at Kansas State University demonstrated that replacing a portion of alfalfa hay, corn silage, and corn grain with wet corn gluten feed increased dry matter intake (DMI), energy corrected milk (ECM), and production efficiency (ECM/DMI). Researchers at Kansas State University developed a novel pelleted product (SHSL) combining the highly digestible source of structural carbohydrates from raw soybean hulls (RSH) and carbohydrates, soluble protein, vitamins, and minerals of corn steep liquor (CSL) in a ratio of 75 to 25, respectively, on a DM basis. They observed that replacing a portion of alfalfa hay, corn silage, ground corn, and expeller soybean meal (SBM) with SHSL at a level of 20% of DM was possible because it improved milk, ECM, and protein yield. Furthermore, recent research at Kansas State University demonstrated that diets including WCGF or SHSL maintained performance during the first 13 weeks postpartum and improved milk, energy corrected milk (ECM), milk fat and protein production as well as production efficiencies during weeks 14 to 30 postpartum.

The objective of our experiment was to evaluate the effect of WCGF and SHSL on diet digestibility and rumen traits.

Procedures

Four ruminally cannulated and two intact multiparous Holstein cows in late lactation (168 ± 7 DIM) were used in a 3 × 3 replicated Latin square design to evaluate diet digestibility and rumen parameters in response to feeding WCGF and SHSL. Cows were housed in a tie-stall facility at the Kansas State University Dairy Teaching and Research Center. Treatment periods were 14 days and included a 10-day adaptation and 4-day collection period. Diets (Table 1) were fed as a total mixed ration twice daily (0700 and 1900 hr) for ad libitum consumption. Orts were removed and weighed once daily and used to adjust feeding levels to ensure 10% feed refusal. Samples of dietary components (alfalfa hay, concentrate, corn silage, SHSL, WCGF, and whole cottonseed) were collected, frozen, and composited by period. Fecal grab samples were collected every 6 hr advanced by 2 hr each day, beginning at 0700 on day 11 and ending at 0500 on day 14.

Cows were milked at 0630 and 1830 hr daily and individual milk weights recorded. Milk samples (AM, PM composite) were obtained once each period for analyses of protein, fat, lactose, SCC, and MUN.

Fermentation profiles were measured on day 11. Rumen fluid was collected with a suction strainer just prior to feeding (0 hr) and at 3, 6, 9, and 12 hr after feeding.

Cows were pulse dosed prior to the A.M. feeding on day 11 with CoEDTA to estimate liquid passage. Samples of rumen fluid were collected just prior to dosing (0 hr) and 3, 6, 9, 12, and 24 hr following dosing.

On day 14 at 0700 hr rumen contents were manually removed, weighed, mixed by hand, and sampled in triplicate to measure ruminal volume and solids passage rate.

Results and Discussion

Ingredient and chemical composition of experimental diets are reported in Table 1. Dietary treatments had no effect on DMI, milk production, production efficiencies, milk component percentages and yield, and concentrations of MUN (Table 2).

Apparent total tract digestibilities of DM, organic matter (OM), CP, NDF, ADF, and starch were similar for all diets (Table 3). Similar energy densities (NE_L) of experimental diets (Table 1) as well as production responses (Table 2) support the similar digestibility coefficients.

Ruminal pH is an acceptable and accurate indicator of the effectiveness of fiber. As reported in Table 4, average ruminal pH was not different among diets, indicating that the partial replacement of corn silage and alfalfa hay with WCGF or SHSL produced levels of effective fiber similar to the control diet.

Similar concentrations of ruminal NH_3, free amino acids, and peptide N (Table 4) indicate that protein degradation and carbohydrate fermentation were not greatly different among diets. These findings were expected because diets in this study were formulated to have similar amounts of total crude protein and ruminally degradable protein.

Total volatile fatty acid concentrations did not differ among diets, but the WCGF and SHSL diets decreased ($P<0.05$) molar proportions of acetate and increased ($P<0.05$) molar proportions of propionate (Table 4), likely due to lower amounts of alfalfa hay in these diets. The molar ratio of acetate to propionate, often associated with milk fat depression, decreased ($P<0.05$) in cows fed WCGF or SHSL, but milk fat percentages and yield (Table 2) were not affected. No differences were observed in ruminal proportions of butyrate, isobutyrate, isovalerate, and valerate (Table 4). Rumen fill (total, DM, OM, and liquid) and solid and liquid passage rate (%/hr) were similar across treatments (Table 5).

Conclusion

Inclusion of WCGF or SHSL at 20% of dietary DM as a partial replacement for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported performance similar to the control diet. In addition, combining WCGF or SHSL with corn silage and alfalfa hay maintained milk fat yields and ruminal pH, thereby demonstrating that WCGF and SHSL served as effective sources of fiber when fed at 20% of dietary DM. These results indicate that WCGF and SHSL can serve as alternative feedstuffs in diets fed to lactating dairy cattle.

Acknowledgments

Funding was provided by Minnesota Corn Processors, Inc., Marshall, Minnesota and the Kansas State University Agricultural Experiment Station. Sincere appreciation is expressed to C.K. Armendariz for laboratory assistance and personnel at the Kansas State University Dairy Teaching and Research Center and Feed Processing Center for their assistance during these experiments.

Table 1. Ingredient and Nutrient Composition of Diets

	Diet[1]		
Item	Control	WCGF	SHSL
Ingredient	-------------------% of dry matter------------------		
Alfalfa hay	30.00	20.04	20.12
Corn silage	15.00	10.02	10.06
Corn grain	32.05	27.03	30.17
WCGF	-	20.04	-
SHSL	-	-	20.12
Whole cottonseed	9.30	9.30	9.34
Solvent soybean meal	4.39	-	1.40
Expeller soybean meal	3.30	7.71	3.32
Fish meal	1.30	1.31	1.31
Molasses	1.00	1.00	1.01
Dicalcium phosphate	0.88	0.59	0.18
Limestone	1.36	1.54	1.62
Sodium bicarbonate	0.75	0.75	0.67
Magnesium oxide	0.21	0.21	0.22
Trace mineralized salt[2]	0.32	0.32	0.32
Vitamin ADE premix[3]	0.11	0.11	0.11
Vit E premix	0.02	0.02	0.02
Sodium selenite premix[4]	0.01	0.01	0.01
Nutrient			
Dry matter, %	82.8	79.7	82.1
Crude protein, %	18.7	18.7	18.7
RUP, %	7.4	7.6	7.7
ADF, %	17.1	15.9	19.5
NDF, %	25.7	28.7	28.9
NE_L, Mcal/kg	1.65	1.69	1.64
NFC[5], %	44.8	42.2	41.9
Calcium, %	1.26	1.25	1.36
Phosphorus, %	0.61	0.60	0.56
Sulfur, %	0.52	0.45	0.48

[1]C= Control, WCGF= Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, 0.004% Co.

[3]Contributed 5,733 IU vitamin A, 2,866 IU vitamin D, 17 IU vitamin E per kg diet DM.

[4]Contributed 0.06 mg Se per kg of diet DM.

[5]NE_L, NRC, 2001.

[6]Nonfiber carbohydrate = 100 – (%NDF + %CP + %Ether Extract + %Ash).

Table 2. Effects of Diet on Performance of Cows

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
DMI, lb/d	36.2	39.7	37.9	6.00
Milk, lb/d	48.4	58.9	53.1	9.00
ECM[2], lb/d	46.3	55.1	50.9	10.2
ECM/DMI	1.33	1.36	1.35	0.13
Milk fat, %	3.33	3.04	3.16	0.33
Milk fat, lb/d	1.60	1.83	1.74	0.42
Milk protein, %	2.82	2.88	2.87	0.07
Milk protein, lb/d	1.37	1.70	1.52	0.26
Milk lactose, %	4.81	4.77	4.74	0.19
Milk lactose, lb/d	2.34	2.80	2.54	0.49
MUN, mg/dL	15.1	13.9	14.7	1.00
SCC × 1000	200	144	189	80.5

[1]WCGF = Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).
[2]Energy corrected milk.

Table 3. Percent Apparent Total Tract Digestibility of Diets

	Diet[1]			
Measurement	Control	WCGF	SHSL	SEM
Dry matter	71.3	71.3	72.2	2.1
Organic matter	73.2	73.0	73.4	2.0
Crude protein	72.2	72.9	73.9	2.1
NDF	62.6	63.7	62.8	2.7
ADF	57.9	57.6	60.0	3.6
Starch	89.6	91.4	87.8	2.2

[1]WCGF = Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

Table 4. Rumen Measurements

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
PH	6.22	6.20	6.22	0.14
Ammonia, mM	8.83	8.83	9.04	1.17
Free amino acids, mM	1.80	2.48	1.72	0.51
Ruminal peptide N, mM	3.79	4.70	4.58	2.30
Total VFA, mM	104.6	97.6	98.8	8.07
VFA, mol/100 mol				
Acetate	66.1[a]	63.4[b]	64.1[b]	0.83
Propionate	19.5[b]	22.9[a]	22.6[a]	1.33
Butyrate	10.6	10.2	9.7	0.58
Isobutyrate	1.10	1.07	1.09	0.11
Isovalerate	1.38	1.23	1.24	0.11
Valerate	1.30	1.23	1.19	0.056
Acetate:propionate	3.38[a]	2.79[b]	2.89[b]	0.21

[1]WCGF = Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[a,b] Means within item with dissimilar superscript letters differ ($P<0.05$).

Table 5. Rumen Kinetic Measurements

	Diet[1]			
Measurement	Control	WCGF	SHSL	SEM
Rumen fill, lb				
Total	156	173	158	9.4
Dry matter	20.1	22.3	21.6	2.0
Organic matter	17.6	19.8	19.0	2.0
Liquid	135	150	137	7.7
Passage rate, %/hr				
Solid	9.4	8.2	8.2	2.2
Liquid	13.2	12.7	13.1	1.5

[1]WCGF = Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

COMPLETE LACTATIONAL PERFORMANCE OF COWS FED WET CORN GLUTEN FEED AND PELLET CONSISTING OF RAW SOYBEAN HULLS AND CORN STEEP LIQUOR

E. E. Ferdinand, J. E. Shirley, E. C. Titgemeyer, J. M. DeFrain, A. F. Park, D. E. Johnson[1], *R. T. Ethington*[2]

Summary

We evaluated the effect of wet corn gluten feed and a novel product containing raw soybean hulls and corn steep liquor on performance in lactating dairy cows. Forty-six multiparous Holstein cows were used in a randomized incomplete block design. Cows were housed in tie stalls for the first 13 weeks of lactation and moved to group pens for the remainder of the study. Cows were blocked by calving date and assigned to control, wet corn gluten feed (20% of diet DM), or the novel product (20% of diet DM). Diets were administered as total mixed rations at the first feeding postpartum. Control contained (DM basis) 30% alfalfa hay, 15% corn silage, 32% corn, 9.3% whole cottonseed, 4.4% solvent soybean meal (SBM), 3.3% expeller SBM, 1.3% fish meal, 1% wet molasses, and 3.7% vitamins/minerals. Wet corn gluten feed replaced 10% alfalfa hay, 5% corn silage, 5% corn grain, and expeller SBM replaced solvent SBM to maintain diet rumen undegradable protein. The novel product replaced 10% alfalfa hay, 5% corn silage, 3% solvent SBM, and 2% corn. Diet crude protein % and energy density (Mcal/lb, NE_L) for control, wet corn gluen feed, and the novel product were 18.4, 0.73; 18.2, 0.75; 18.5, 0.73; respectively. Milk, energy corrected milk, dry matter intake, and production efficiency (ratio of milk to DM intake) did not differ among diets during the first 91 days of lactation, but there was a diet by week interaction for production efficiency. Cows fed control were more efficient during the first 2 weeks postpartum than cows fed wet corn gluten feed and the novel product, likely due to increased fat mobilization from adipose tissue because intake as a percent of body weight was less for cows fed control. During weeks 3 through 14 postpartum, wet corn gluten feed and the novel product improved milk, energy corrected milk, and milk component yield, and production efficiency. Inclusion of wet corn gluten feed and the novel product at 20% of dietary DM as a partial replacement for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported performance during early lactation and improved performance during mid and late lactation. In addition, combining wet corn gluten feed or the novel product with corn silage and alfalfa hay maintained milk fat yields, thereby demonstrating that they can serve as effective sources of fiber when fed at 20% of dietary DM. Improved performance attributed to wet corn gluten feed and the novel product is due to factors other than improved digestibility of the diets. These results indicate that wet corn gluten feed and the novel product can serve as alternative feedstuffs in diets fed to lactating dairy cattle.

(Key Words: Wet Corn Gluten Feed, Soybean Hulls, Corn Steep Liquor, By-product.)

[1]Department of Statistics.
[2]Minnesota Corn Processors, Inc., Marshall, MN.

Introduction

Dairy cattle experience negative energy balance during the first weeks of lactation because they do not consume sufficient dry matter (DM) to offset the demands of the mammary gland. Thus, mammary function during this period is supported by mobilization of stored nutrients, primarily lipids with some protein and carbohydrates, as well as nutrients supplied by the diet. The dietary nutrient supply is a function of nutrient density, dry matter intake, and diet digestibility. Nutrient density of the diet is a formulation issue, digestibility is primarily dependent on diet ingredients and rumen function, and dry matter intake is likely influenced by both ruminal and metabolic factors.

Diets for the early postpartum cows should be formulated to meet the requirements of a transitioning ruminal microbial population and to supply nutrients, especially energy, to a highly metabolically active cow. The form of energy in the diet is an important issue because rapidly fermented starch from concentrates increases ruminal acidity and can lead to decreased fiber digestion and the development of subclinical or acute acidosis. However, excess fibrous carbohydrates reduce the energy density of the diet and decrease productivity.

By-product feedstuffs such as wet corn gluten feed (WCGF) and soybean hulls have been successfully fed to lactating dairy cows and provide a highly digestible source of fibrous carbohydrates without increasing ruminal acidity. On a DM basis, WCGF contains 18 to 22% starch, 42% neutral detergent fiber (NDF), and a highly rumen degradable (65%) protein fraction. Previously, we replaced a portion of alfalfa hay, corn silage, and corn grain with WCGF and reported an increase in DM intake, energy corrected milk (ECM), and production efficiency (ECM/DMI).

Recently scientists at Kansas State University developed a novel pelleted product (SHSL) by combining a digestible source of structural carbohydrates from raw soyhulls with carbohydrates, soluble protein, vitamins, and minerals from corn steep liquor (CSL) in a 75 to 25 ratio, respectively, on a DM basis. They observed that replacing a portion of alfalfa hay, corn silage, ground corn, and solvent SBM with SHSL at a level of 20% of DM improved ECM and protein yields, without depressing milk fat yield. Furthermore, in a subacute ruminal acidosis model, it was observed that SHSL buffered the rumen similarly to alfalfa hay.

Studies that have evaluated production responses to WCGF or SHSL have been relatively short term and did not evaluate early or complete lactation responses. Therefore, the objective of our experiment was to evaluate the effect of WCGF and SHSL on the performance of lactating dairy cows during early lactating as well as over a complete lactation. Our hypothesis was that inclusion of a digestible fibrous carbohydrate source (WCGF or SHSL) as a partial replacement for alfalfa hay, corn silage, and corn grain would not increase ruminal acid load and would improve diet digestibility, thus enhancing nutrient delivery to the cow and improving performance.

Procedures

Forty-six multiparous Holstein cows were used in a randomized incomplete block design, blocked by calving date, and assigned three dietary treatments. Dietary treatments (Table 1) were control, WCGF (20% of diet DM), and SHSL (20% of diet DM). Wet corn gluten feed replaced 10% alfalfa hay, 5% corn silage, and 5% ground corn grain and expeller soybean meal replaced solvent soybean meal to maintain dietary rumen undegradable protein (RUP). Soybean hull-steep liquor pellets replaced 10% alfalfa hay, 5% corn silage, 3% solvent SBM, and 2% ground corn grain. Treatments were initiated at the first feeding postpartum and continued throughout lactation or until cows were removed from the study. Cows were housed and fed individually in a tie-stall facility for the first 13 weeks postpartum and moved to group pens with free stalls for the remainder of the study. Both facilities were located at the Dairy Teaching and Research Center, Kansas State University, Manhattan. Two group pens were used for each treatment, and cows were moved to the pens on day 92 postpartum. Each pen eventually contained eight cows except one SHSL pen that had six cows. The study was terminated when less than four cows constituted a pen. Lactation yields were standardized to 305-2x-ME. Cows fed control, WCGF, and SHSL averaged 248, 283, and 266 days in milk (DIM), respectively, when the study was terminated.

Cows were injected with recombinant bST at 14-day intervals beginning at 66 ± 6 days postpartum. Urine ketones were monitored daily for 14 days postpartum and rectal temperature was measured daily for 7 days postpartum.

Diets were offered as a TMR twice daily (0600 and 1700 hr) for ad libitum consumption. Feed intakes of individual cows were recorded through 13 weeks postpartum, and pen intakes (two pens per treatment) were measured for the remainder of lactation.

Cows were milked daily at 0530 and 1630 hr and individual milk weights were recorded. Milk samples (AM, PM composite) were obtained weekly for analyses of protein, fat, lactose, SCC, and urea nitrogen (MUN).

Body weight was measured on two consecutive days weekly, immediately after the PM milking, and the average used for analysis. Body condition was scored weekly (1 = thin and 5 = fat) using 0.25 increments.

Coccygeal venous blood was collected 2 hr after feeding on days 1, 7, 14, 21, 28, 60, 90, 120, 150, 180, and 210 postpartum to determine plasma concentrations of albumin, glucose, urea nitrogen, total alpha amino nitrogen, triglycerides, and non-esterified fatty acids. Urine and fecal samples were obtained on days 1, 7, 14, 21, 28, 60, and 90 postpartum to determine pH.

Results and Discussion

General observations. The ingredient and chemical composition of experimental diets are reported in Table 1. Diets were formulated to be isonitrogenous (18.4% CP, DM basis) and to contain similar amounts of RUP, NE_L, calcium, phosphorus, and sulfur. Expeller SBM and solvent SBM were varied across diets to balance dietary RUP. Diet RUP was lower for the control diet, but was surplus in all diets. Dietary forage NDF (% of diet DM) was 18, 12, and 12% for C, WCGF, and SHSL, respectively. Total NDF was 29.6% of diet DM in the WCGF and SHSL diets compared to 27% in the control diet, which follows the general recommendation that total dietary NDF should be greater when high NDF by-product feedstuffs are substituted for a portion of the forage. Dietary nonfiber carbohydrate (NFC) decreased as NDF increased, but NE_L remained constant. Diets were formulated to contain 1% calcium and 0.5% phosphorus (DM basis) using standard ingredient values. Sulfur content of the diets is reported because it can be excessive in diets containing steep liquor.

Several health issues are problematic in fresh cows and were of particular interest in our study because of the decrease in forage NDF when WCGF and SHSL were included in the diet. Incidences of disease did not differ among diets, and cows that experienced disorders were treated and remained in the study.

Cows fed WCGF and SHSL attained higher peak milk yield (108.7 and 107.6 lb/day, respectively) than cows fed the control diet (100.1 lb/day) and peaked later in lactation (day 75 and 73, respectively) than control (day 39). Furthermore, cows fed WCGF and SHSL had greater peak DM intake and peaked later in lactation (64.2 lb on day 71; 65.7 lb on day 73; respectively) than cows fed the control diet (61.3 lb, day 62).

Cow performance during weeks 1 to 13. Production responses to dietary treatment for weeks 1 through 13 are reported in Table 2. Total DM intake was numerically higher for cows fed WCGF and SHSL than those fed control. A graphical representation of daily DM intake (data not shown) indicated that cows adjusted to all diets similarly and did not suggest that ruminal acidosis was problematic.

Cows fed WCGF and SHSL produced 9.0 and 6.5% more milk, respectively, than cows fed control but this increase was not statistically different, likely due to the number of cows available for study. Wet corn gluten feed and SHSL were reported to improve milk yield by cows fed diets similar to those used in our study, but cows in those studies were in mid lactation. In our study, production efficiencies were not different among treatments during weeks 1 to 13 of lactation.

The numerical differences in ECM were less than observed for actual milk yield because fat concentration was lower in milk from cows consuming WCGF and SHSL. The decrease in milk fat percentage was significant, but not sufficient to decrease milk fat yield below control and thus can be attributed to dilution. The ability of diets to maintain milk fat has been used as an indicator of effective fiber content. Diets with the byproducts contained 20% alfalfa hay (DM basis) and a forage NDF of 12.1% of DM. They did depress milk fat percentage but maintained fat yield. Thus, WCGF and SHSL contribute to the effective fiber content when included at 20% of the diet DM. Milk protein percentage and yield were similar across treatments, but WCGF increased lactose percentage over control and SHSL. Milk urea N concentrations did not differ across diets.

Changes in bodyweight and body condition score during the first 13 weeks postpartum were similar across diets and failed to support the hypothesis that cows fed control were more efficient because they mobilized more body fat. However, subtle changes in bodyweight may be masked by rumen fill and the subjective nature of body condition scoring.

Urine and fecal pH were not different among dietary treatments. Urine pH was used to evaluate differences in DCAD balance. Fecal pH was used as a gross measurement of shifts in site of digestion by diets.

Cow performance during weeks 14 to 30. All cows utilized in this study were fed a common diet and managed similarly during the dry period in order to remove prepartum events as a confounding factor. Our justification for a complete lactation study was based on the premise that cow performance response to diets in the immediate (first 60 days) postpartum period is confounded by nutritional support from tissue mobilization, metabolic instability, and metabolic adaptations by the mammary gland. Thus, performance response to diets following peak milk production should provide a more accurate representation of nutrient delivery by experimental diets. Further, if a diet failed to meet the lactational demands of the cow, short-term production could be supported by fat mobilization, but future performance would be impaired.

The response of cows to experimental diets during weeks 14 through 30 is reported in Table 3. All cows consumed similar amounts of total DM, but cows fed WCGF and SHSL produced more (P<0.01) milk and ECM with a lower (P<0.05) than cows fed control. Milk protein concentration was slightly reduced by the two byproduct diets and this effect was significant for SHSL. However, yields of milk fat and protein were increased (P<0.01) by both WCGF and SHSL. Compared to control, milk lactose percentage and yield was greater (P<0.01) for cows fed WCGF and SHSL. During weeks 14 to 30 postpartum, production efficiencies were greater for cows fed WCGF and SHSL than for control cows. This is in contrast to the observation for the first 13 weeks of lactation where production efficiencies were not affected by treatment. Likely, the production efficiencies during the first 13 weeks were misleading because of the contribution of mobilized tissue to mammary gland function. During early lactation, control cows probably mobilized more body tissue (predominantly adipose) to support milk production. However, there are limits to tissue mobilization, and these were likely reached during the initial phase of the trial. Thus, the improved production efficiencies for the WCGF and SHSL diets during the second phase of the experiment (weeks 14 to 30 postpartum) are probably better estimates of the true differences among diets in their ability to support lactation than the production efficiencies of the first 13 weeks. Observed body weight and body condition score changes do not support this concept, but they may not be sufficiently precise to detect subtle changes. However, control cows reached peak milk at 39 days in milk (DIM) compared to 75 and 73 DIM for cows fed WCGF and SHSL respectively, suggesting that control cows mobilized more body tissues than cows fed either of the byproduct containing diets. In a companion study, WCGF did not improve total tract digestibility, which implies that other factor(s) are responsible for the observed improvement in production efficiency.

Cow performance during 305-2x-ME. 305-2x-ME milk, ECM, milk fat yield, and milk CP yields were numerically greater for cows fed WCGF and SHSL, but were not different due to large standard errors and a small number of experimental units (Table 4). The numerically higher 305-2x-ME production responses for cows fed WCGF and SHSL reflect the numerically higher yields of milk from cows fed WCGF and SHSL for the first 13 weeks postpartum and statistically higher yield observed for weeks 14 to 30 postpartum.

Conclusion

Inclusion of WCGF and SHSL at 20% of dietary DM as partial replacements for alfalfa hay, corn silage, corn grain, and SBM in diets fed to lactating dairy cattle supported performance during early lactation and improved performance during mid and late lactation. In addition, combining WCGF or SHSL with corn silage and alfalfa hay maintained milk fat yields, thereby demonstrating that WCGF and SHSL can serve as effective sources of fiber when fed at 20% of dietary DM. Improved performance attributed to WCGF and SHSL is due to factors other than improved digestibility of the diets. These results indicate that WCGF and SHSL can serve as alternative feedstuffs in diets fed to lactating dairy cattle.

Acknowledgments

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Table 1. Ingredient and Nutrient Composition of Diets (Exp. 1)

	Diet[1]		
Item	Control	WCGF	SHSL
Ingredient	-----------------------% of dry matter-----------------------		
Alfalfa hay	30.00	20.04	20.12
Corn silage	15.00	10.02	10.06
Corn grain	32.05	27.03	30.17
WCGF	-	20.04	-
SHSL	-	-	20.12
Whole cottonseed	9.30	9.30	9.34
Solvent soybean meal	4.39	-	1.40
Expeller soybean meal	3.30	7.71	3.32
Fish meal	1.30	1.31	1.31
Molasses	1.00	1.00	1.01
Dicalcium phosphate	0.88	0.59	0.18
Limestone	1.36	1.54	1.62
Sodium bicarbonate	0.75	0.75	0.67
Magnesium oxide	0.21	0.21	0.22
Trace mineralized salt[2]	0.32	0.32	0.32
Vitamin ADE premix[3]	0.11	0.11	0.11
Vit E premix	0.02	0.02	0.02
Sodium selenite premix[4]	0.01	0.01	0.01
Nutrient			
Dry matter, %	82.6	74.6	84.5
Crude protein, %	18.4	18.2	18.5
RUP, %	7.09	7.41	7.55
ADF, %	18.2	16.7	20.3
NDF, %	27.0	29.6	29.6
NE_L[5], Mcal/kg	1.62	1.65	1.62
NFC[6] ,%	42.3	40.4	40.3
Calcium, %	1.38	1.43	1.20
Phosphorus, %	0.63	0.69	0.56
Sulfur, %	0.25	0.28	0.28

[1]WCGF= Wet corn gluten feed, SHSL= pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Composition: not less than 95.5% NaCl, 0.24% Mn, 0.24% Fe, 0.05% Mg, 0.032% Cu, 0.032% Zn, 0.007% I, 0.004% Co.

[3]Contributed 5,733 IU vitamin A, 2,866 IU vitamin D, 17 IU vitamin E per kg of diet DM.

[4]Provided 0.06 mg Se per kg of diet DM.

[5]NE_L, NRC, 2001.

[6]Nonfiber carbohydrate = 100 – (%NDF + %CP + %Ether Extract + %Ash).

Table 2. Effects of Diet on Performance during Weeks 1 to 13 Postpartum

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
DM intake, lb/day	51.6	54.9	53.8	1.7
Milk, lb/day	90.8	99.0	96.8	3.5
ECM[2], lb/day	95.3	99.9	97.2	3.5
ECM/DM intake	1.96	1.86	1.85	0.058
Milk fat, %	4.00[a]	3.68[b]	3.75[b]	0.075
Milk fat, lb/day	3.55	3.59	3.51	0.13
Milk CP, %	2.99	2.99	3.00	0.040
Milk CP, lb/day	2.69	2.91	2.84	0.11
Milk lactose, %	4.87[b]	4.99[a]	4.91[b]	0.030
Milk lactose, lb/day	4.43	4.93	4.74	0.19
MUN, mg/dL	14.7	14.7	14.8	0.36
SCC × 1000	665	209	531	224
Initial BW, lb	1583	1581	1530	139
BW change, lb	152	174	187	34.0
Initial BCS	3.04	3.13	3.03	0.096
BCS change	0.35	0.31	0.24	0.12

[1]WCGF = Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).

[2]Energy corrected milk.

[a,b]Means with dissimilar superscript letters differ (P<0.01).

Table 3. Effects of Diet on Performance during Weeks 14 to 30 Postpartum

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
DM intake, lb/day	58.7	56.4	60.4	2.03
Milk, lb/day	77.4[b]	87.5[a]	92.8[a]	1.92
ECM[2], lb/day	80.0[b]	88.0[a]	90.2[a]	1.26
ECM/DM intake	1.37[d]	1.56[c]	1.49[c]	0.037
Milk fat, %	3.74[c]	3.55[d]	3.35[d]	0.063
Milk fat, lb/day	2.89[d]	3.10[c]	3.09[c]	0.05
Milk CP, %	3.12[c]	3.04[cd]	3.00[d]	0.025
Milk CP, lb/day	2.40[b]	2.67[a]	2.78[a]	0.04
Milk lactose, %	4.83[b]	4.93[a]	4.92[a]	0.015
Milk lactose, lb/day	3.75[b]	4.32[a]	4.56[a]	0.10
MUN, mg/dL	14.5	14.8	14.9	0.28
SCC × 1000	392	585	524	210
Initial BW, lb	1372	1431	1323	77.8
BW change, lb	-49	-46	-3	34.2
Initial BCS	2.71	2.95	2.82	0.14
BCS change	0.08	0.11	-0.06	0.04

[1]WCGF = Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).
[2]Energy corrected milk.
[a,b]Means with dissimilar superscript letters differ (*P*<0.01).
[c,d]Means with dissimilar superscript letters differ (*P*<0.05).

Table 4. 305-2x-ME Performance

	Diet[1]			
Item	Control	WCGF	SHSL	SEM
Milk, lb	23,704	25,543	26,162	1,336
ECM[2], lb	24,224	25,816	26,206	1,398
Milk fat, lb	904	913	924	71
Milk protein, lb	717	783	789	33

[1]WCGF= Wet corn gluten feed, SHSL = pellet containing 75% raw soybean hull, 25% corn steep liquor (DM basis).
[2]Energy corrected milk.

COMPARATIVE STUDY OF THREE EXPELLER PROCESS SOYBEAN MEALS IN DIETS FOR LACTATING DAIRY COWS

V. Burgos, J. E. Shirley, and E. C. Titgemeyer

Summary

Forty-eight primiparous Holstein cows were used in two simultaneous 3×3 Latin squares with 28-day periods to evaluate expeller soybean meal from three sources. Six pens containing eight cows each were utilized. Cows were pen fed diets formulated in accordance with NRC (2001) recommendations and based on the assumption that the three sources of soybean meal were nutritionally identical. Diets contained on a dry matter basis, 24.3% chopped alfalfa hay, 9.3% field processed corn silage, 9.2% whole fuzzy cottonseed, 19.2% wet corn gluten feed (Minnesota Corn Processors, Inc., Columbus, NE), and 38% grain mix (70.2% dry rolled corn grain, 18.44% expeller soybean meal, 2.15% wet molasses, 3.47% Menhaden fish meal, and 5.74% min/vit premix). The sources of expeller soybean meal were Grain States Soya, Inc., West Point, NE; NCKP, LLC., Washington, KS; and Bruning Grain and Feed, Bruning, NE. All cows averaged 77 lbs. of milk and consumed approximately 55 lbs. of dry matter daily. Dry matter intake averaged 3.9% of body weight and their production efficiency (ECM/DMI) was 1.45. No differences due to source of soybean meal were observed.

(Key Words: Soybean, Expeller Processed, Cows.)

Introduction

Several expeller process soybean meals with similar specifications are available to dairy producers in Kansas at varied prices. Some of these products have been evaluated in research studies but others have only on-farm results without a control group for comparison. Cow performance data obtained in comparative studies with known products will improve our decision making process. The purpose of this study was to determine if cow performance or price is the deciding factor when comparing three expeller process soybean meals.

Procedures

Forty-eight primiparous Holstein cows were used in two simultaneous 3×3 Latin squares with 28-day periods. Cows were housed and fed in a freestall facility at the Kansas State University Dairy, Manhattan, Kansas. Six pens containing eight cows each were utilized. Cows were pen fed diets formulated in accordance with the Dairy NRC (2001) and based on the assumption that the three sources of soybean meal were nutritionally identical. Diets contained, on a dry matter basis, 24.3% chopped alfalfa hay, 9.3% processed corn silage, 9.2% whole fuzzy cottonseed, 19.2% wet corn gluten feed (Minnesota Corn Processors, Inc., Columbus, NE.), and 38% grain mix (70.2% dry rolled corn grain, 18.44% expeller soybean meal, 2.15% wet molasses, 3.47% Menhaden fish meal, and 5.74% min/vit premix). The experimental diets (Table 1) differed only in source of expeller soybean meal; 1) Soy Best, 2) NCKP, and 3) BGF (Bruning Grain and Feed) and were offered ad libitum as a total mixed ration twice daily. Cows were fed each diet for 28 days with pen feed intake and individual cow milk yield measured daily. Milk samples (AM/PM composite) were analyzed for milk composition weekly with analysis of milk protein, fat, lactose, solids-not-fat, urea nitrogen, and somatic cells measured by the Heart of America DHI Laboratory, Manhattan, Kansas. Body weights and condition scores were measured initially and at the end of each 28-day period.

Results and Discussion

The first lactation cows used in the study averaged 77 pounds of milk and consumed approximately 55 pounds of dry matter daily. Dry matter intake as a percentage of bodyweight averaged 3.9% and they gained an average of 28 pounds of bodyweight (1 lb per day) during the 28-day feeding period. Results of the study are depicted in Table 2. No differences due to source of soybean meal were observed in any of the parameters measured.

Table 1. Ingredient and Nutrient Composition of Diets

	Diet (% of dry matter)		
Ingredient	Soy Best	NCKP	BGF
Alfalfa hay	22.87	22.87	22.87
Corn silage	9.59	9.59	9.59
WCGF	18.34	18.34	18.34
Whole cottonseed	8.65	8.65	8.65
Corn grain	28.50	28.50	28.50
Soy Best[1]	7.41	-	-
BGF[2]	-	-	7.41
NCKP[3]	-	7.41	-
Wet molasses	0.94	0.94	0.94
Fish meal	1.38	1.38	1.38
Limestone	0.75	0.75	0.75
Sodium bicarb	0.34	0.34	0.34
Trace mineral salt	0.23	0.23	0.23
Magnesium oxide	0.79	0.79	0.79
Vitamin ADE premix	0.12	0.12	0.12
Vit E premix	0.02	0.02	0.02
Sodium selenite	0.01	0.01	0.01
Zinpro 4-plex™ [4]	0.06	0.06	0.06
Nutrient*			
CP	17.0	16.9	16.8
NDF	26.3	26	26.0
ADF	14.6	14.5	14.6
NFC	47.7	48.1	48.2
Ether extract	3.5	3.5	3.5
Calcium	0.8	0.8	0.9
Phosphorus	0.4	0.4	0.4
NE_L, Mcal/lb	0.71	0.71	0.71

*Calculated values based on Dairy NRC 2001 computer program.
[1]Grain States Soya, Inc., West Point, NE.
[2]Bruning Grain and Feed, Bruning, NE.
[3]NCKP, LLC., Washington, KS.
[4]Zinpro 4-plex™ – Zinpro Inc., Eden Prairie, MN.

Table 2. Production Responses of Cows to Diets

	Diets		
Parameters	Soy Best	NCKP	BGF
DMI, lb/day	55.94	55.24	55.28
DMI, % of body wt.	3.93	3.89	3.89
Milk, lb/day	77.9	76.8	76.9
ECM, lb/day	80.8	80.2	80.2
Milk fat, %	3.73	3.77	3.77
Milk fat, lb/day	2.86	2.88	2.86
Protein[1], %	3.27	3.24	3.25
Protein, lb/day	2.53	2.49	2.49
Lactose, %	5.34	5.41	5.41
Lactose, lb/day	4.25	4.18	4.18
SNF[2], %	10.10	10.05	10.07
Initial wt., lb	1411	1407	1406
Final wt., lb	1436	1434	1439
Body wt. change, lb	+25.6	+26.6	+33.2
Initial BCS	3.15	3.18	3.10
Final BCS	3.24	3.34	3.30
BCS change	+0.09	+0.16	+0.20

[1]Milk true protein.
[2]Solids-not-fat.

COMPARATIVE VALUE OF FULL-FAT CORN GERM, WHOLE COTTONSEED, AND TALLOW AS ENERGY SOURCES FOR LACTATING DAIRY COWS

W. F. Miller, J. E. Shirley, E. C. Titgemeyer, M. J. Brouk, M. V. Scheffel, and R. T. Ethington [1]

Summary

We used 24 multiparous Holstein cows in 4 × 4 Latin square design to evaluate full-fat corn germ as a replacement for whole cottonseed and tallow in total mixed diets for lactating dairy cows. Experimental diets on a dry matter basis were: 1) control 3.5% fat; 2) whole cottonseed 5.1% fat; 3) tallow 5.1% fat; 4) full-fat corn germ 5.1% fat. Diets were fed as total mixed rations typical of that fed on commercial dairy operations. Cottonseed meal and cottonseed hulls were included in the control, tallow, and full-fat corn germ diets to balance for fiber and protein fractions equal to those in the whole cottonseed diet. Dry matter intake, milk production, and energy corrected milk did not differ among the diets. Milk from cows fed full-fat corn germ contained less fat than milk from cows fed whole cottonseed but was similar to that of milk from cows fed control or tallow diets. Milk protein percentage was lower for cows fed full-fat corn germ than those fed control, but similar to cows fed whole cottonseed or tallow. Percentage milk lactose did not differ among dietary treatments. Cows fed WCS produced more pounds of milk fat than cows fed full-fat corn germ or tallow, but protein and lactose yield did not differ among the diets. Cows fed whole cottonseed produced milk more efficiently than cows fed control, tallow, or full-fat corn germ. Unexpectedly, efficiency of energy corrected milk production was not improved by tallow and tallow did not depress dry matter intake. Somatic cell count did not differ among experimental diets. Urea nitrogen concentration was lower in milk from cows fed full-fat corn germ and tallow than those fed whole cottonseed. All diets led to gains in body weight.

The handling and storage characteristics of full-fat corn germ enhances its desirability as a feedstuff for dairy cattle. Full-fat corn germ supported milk production as well as whole cottonseed but not milk fat percentage or fat yield at the level fed in our diets. Additional studies need to be conducted to determine the most advantageous amount to feed full-fat corn germ and clarify the mechanisms by which it depresses milk fat production.

(Key Words: Energy, Full-Fat Corn, Tallow, Cottonseed, Cows.)

Introduction

Lipids are frequently incorporated into diets for lactating dairy cows to increase energy density without reducing fiber intake. Commonly used lipid sources include whole cottonseed and tallow. An alternative fat source may be available in the form of full-fat corn germ obtained from the wet milling of corn. Wet milling of corn involves steeping and coarse grinding resulting in a pulp-like material containing full-fat corn germ, hull, starch, and gluten. Full-fat corn germ (FFCG) can then be separated based on bulk density via a liquid cyclone separator. Normally, further processing

[1]Minnesota Corn Processors, Inc., Marshall, MN.

of full-fat corn germ takes place by pressing, expeller, or solvent procedures designed to recover corn oil. This results in concurrent production of corn germ meal. Full-fat corn germ can be stored using conventional bins and handled by standard augers or conveyors. Typically FFCG contains 3 to 6% moisture, 13 to 15% crude protein, 43 to 51% crude fat, and an estimated NE_L of 1.54 to 1.66 Mcal/lb; with approximate concentrations of major fatty acids: linoleic (18:2), oleic (18:1) and palmitic (16:0) at 56%, 28%, and 11% of crude fat, respectively. The objective of our study was to determine if FFCG is an acceptable source of fat for dairy cows to support lactation.

Procedures

We used 24 multiparous Holstein cows averaging 124 DIM, milked 2× daily in a 4 × 4 Latin square design. Cows were housed in a tie-stall barn and offered diets for ad libitum intake twice daily over four 28-day periods. Experimental diets (Table 1) were: control (C) at 3.5% fat; 2) whole cottonseed (WCS) at 5.1% fat; 3) tallow (T) at 5.1% fat; and 4) full-fat corn germ (FFCG) at 5.1% fat. Diets were offered as total mixed rations (TMR). Samples of TMR and feed refusals were collected weekly and dried at 105˚C to determine dry matter of diets. Alfalfa hay, corn silage, whole cottonseed, and grain mixes were sampled and composites by period were sent to Northeast DHI Forage Testing Lab, Ithaca, NY for analyses. Cottonseed meal and cottonseed hulls were included in the C, T, and FFCG diets to balance for fiber and protein fractions equal to those in the WCS diet. Individual feed intake and milk yield were recorded daily. Weekly milk samples (AM-PM composite) were analyzed for fat, protein, lactose, urea nitrogen (MUN), and somatic cells by Heart of America DHI Laboratory, Manhattan, KS. Individual body weights were measured on two consecutive days at the beginning of the study and at the end of each period following the AM milking. Body condition (1 = thin and 5 = fat) was scored at the beginning of the study and at the end of each period.

Results and Discussion

Dry matter intake, milk yield, energy corrected milk (ECM), lactose percentage, protein and lactose yield and SCC did not differ among diets. Efficiency of milk production was improved by the addition of fat from WCS, but not from T or FFCG when compared to cows fed C. Cows fed FFCG had lower ($P<0.05$) milk fat percentage and fat yield than cows fed WCS, but similar to cows fed C and T (Figures 1 and 2). Milk protein percentage ($P<0.05$), but not yield, was greater for cows fed C than for those fed diets containing the three fat sources. Concentrations of urea nitrogen were lower ($P<0.05$) in milk from cows consuming FFCG and T than in milk from cows fed WCS, but not for those fed C.

Milk fat depression in lactating dairy cows can result from a deficiency of lipid precursors delivered to the mammary tissue for milk fat synthesis and inhibition of milk fat synthesis by mammary tissue. Adding supplemental fat to the diet can depress ruminal fiber degradation, most notably when polyunsaturated fatty acids, such as linoleic acid (a long chain polyunsaturated fatty acid of plants), are fed. Dietary fat sources rich in saturated fatty acids, such as tallow, typically do not have the same negative effect on the rumen environment or milk fat synthesis by the mammary tissue. Lipid is metabolized in the rumen by two major microorganisms, *Butyrivibrio fibriosolvens* and *Anaerovibrio lipolytica*. Triglycerides are first hydrolyzed to free fatty acids then unsaturated fatty acids are hydrogenated to form saturated fatty acids by bacteria. Hydrolysis of triglycerides by bacteria and protozoa occurs rapidly in the rumen, whereas biohydrogenation by bacteria is gradual, which leads to ruminal accumulation of polyunsaturated long chain fatty acids that are toxic to fiber digesting bacteria and protozoa. Dietary fats, such as oils, are able to coat fiber particles and bacteria causing further reduction in fiber degradation in the rumen. Reduction in fiber digestion limits the availability of acetate for de novo synthesis of fat by the mammary gland.

Rumen bacteria possess an isomerase enzyme that changes the position of the double bond within linoleic acid and other unsaturated fatty acids, subsequently generating conjugated linoleic acid (CLA) and *trans* fatty acids (*trans*-11 and *trans*-10). *Trans*-11 (vaccenic acid) comprises greater than 80% of the *trans* fatty acids and can be transformed into *cis*-9, *trans*-11 CLA by desaturase enzyme activity within the mammary gland, thus increasing the CLA content of milk. The trans-10 isomer is transformed into *trans*-10, *cis*-12 CLA. The *trans*-10 isomer and *trans*-10, *cis*-12 CLA can inhibit milk fat synthesis by mammary tissue resulting in depressed milk fat percentage and yield. Lipids from intact seeds, such as WCS, release oil slowly in the rumen, which probably reduces the ruminal concentration of CLA and *trans* fatty acids, thus reducing the potential to depress de novo fatty acid synthesis in mammary tissue. The lower milk fat percentage for cows fed FFCG diet would suggest that the oil contained in FFCG was promptly liberated from the germ and negatively influenced the rumen environment or was converted to *trans* fatty acids, thus reducing mammary fat synthesis.

Efficiency of milk production is estimated by the ratio of milk yield to dry matter intake (ECM/DMI) and provides a measure of utilization of feedstuffs for milk production. Characteristically, lactating dairy cows fed diets supplemented with fat, such as T or WCS, produce milk more efficiently due to the increased caloric content of the diet. Historically, lactating dairy cows supplemented with fat show improved lactation performance over cows fed diets without supplemental fat. Cows fed WCS produced milk more efficiently than cows fed C, T, or FFCG, but we did not observe an improvement in efficiency for cows that consumed T compared to cows that consumed C. The lack of response to tallow was unexpected and may be due to an interaction between tallow and wet corn gluten feed.

Conclusion

The handling and storage characteristics of full-fat corn germ enhances its desirability as a dairy cattle feedstuff. Full-fat corn germ supported milk production as well as WCS and T, but milk fat percentage and fat yield were less with FFCG than WCS at the level fed in our diets. Unexpectedly, cows consuming T did not produce milk as efficiently as cows consuming C, perhaps indicating various factors other than fat source alter measures of lactation. Additional studies need to be conducted to determine the most advantageous amount of full-fat corn germ to feed and clarify the mechanisms by which it depresses milk fat production.

Table 1. Ingredient and Nutrient Composition of Experimental Diets

	Diet			
Item	Control	Whole cottonseed	Tallow	Full-fat corn germ
Ingredient	------------------------------ % of DM ------------------------------			
Alfalfa hay	23.05	23.01	23.0	3.08
Corn silage	9.94	9.92	9.92	0.95
Wet corn gluten feed	19.43	19.40	19.39	9.46
Corn ground	28.42	26.87	26.89	5.74
Whole cottonseed	-	9.44	-	-
Tallow	-	-	1.67	-
Full-fat corn germ	-	-	-	0.4
Cottonseed hulls	3.31	-	3.30	0.0
Cottonseed meal	4.49	-	4.48	0.52
Soybean meal, expeller[1]	6.99	6.98	6.98	0.98
Fish meal	1.30	1.30	1.30	0.30
Molasses	0.97	0.97	0.96	0.90
Limestone	0.66	0.70	0.68	0.68
Magnesium oxide	0.21	0.21	0.21	0.21
Trace mineralized slat	0.31	0.31	0.31	0.31
Sodium bicarbonate	0.73	0.73	0.73	0.73
Vitamin ADE premix	0.12	0.12	0.12	0.12
Selenium premix	0.01	0.01	0.01	0.01
Zinpro 4-plex™ [2]	0.05	0.05	0.05	0.05
Nutrient[3]				
CP	18.9	18.7	18.7	18.7
NDF	29.7	30.0	29.5	29.9
ADF	16.3	17.0	16.2	16.3
NFC	42.9	41.1	41.7	41.3
Fat	3.5	5.1	5.1	5.1
Calcium	0.89	0.91	0.90	0.90
Phosphorus	0.45	0.45	0.45	0.45
NE_L, Mcal/lb	0.71	0.74	0.73	0.73

[1]Soy Best - Grain States Soya, Inc., West Point, NE.
[2]Zinpro 4-plex - Zinpro Inc., Eden Prairie, MN.
[3]Values from Dairy NRC 2001.

Table 2. Lactation Performance of Cows

	Diet[1]				
Item	Control	Whole cottonseed	Tallow	Full-fat corn germ	SEM
DMI[2], lb/day	57.3	56.3	56.5	57.3	0.58
Milk, lb/day	90.2	90.8	89.8	91.0	1.02
ECM[3], lb/day	88.7	90.0	87.7	87.6	0.95
Efficiency, ECM/DMI	1.55^{a}	1.60^{b}	1.56^{a}	1.54^{a}	0.014
Milk fat, %	3.38^{ab}	3.45^{a}	3.37^{ab}	3.26^{b}	0.05
Milk protein, %	3.09^{a}	3.06^{b}	3.05^{b}	3.06^{b}	0.01
Milk lactose, %	5.29	5.26	5.25	5.29	0.01
Milk fat, lb/day	3.03^{ab}	3.13^{a}	2.99^{b}	2.93^{b}	0.05
Milk protein, lb/day	2.77	2.76	2.72	2.76	0.03
Milk lactose, lb/day	4.77	4.78	4.72	4.81	0.06
SCC[4], ×1000	254.0	429.0	431.0	287.0	98.0
Milk urea nitrogen, mg/dl	16.64^{ab}	17.11^{a}	16.29^{b}	16.30^{b}	0.14
Initial body condition score	2.69	2.75	2.72	2.74	-
Initial body weight, lb	1,542	1,547	-	1,540	-
Change in body weight, lb	29.9	16.2	28.8	34.1	7.0

[a,b]Means with different superscripts differ ($P<0.05$).
[1]Control = 3.5% ether extract; whole cottonseed, tallow, full-fat corn germ = 5.1% ether extract.
[2]DMI = dry matter intake.
[3]ECM = energy corrected milk.
[4]SCC = somatic cell count.

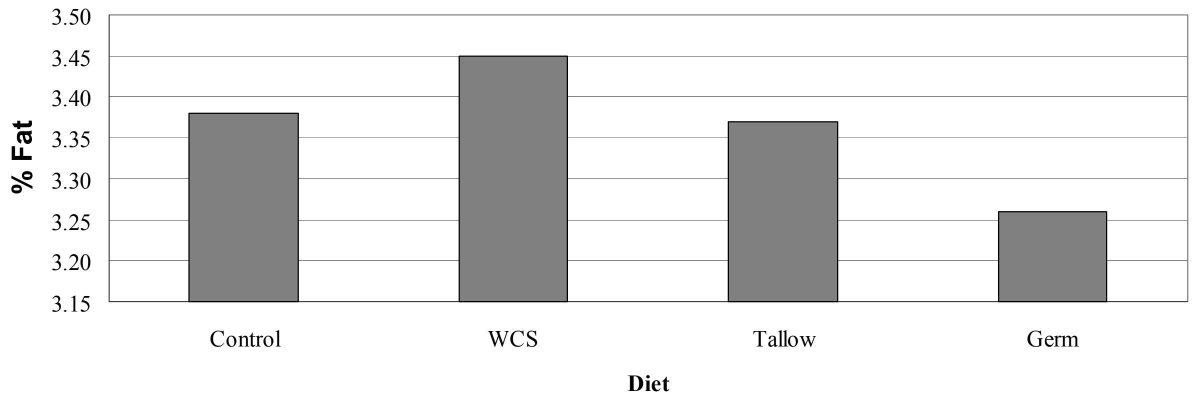

Figure 1. Percentage Milk Fat.

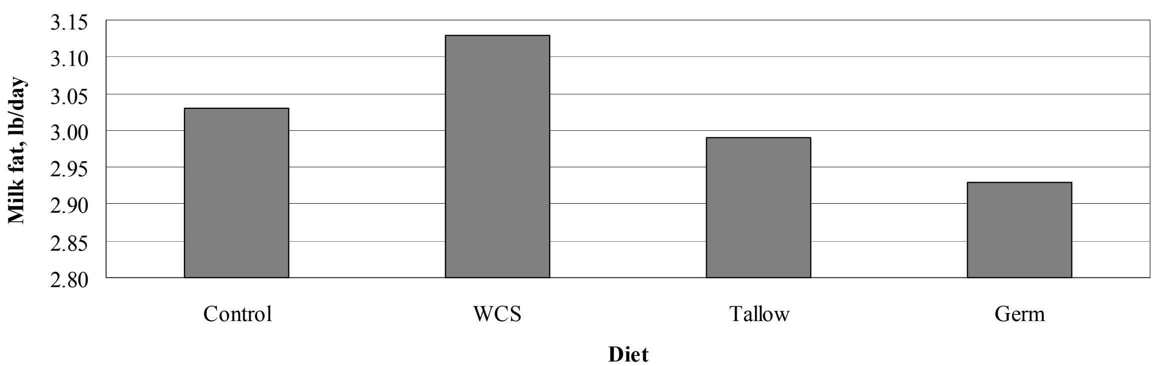

Figure 2. Pounds of Milk Fat Per Day.

PERFORMANCE OF DAIRY HEIFERS FED HIGH FORAGE DIETS SUPPLEMENTED WITH BAMBERMYCINS, LASALOCID, OR MONENSIN

A. Hammond, J. E. Shirley, M. Scheffel,
E. C. Titgemeyer, and J. S. Stevenson

Summary

One hundred and twenty Holstein heifers weighing approximately 450 lb at the beginning of the study were used to evaluate the impact of bambermycins (Gainpro®), monensin (Rumensin®), and lasalocid (Bovatec®) on performance when included in high forage diets fed ad libitum. Heifers were housed in 24 pens (5 hf/pen) containing a super hutch. Pens were blocked (3 pens/block) from heaviest to lightest and randomly assigned within blocks to bambermycins, lasalocid, or monensin treatment. Bambermycins, lasalocid, and monensin were mixed with fine ground corn and fed as topdressing to deliver 20.25, 150, and 150 mg/hd daily, respectively. Diets were formulated (NRC 2001) to support body weight gains of less than 2 lb/hd daily using a mix of chopped alfalfa hay and corn silage (lighter weight heifers) or chopped alfalfa hay, chopped prairie hay, and corn silage (heavier weight heifers) supplemented with a mineral/vitamin premix. All heifers were fed a common total mixed ration, differing only in topdressing. Diets were fed once daily for ad libitum intake. The study continued until the average bodyweight exceeded 800 lbs. (140 days on study) at which time they were inseminated and first service conception rate determined.

Heifers fed monensin consumed less dry matter (DMI) (P<0.05) than those fed bambermycins and lasalocid during the periods d 29 to 56, 57 to 84, and 113 to 140 but DMI was similar across treatments during the 140-day study. No differences were observed for ADG over the 140-d study but heifers fed bambermycins and monensin tended (P=0.06) to gain faster during days 85 to 112 than heifers fed lasalocid. Feed efficiency (gain/feed) varied, but heifers consuming diets containing bambermycins and monensin were more efficient (P<0.05) during days 85 to 112 and tended to be more efficient (P=0.051) during the 140-day study than heifers consuming lasalocid. Bodyweight, condition score, and hip height were similarly influenced by dietary treatments. First service conception rates were 60, 47 and 55% for heifers fed bambermycins, lasalocid, and monensin, respectively.

(Key Words: Inophores, Growth, Heifers.)

Introduction

Replacement dairy heifers represent the future herd and ultimately the success of the producer. Lactational performance of dairy cows is a function of genetics and management. The management part of the equation begins when the heifer is born and continues until it leaves the herd. Recently, interest has been refocused on the impact of heifer rearing programs on lactational performance because producers are breeding heifers to calve at an earlier (less than 24 months) age in order to reduce rearing cost. Calving heifers at less than 24 months of age and weighing 1300 lbs. at calving may require a growth rate of greater than 1.8 lbs daily. Earlier work at Michigan State University indicated that rapid growth (greater than 1.8 lb daily) between 3 and 9 months of age has a negative effect on first lactation performance. However, this concept has been questioned because the genetic potential for growth is perceived to be different in today's heifer compared to heifers 35 years ago. Heifer growth rate is influenced by the rate of accumulation of lean body tissue (protein) and fat deposition. One of the current concepts related to heifer growth is that growth rates greater than 1.8 lb daily do not have a negative impact on mammary development if growth is primarily due to an increase in lean body tissue between 3 and 9 months of age. Thus, diets formulated to support rapid growth but limit depositions of body fat are receiving increased attention.

A second issue of interest to producers is cost of gain. Target feeding programs have been developed such that targeted growth rates are achieved with minimal feed consumption and minimal feed cost. Target feeding programs assume that the nutritional requirements of growing dairy heifers can be met with a limit fed diet if it contains the correct nutrient mix and density. Target feeding programs are generally less expensive (cost per lb of gain) than ad libitum feeding programs that contain a high percentage of forage. However, many producers that grow their own forage continue to develop replacement dairy heifers on high forage diets.

Ionophores (monensin and lasalocid) are extensively used as diet supplements for dairy heifers. Monensin, in particular, has been shown to improve rate of gain and feed efficiency in heifers offered limit-fed diets. Recently, bambermycin has been approved as a feed additive for dairy heifers. Feed additives that enhance performance, reduce cost of gain, and promote the deposition of lean body tissue are important components of dairy heifer nutritional programs. The major decision for the producer is which additive to use.

Several studies at this station have evaluated the relative impact of monensin and lasalocid on heifer performance when included in a limit-fed target-feeding program. We are unaware of studies that directly compare these ionophores with bambermycin. The purpose of this study was to evaluate the relative impact of bambermycin and ionophores on the performance of dairy heifers when included in high forage diets.

Procedures

One hundred and twenty Holstein heifers were transported from Cimarron Dairy, Cimarron, Kansas (5 hr trip) 21 days prior to initiation of the study. All heifers received a Micotil ® injection (10 mg/kg bodyweight) immediately prior to transport and on day 5 after arrival at the Kansas State University study site. The heifers also received Safe Guard® dewormer (5mg fenbendazole/kg bodyweight) 5 days after arrival. A common total mixed ration (TMR) consisting of chopped alfalfa hay, corn silage, and concentrate was fed during the 21 day site acclimation period. The heifers were weighed on two consecutive days prior to assignment to treatment and ranked from highest to lowest bodyweight. Heifers were blocked (3 heifers/block) starting with the heaviest and proceeding to the lightest, then heifers within blocks were randomly assigned to pens until 5 heifers were assigned to each of 24 pens. Pens were blocked (3 pens/block) from heaviest to lightest and randomly assigned within blocks to bambermycins, lasalocid, or monensin treatment. Bambermycins, lasalocid, and monensin were mixed with fine ground corn and fed as topdressing to deliver 20.25, 150, and 150 mg/hd daily, respectively.

Diets were formulated (NRC 2001) to support bodyweight gains of less than 2 lb/hd daily using a mix of chopped alfalfa hay and corn silage (lighter weight heifers) or a mix of chopped alfalfa hay, chopped prairie hay, and corn silage (heavier weight heifers) supplemented with a mineral/vitamin premix. All heifers were fed a common TMR, differing only in treatment topdressing. Diets were fed once daily for ad libitum intake. Orts were measured daily and the amount fed adjusted to insure 10 percent refusals. Feed ingredients were sampled weekly and composited by 28-day period for compositional analysis. Heifers were weighed on two consecutive days at the beginning of the study and at the end of each 28-day period. Body condition was scored and hip height measured at the beginning of the study and at the end of each 28-day period. Pen was used as the experimental unit in data analysis. All heifers were inseminated at the end of the study using a time-breeding protocol and first service conception rate determined.

Results and Discussion

The average chemical composition of feed ingredients used in the study is shown in Table 1. Diet composition (Table 2) is shown for weight groups ranging from 450 to 750 lbs in 50 lb increments. The response of heifers to treatments are shown in Tables 3 and 4. Heifers fed monensin consumed less DM (P<0.05) than those fed bambermycins and lasalocid during the periods 29 to 56 days, 57 to 84 days, and 113 to 140 days but DMI was similar across treatments during the 140-day study. No differences were observed for ADG over the 140-day study but heifers fed bambermycins and monensin tended (P=0.06) to gain faster during the 85 to 112 day period than heifers fed lasalocid. Feed efficiency (gain/feed) was variable across the 28-day periods, but heifers consuming diets containing bambermycins and monensin were more efficient (P<0.05) during the 85 to ll2 day period and tended to be more efficient (P=0.051) during the 140-day study than heifers consuming the diet containing lasalocid. Bodyweight, condition score, and hip height (Table 4) were similarly influenced by dietary treatments. The first service conception rates (Table 4) were 60, 47, and 55% for heifers fed bambermycins, lasalocid, and monensin, respectively.

The results of this study are interesting because earlier studies at this station found that heifers limit fed diets containing monensin out performed heifers limit fed diets containing lasalocid. The limit fed diets contained primarily chopped alfalfa hay and corn silage with no prairie hay and were formulated to be deficient in energy and surplus in protein similar to diets in the present study. Apparently, lasalocid is better suited for use with ad libitum feeding programs than it is with limit-fed targeted-gain programs. However, the difference in feed efficiency between treatments approached significance (P=0.051) with heifers fed bambermycins and monensin being the most efficient and should be considered when selecting the appropriate supplement to include in diets for dairy replacement heifers.

Table 1. Feed Ingredient Analysis

	Ingredient				
Component	Alfalfa Hay	Prairie Hay	Corn Silage	Concentrate*	Topdressing
	- - - - - - - - - -	- - - - - - - - -	Dry Matter Basis	- - - - - - - - -	- - - - - - - - - -
% DM	90.60	92.75	35.56	89.00	88.53
% Crude protein	21.26	6.03	10.21	44.90	8.74
NEG, Mcal/lb	0.30	0.25	0.44	0.66	0.68
ADF	33.29	41.62	26.97	7.00	3.87
NDF	43.41	64.35	44.77	8.80	9.20
NFC	27.77	22.85	37.63	N/A	76.40
Ca	1.50	0.78	0.29	2.04	1.50
P	0.30	0.09	0.30	1.39	1.01

*Contains 46.5% corn grain, 48.35% of 48% SBM, 1.25% molasses, 1.55% TM salt, 0.6% dicalcium phosphate, 0.3% vitamin A, D, E premix, and 1.45% vitamin E. It was only used during the first 28 days of this study.

Table 2. Diet Composition, % of Dry Matter

	Live Body Weight, lb							
Ingredient	450*	500*	500	550	600	650	700	750
Alfalfa hay	67.00	63.52	54.57	39.64	39.95	36.30	38.17	34.23
Prairie hay	0.00	0.00	0.00	14.16	16.65	24.2	14.68	19.97
Corn silage	3.00	10.89	34.10	35.39	33.30	30.25	38.17	37.07
Corn grain	13.20	11.98	10.00	9.34	8.79	7.99	7.75	7.53
SBM, solv. 48% CP	15.00	11.80	0.00	0.00	0.00	0.00	0.00	0.00
Molasses	0.30	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Dicalcium phosphate	0.23	0.36	0.33	0.41	0.33	0.35	0.35	0.34
Salt	0.50	0.45	0.55	0.63	0.54	0.54	0.53	0.51
Vitamin A, D, E	0.30	0.28	0.07	0.07	0.06	0.06	0.06	0.06
Vitamin E	0.47	0.45	0.38	0.36	0.38	0.31	0.29	0.29

*Offered only during the first 28 days of study.

Table 3. Performance Response of Heifers to Treatments

Item	Bambermycin	Lasalocid	Monensin	SEM	*P*-value
Pens	8	8	8		
No. heifers	40	40	40		
Daily intake (DM), lb					
01-28 days	14.62	14.68	14.84	0.1853	0.8051
29-56 days	16.18[ab]	16.69[a]	15.81[b]	0.1601	0.0177
57-84 days	16.49[ab]	16.98[a]	5.96[b]	0.1517	0.0398
85-112 days	17.72	17.88	16.93	0.1636	0.0659
113-140 days	19.22[a]	18.87[a]	18.25[b]	0.1420	0.0492
1-140 days	16.84	17.02	16.36	0.1462	0.1014
Average daily gain (ADG), lb					
01-28 days	2.05	2.05	2.18	0.0439	0.2681
29-56 days	2.01	2.12	2.05	0.0279	0.3467
57-84 days	2.05	2.03	2.03	0.0255	0.9268
85-112 days	2.34	2.05	2.18	0.0380	0.0633
113-140 days	1.94	1.87	1.90	0.0341	0.6280
1-140 days	2.07	2.03	2.07	0.0177	0.4587
Efficiency (gain/feed)					
01-28 days	0.1401	0.1390	0.1467	0.0053	0.5309
29-56 days	0.1237	0.1268	0.1297	0.0034	0.3674
57-84 days	0.1243	0.1193	0.1278	0.0035	0.1988
85-112 days	0.1314[a]	0.1148[b]	0.1291[a]	0.0039	0.0197
113-140 days	0.1017	0.1000	0.1037	0.0045	0.6340
1-140 days	0.1234	0.1191	0.1265	0.0021	0.0515
First service conception rate, %					
	60.00	47.00	55.00		0.53

[a,b]Means not bearing common superscripts differ (P<0.05).

Table 4. Body Weight, Hip Height, and Body Condition Score

	Treatment				
Item	Bambermycin	Lasalocid	Monensin	SEM	*P*-value
Body weight, lb					
day 0	542.75	541.45	545.90	4.7376	0.3926
day 28	600.36	598.70	607.06	5.3074	0.1516
day 56	656.31	657.99	664.40	5.5050	0.2104
day 84	713.70	714.67	721.46	5.3719	0.2668
day 112	779.13	773.59	782.61	5.8993	0.2542
day 140	833.69	824.78	835.48	5.4601	0.3371
Change/period	48.50	47.22	48.28	0.4139	0.4587
Hip height, in					
day 0	45.65	45.60	45.63	0.7174	0.9863
day 28	46.37	46.55	46.75	0.6052	0.2920
day 56	47.20	47.28	47.45	0.5908	0.6038
day 84	48.70	48.60	48.67	0.5256	0.9097
day 112	49.30	49.40	49.30	0.5575	0.9223
day 140	50.30	50.37	50.25	0.5442	0.9122
Change/period	0.77	0.79	0.77	0.1172	0.9006
Body condition score (BCS)					
day 0	3.29	3.35	3.36	0.0290	0.1301
day 28	3.26	3.26	3.30	0.0362	0.4608
day 56	3.24	3.21	3.29	0.0267	0.0542
day 84	3.16	3.15	3.16	0.0134	0.7528
day 112	3.22	3.22	3.23	0.0149	0.9067
day 140	3.16	3.17	3.19	0.0287	0.7817
Change/period	-0.02	-0.03	-0.03	0.0083	0.6963

MILKING FREQUENCY, ESTRADIOL CYPIONATE, AND bST ALTERS MILK YIELD AND REPRODUCTIVE OUTCOMES IN DAIRY COWS

C. A. Blevins, J. J. Aberle, J. E. Shirley, B. A. Hensley, S. M. Tiffany, and J. S. Stevenson

Summary

The objective of this study was to determine how milking frequency, estradiol cypionate (ECP) postpartum therapy given at 1 week after calving, and biweekly bovine somatotropin (bST) administration alter lactational and reproductive outcomes in dairy cattle. Holstein cows (n=144) were randomly assigned to eight treatments (18 cows per treatment): 1) twice daily milking frequency (2x), 10-mg injection of ECP at 1 week after calving (ECP), and bST (given biweekly according to label beginning in the ninth week of lactation); 2) 2x milked, oil (cottonseed oil vehicle for ECP), bST; 3) 2x milked, ECP, and no bST; 4) 2x milked, oil, and no bST; 5) four-times daily milking frequency (4x; first 30 days in milk then 2x thereafter), ECP, and bST; 6) 4x milked, oil, and bST; 7) 4x milked, ECP, and no bST; and 8) 4x milked, oil, and no bST. Milk yields were recorded at each milking during the first 90 days of lactation. Milk samples were collected weekly at each milking and composited to determine milk components (percentages of fat, protein, lactose, solids-not-fat [SNF], milk urea nitrogen [MUN], and somatic cell count [SCC]). Energy-corrected milk yields were calculated for the first 90 days and for whole lactation yields (305-2x-ME standardized lactation records). Ovulation before first AI was synchronized beginning between 59 and 72 DIM using 100 µg of GnRH given 7 days before 25 mg of $PGF_{2\alpha}$, followed in 24 hr by 1 mg of ECP. Cows were inseminated after detected estrus or at 48 hr after ECP. Pregnancy rates were assessed by transrectal ultrasonography 28-30 days after AI. Postpartum ECP therapy increased milk production for first-lactation 2x cows, but decreased milk yields of the multiparous 4x cows until bST restored those yields. Pregnancy rates were greater for the 4x cows given the postpartum ECP therapy injection, despite fewer cows cycling before AI. In conclusion, postpartum ECP therapy increased pregnancy rates in 4x cows, but had a detrimental effect on milk yields of 4x milked cows unless bST was administered.

(Key Words: Estradiol Cypionate, bST, Milking Frequency, Fertility.)

Introduction

Conception in lactating dairy cows began to decline in the mid 1970s and accelerated in the late 1980s during which time average milk yield for DHIA herds in the U.S. has increased steadily from nearly 15,000 to nearly 21,000 lb per cow. Some studies reported that the increase in milk yield is genetically based and has precipitated the decline in conception rates. Because milk yield per cow can be increased by daily milking frequency and the administration of bovine somatotropin (bST), many dairy producers have opted to milk cows three times daily and use bST to increase gross income and thereby reduce fixed costs that are associated with empty milking parlors.

Another common practice on many dairies is the use of a prophylactic postpartum therapy of estradiol cypionate (ECP) to assist transition cows that may have had calving difficulties and retained placentae. Injections of ECP facilitate uterine contractions by increasing endometrial oxytocin receptors that respond to endogenous secretion or injections of oxytocin. Legal label indications for ECP include: 1) correcting anestrus (absence of heat period) in the absence of follicular cysts in some cases; 2) treating cattle having a persistent corpus luteum due to certain causes; 3) expulsion of purulent material from the uterus in pyometra of cows; and 4) stimulate uterine expulsion of retained placentas and mummified fetuses.

In light of these changes in management, little is known about the direct or indirect effects of increased milking frequency and ECP on various reproductive traits, such as resumption and occurrence of estrous cycles (estrus and ovulation), conception rates, and calving intervals. Further, some studies report positive effects of bST on fertility while others show negative effects.

Our objective was to determine the effect of increased milking frequency (2x to 4x/day) during the first 30 days in milk, treatment of bST, and treatment of postpartum ECP therapy on lactation and reproductive outcomes.

Procedures

Holstein cows (n=144) were assigned randomly to a 2×2×2 factorial experiment consisting of eight treatments (18 cows per treatment). The main effects (Figure 1) were milking frequency, postpartum injection of 10 mg of estradiol cypionate (ECP; Pharmacia Animal Health, Kalamazoo, MI) at 8 ± 2.6 days in milk, and bST (administered according to label indications beginning in the 9th week of lactation). Cows with previous lactations were paired based on their previous 305-2x-ME record, heifers were paired based on their predicted transmitting ability (PTA) for milk, and pairs were assigned randomly to either of the milking frequency treatments. The eight treatments were: 1) twice daily milking frequency (2x), 10-mg injection of ECP at 1 week after calving (ECP), and bST (given according to label beginning in the 9th week of lactation); 2) 2x milked, oil (cottonseed oil vehicle for ECP), bST; 3) 2x milked, ECP, and no bST; 4) 2x milked, oil, and no bST; 5) four-times daily milking frequency (4x; first 30 days in milk then 2x thereafter), ECP, and bST; 6) 4x milked, oil, and bST; 7) 4x milked, ECP, and no bST; and 8) 4x milked, oil, and no bST.

Milk yields were recorded at each milking during the first 90 days of lactation. Milk samples were collected weekly at each milking and composited to determine milk components ([percentages of fat, protein, and lactose], solids-not-fat, milk urea nitrogen, and somatic cell count). Energy-corrected milk yields were calculated for the first 90 days and for whole lactation yields (305-2x-ME standardized lactation records). Body weights and body condition scores (1 = thin and 5 = fat) were assessed weekly in all cows during the first 10 weeks after calving.

Blood samples were collected twice weekly from 82 cows beginning after calving until just before first inseminations were scheduled to occur between 69 and 82 days in milk. Blood serum was harvested and analyzed for concentrations of progesterone. Concentration of progesterone for each cow was graphically plotted and occurrence of ovulation was estimated from patterns of serum progesterone that occur during a normal estrous cycle. Based on these patterns, days from calving to first and second ovulation were calculated.

Ovulation before first AI was synchronized (Heatsynch) beginning between 59 and 72 DIM using 100 µg of GnRH given 7 days before 25 mg of $PGF_{2\alpha}$, followed in 24 hr by 1 mg of ECP. Cows were inseminated after detected estrus, or in the absence of estrus, at 48 hr after ECP (timed artificial insemination [TAI]). Blood was collected prior to each hormonal injection for later analysis of serum concentrations of progesterone. From these concentrations, the percentage of cycling and anestrous cows were determined before ovulation synchronization and AI. Those cows that had resumed estrous cycles had elevated concentrations of progesterone in any of the three samples (cycling), whereas those that remained anestrus had low concentrations of progesterone in all three samples. Pregnancy rates were assessed by transrectal ultrasonography 28 to 30 d after AI.

Based on visual observation of estrus during the period that included ovulation synchronization, the following were calculated: days to first postpartum estrus, the percentage in estrus after the ECP treatment injection, percentage of cows in estrus at least once before ovulation synchronization, percentage in estrus prior to TAI, and hours from breeding protocol injection of ECP to estrus.

In general, data were analyzed as a factorial experiment using analysis of variance (General Linear Models procedure of SAS). When interactions of main effects were detected, eight treatments replaced main effects. For those data collected prior to first administration of biweekly injections of bST (60 days in milk or the first 8 weeks of milk data), only two main effects (milking frequency and postpartum ECP therapy treatment) were included in models. When significant F ratios were determined by analyses of variance, mean separations were made using the Tukey-Kramer adjustment for multiple mean comparisons.

Results and Discussion

Reproductive Traits

Among the ovulatory traits assessed, days to first and second postpartum ovulation were not different among treatments (Table 1) in the reduced number of cows (n=82) in which blood was collected twice weekly during the first 60 days postpartum. In contrast, in all 143 cows (blood samples missing from one cow), 20% fewer ($P<0.01$) cows in the 4x + ECP treatment were cycling before initiating the Heatsynch breeding protocol.

Among estrual traits assessed by visual observation, both milk frequency and ECP treatment influenced behavior. Milking 4x daily compared to 2x daily reduced ($P<0.01$) days to first estrus and the percentage of cows in estrus after ECP treatment. All of which implies that estrus behavior was reduced by increased milking frequency. Treatment with ECP compared to oil at the end of the first week postpartum, decreased ($P<0.01$) days to first behavioral estrus and increased ($P<0.01$) the percentage of cows in estrus after ECP. These effects of ECP reflect its estrogenicity and ability to induce sexual behavior. The percentages of cows in estrus at least once before TAI or after $PGF_{2\alpha}$, or the timing of the estrus after $PGF_{2\alpha}$ were not affected by treatments.

Pregnancy rates averaged 41% (Figure 2). Of the four treatment groups, the 4x + ECP cows had the greatest ($P<0.05$) pregnancy rate of 53%. A three-way interaction ($P<0.05$) of milking frequency, ECP therapy, and occurrence of estrus after $PGF_{2\alpha}$ was detected. The difference was observed in the oil-treated groups (2x + oil and 4x + oil), where pregnancy rates of the 4x milked cows after TAI group were the lowest and those of the 2x milked cows after detected estrus were the lowest. It seems that the ECP therapy injection produced more consistent pregnancy rates regardless of milking frequency or whether inseminations were made after detected estrus, or by TAI, in the absence of estrus.

Body Weight and Condition

Average body weights and body condition scores during the first week after calving are summarized in Table 2 along with the average percentage change in both traits during the first 10 weeks of lactation. Neither milking frequency nor ECP treatment had any effect on body weight change in first-lactation cows. However, a tendency (P=0.07) was detected for an interaction between milking frequency and ECP therapy treatment for change in body condition score. Cows milked 4x daily and treated with oil lost the most body condition compared to the least condition loss for cows milked 2x daily and treated with oil.

Losses in body weight were greater (P<0.05) for multiple-lactation cows that were milked 4x daily than those milked 2x daily. A tendency (P=0.06) for a treatment × week interaction also was detected. The interaction was caused by a more rapid increase in body weight gain in the cows in the 2x + oil treatment. By week 5 of lactation, these cows had exceeded their first week's body weight by the fifth week (exceeded 100%), whereas that only occurred in two of the three remaining treatments by the tenth week. Treatment had no effect on changes in body condition scores in multiple-lactation cows.

Lactational Traits

First-lactation cows. During the first 8 weeks of lactation before initiation of bST treatment, first-lactation cows treated with ECP produced more (P<0.05) ECM than cows treated with oil. However, a treatment × week interaction (P<0.001) also was detected (Panel A; Figure 3). Increased milking frequency did not consistently improve yields because only 4x + ECP cows produced more ECM than cows in all other treatment during the first 2 weeks; more than 4x + oil and 2x + oil, treated cows during week 3; and more than 4x + oil cows during week 4. The interaction was partly caused by the convergence of yields to similar values after day 30 after which time all cows were milked 2x daily.

Yields of first-lactation cows after initiation of bST treatment were unaffected by treatments only among the cows previously milked 4x daily. The cows in the 4x + oil + no bST and 4x + ECP + bST produced (P<0.001) more ECM during 60 to 90 days in milk than the 4x + ECP + no bST cows. These results are consistent treatment effects on yields during the first 60 days in milk and reinforce the negative effect of ECP on milk secretion of 4x cows. Further, it demonstrates that bST treatment restored yields of cows previously treated with ECP equal to oil-treated, 4x + no bST levels.

Standardized energy-corrected 305-2x-ME yields of first-lactation cows were affected by an interaction (P<0.05) of milking frequency × ECP therapy (Table 2). Among 2x milked cows, ECP stimulated greater standardized ECM yields, whereas among 4x milked cows, ECP reduced whole lactation yields.

Multiple-lactation cows. The main effects of milking frequency (P=0.05) and ECP (P<0.01) were both significant, but a strong interaction (P<0.001) of treatments and a treatment × week interaction (P<0.001) was detected (Panel B; Figure 3). Yield of ECM for 4x + oil cows was clearly elevated during the first 6 weeks of lactation, with treatment of ECP inhibiting the ability of 4x cows to produce more milk than 2x cows during the first 30 days in milk. During the 4x milking period, the 4x + oil cows differed from the other treatments during weeks 2 and 4; with all treatment groups converging during weeks 7 and 8, except for the 4x + ECP cows in which ECM was clearly lowest of all treatments.

During the 60- to 90-day period after bST treatments began, ECM was affected by the main effects of ECP and bST, but no interaction of treatment × week was detected (Table 2). For older cows, ECP treatment reduced ($P<0.01$) ECM yields uniformly except in the 2x + ECP + no bST cows, where yield seemed to be greater than that for 2x + oil + no bST cows (Table 2). Treatment with bST increased ($P<0.001$) ECM yields in all but the 2x + ECP + bST cows compared to the 2x + ECP + no bST cows (Table 2).

For older cows, whole lactation yields were only affected by bST (Table 2). Treatment with bST consistently increased ($P<0.01$) yields in all treatments, even to restore reduced yields of 4x + ECP cows to levels equal to that of 4x cows treated with oil.

Conclusions

Milking first-lactation cows 4x daily increased yields during the first 30 days of lactation, but only in the absence of ECP. Postpartum ECP therapy stimulated yields in first-lactation cows, but decreased yields in older cows. Treatment with ECP continued to suppress yields in older cows after initiating bST treatments in the 9th week lactation. The long-term carry-over effect of the early lactation injection of ECP affected the entire lactation yield. Whole lactation yields followed similar trends with ECP inhibiting yields in 4x milked cows but enhancing them in 2x milked cows. Administration of bST restored yields of 4x milked + ECP cows to the levels equal to or greater than contemporaries treated with oil or bST. Based on our results, when ECP is used as a postpartum therapy, bST must be used to prevent reduction in whole lactation yields. Increased milking frequency during the first 30 days in milk provided no milk production benefit to cows based on the measures examined in our study.

Reproductive outcomes were generally positive with ECP therapy increasing pregnancy rates at first service and making pregnancy rates consistent after detected estrus or TAI. These positives occurred despite the fact that ECP decreased the number of cows cycling prior to first insemination. Treatment with ECP seemed to have no effect on the occurrence of postpartum ovulation in 82 of the cows blood sampled twice weekly, but negatively affected characteristics related to estrus activity. Increasing milking frequency and use of ECP did not reduce reproductive efficiency.

Table 1. Reproductive Characteristics of Lactating Dairy Cows after Treatments

	Treatment[1]			
Item	2x + oil	2x + ECP	4x + oil	4x + ECP
	---------- Mean ± SE or % (no.) ----------			
Ovulatory traits[1]				
Days to first ovulation	26 ± 3 (20)	25 ± 3 (21)	24 ± 3 (23)	26 ± 3 (18)
Days to second ovulation	44 ± 3 (14)	44 ± 3 (16)	48 ± 3 (20)	45 ± 3 (14)
Percentage cycling before TAI[a]	100 (33)	97 (36)	97 (36)	78 (36)
Estrual traits[2]				
Days to first behavioral estrus[b]	30 ± 4 (17)	17 ± 3 (23)	47 ± 4 (20)	34 ± 4 (21)
Percentage in estrus after postpartum ECP[c]	11 (35)	42 (36)	0 (36)	14 (37)
Percentage in estrus at least once before TAI	49 (35)	64 (36)	56 (36)	57 (37)
Percentage in estrus after $PGF_{2\alpha}$	65 (34)	64 (36)	53 (36)	47 (38)
Hours to estrus after $PGF_{2\alpha}$	27 ± 5 (22)	30 ± 6 (17)	23 ± 6 (15)	28 ± 6 (16)

[1]See experimental protocol in Figure 1.

[2]Based on serum progesterone.

[3]Based on visual observation.

[a]Fewer (P<0.01) 4x + ECP cycling cows.

[b]4x milked (40.2 ± 2.6 days; n=41) differed (P<0.01) from 2x milked (23.7 ± 2.6 days; n=40). ECP (25.4 ± 2.5 days; n=44) differed (P<0.01) from oil (38.5 ± 2.7 days; n=37). Lactation 1 (36.5 ± 2.4 days; n=47) differed (P<0.01) from lactation 2+ (26.6 ± 2.8 days; n=34).

[c]4x milked (7%; n=73) differed (P<0.01) from 2x milked (27%; n=71). ECP (27%; n=73) differed (P<0.01) from oil (6%; n=71).

Table 2. Average Body Weights and Body Condition Scores

	Treatment[1]			
Item	2x + oil	2x + ECP	4x + oil	4x + ECP
	---------------- Mean ± SE			------------------
Body weight, lb				
First lactation	1182 ± 106[3]	1195 ± 92	1116 ± 152	1206 ± 129
	98 ± 1.4[4]	96 ± 1.3	96 ± 1.2	97 ± 1.1
Multiple lactation[a]	1487 ± 182	1459 ± 211	1570 ± 292	1409 ± 179
	101 ± 1.7	98 ± 2.0	96 ± 1.7	96 ± 1.6
Body condition score[2]				
First lactation[b]	2.7 ± 0.3[3]	2.8 ± 0.4	2.5 ± 0.4	2.7 ± 0.3
	91 ± 2.3[4]	89 ± 2.1	84 ± 2.1	89 ± 1.9
Multiple lactation	2.8 ± 0.4	2.5 ± 0.4	2.8 ± 0.7	2.4 ± 0.5
	89 ± 3.0	86 ± 3.7	86 ± 3.0	82 ± 2.8

[1]See experimental protocol in Figure 1.

[2]Thin=1 and fat=5.

[3]Mean body weight or body condition score during the first week after calving.

[4]Average percentage change in body weight or body condition score during the first 10 weeks after calving.

[a]2x milked multiple-lactation cows lost less (*P*<0.05) body weight than 4x multiple-lactation cows.

[b]A tendency (*P*=0.08) for an interaction between milking frequency and postpartum ECP therapy injection for body condition scores.

Table 3. Energy-Corrected Milk (ECM) Yields (lb) of Lactating Dairy Cows

	ECM (60-90 days in milk)		ECM 305-2x-ME	
Treatments[1]	Lactation 1	Lactation 2+[a]	Lactation 1[b]	Lactation 2+[c]
	----- Mean (no.) -----		----- Mean (no.) -----	
2x + ECP + bST	75 (11)	90 (9)	31,633 (11)	31,315 (9)
2x + Oil + bST	76 (11)	99 (8)	29,034 (11)	32,328 (8)
2x + ECP + no BST	75 (9)	99 (7)	31,069 (9)	28,958 (7)
2x + Oil + no BST	75 (9)	93 (6)	29,239 (9)	27,749 (6)
4x + ECP + bST	78 (11)	98 (9)	32,680 (11)	32,729 (9)
4x + Oil + bST	73 (12)	104 (9)	32,279 (12)	30,625 (9)
4x + ECP + no BST	68 (10)	86 (7)	28,326 (10)	25,411 (7)
4x + Oil + no BST	78 (9)	90 (6)	32,652 (9)	28,698 (6)

[1]See experimental protocol in Figure 1.

[a]Oil vs. ECP (P<0.01). No bST vs. bST (P<0.0001).

[b]Milking frequency × ECP interaction (P<0.05): 2x milked + oil = 29,137 ± 945 lb (n=20); 2x milked + ECP = 31,351 ± 945 lb (n=20); 4x milked + oil = 32,465 ± 927 lb (n=21); and 4x milked + ECP = 30,505 ± 919 kg (n=21).

[c]bST effect (P<0.01): No bST = 27,703 ± 1,077 lb (n=26) vs. bST 31,749 ± 927 lb (n=35).

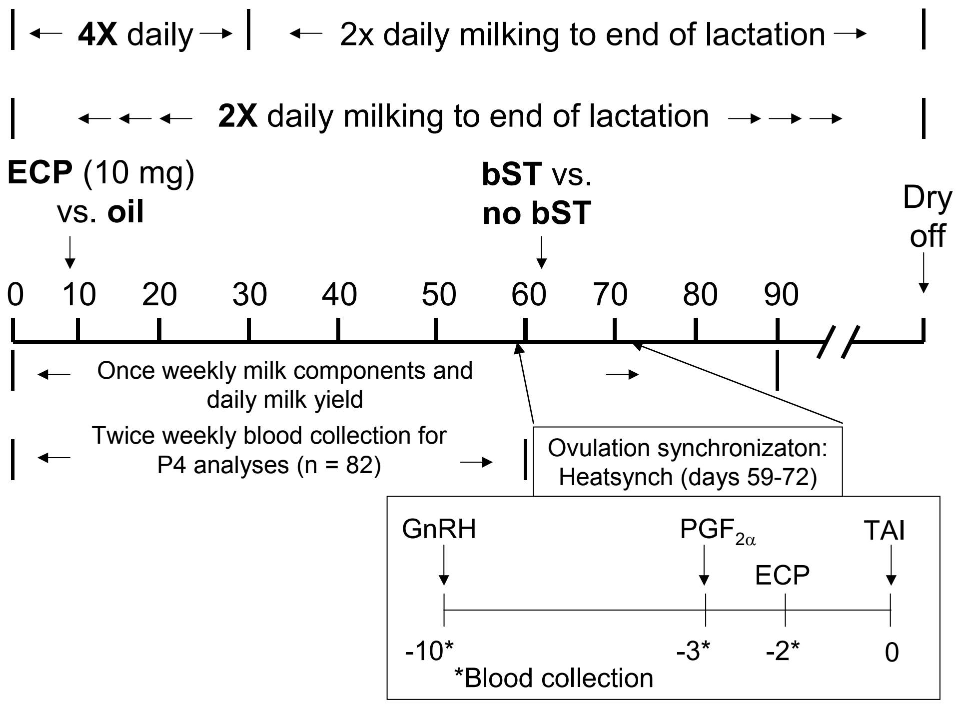

Figure 1. Experimental Protocol.

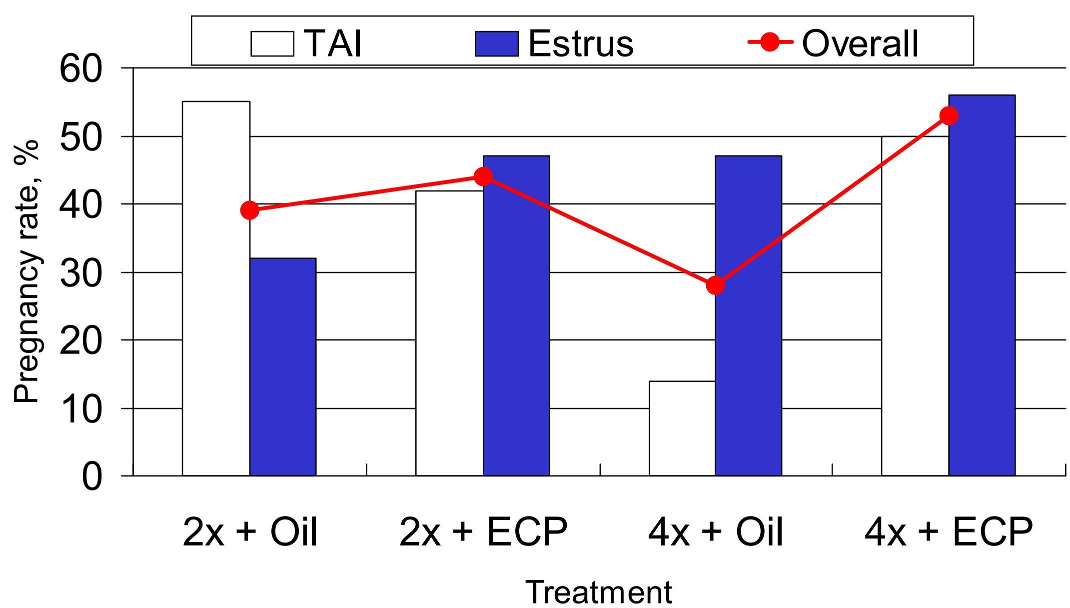

Figure 2. Pregnancy Rate of Dairy Cows 28 to 30 Days After Timed Artificial Insemination (TAI). The overall pregnancy rate differed (P<0.05) among treatments with cows milked 4x daily + ECP having the greatest pregnancy rates. In addition, a three way interaction (P<0.05) was detected for milking frequency, postpartum ECP therapy, and occurrence of estrus after $PGF_{2\alpha}$.

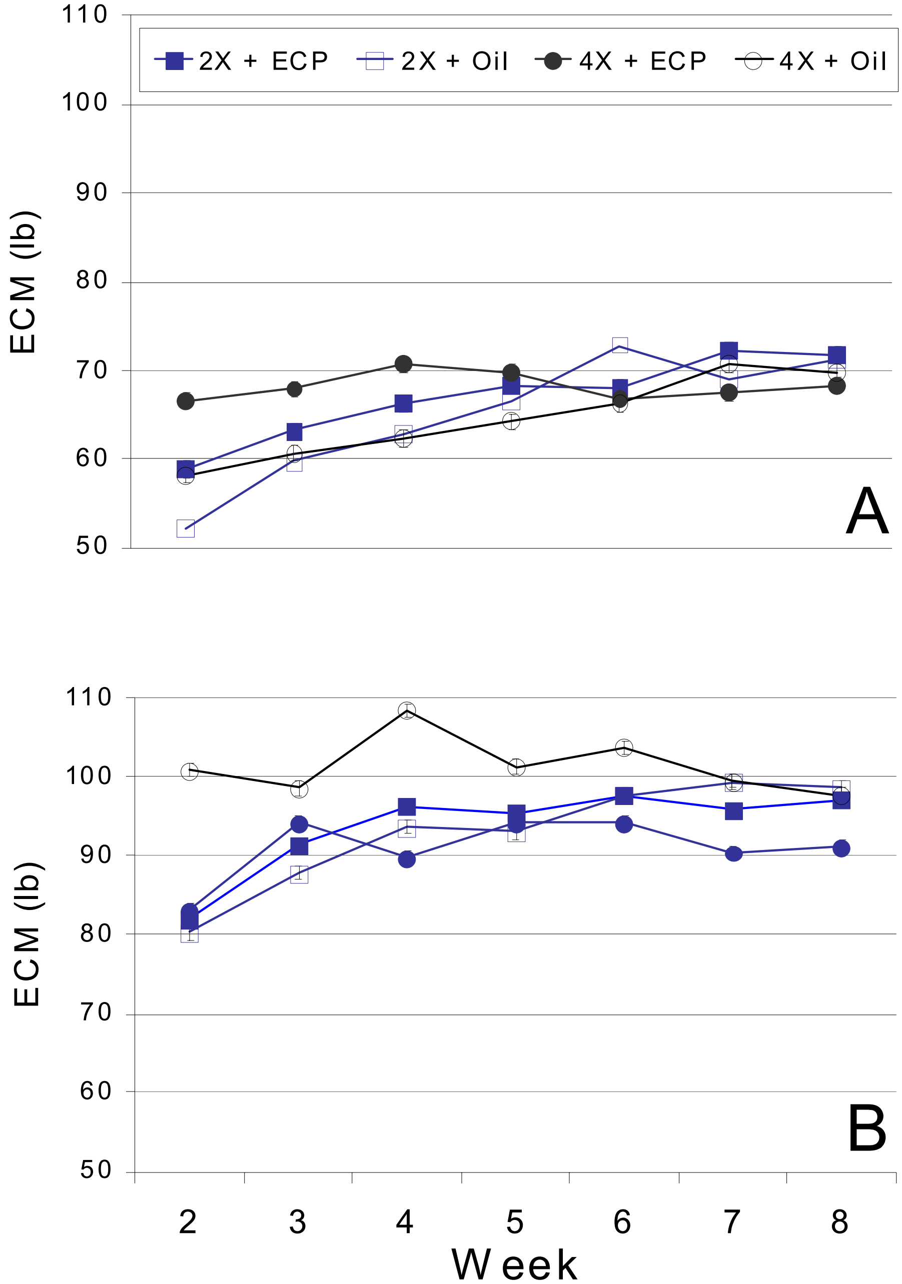

Figure 3. Energy Corrected Milk Yield of First-Lactation (Panel A) and Multiple-Lactation Cows (Panel B) During the First 8 Weeks of Lactation.

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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 result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than from chance.

In some of the articles herein, you will see the notation "$P<0.05$". That means the probability of the differences resulting from chance is less than 5%. If two averages are said 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 ± 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 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 increase 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 all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

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