K-STATE Kansas State University AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

DAIRY DAY 1999

Report of Progress 842

1999 Dairy Day Program

10:00 a.m. Registration

10:25 a.m. Welcome

Lunch **Courtesy of the Kansas Dairy Association (KDA)**

Topics to be presented:

"Designing and Constructing Feed-Line Cooling Systems" . . . . Dr. Joe Harner
Biological and Agricultural Engineering, K-State

"Expansion Issues on Kansas Dairy Farms" . . . . Dr. John Smith
Animal Sciences and Industry, K-State

"Responses of Dairy Cows to Different Cooling Systems" . . . . Dr. Mike Brouk
Animal Sciences and Industry, K-State

"Dry Cow Feeding and Management" . . . . Dr. John Shirley
Animal Sciences and Industry, K-State

"Applications of Ovulation Control and Timed A.I.-Breeding" . . Dr. Jeff Stevenson
Animal Sciences and Industry, K-State

2:30 p.m. Adjourn

Locations:

Wednesday	November 17	Amish Community Building, Whiteside, KS
Thursday	November 18	Methodist Church, Hillsboro, KS
Friday	November 19	Valentino's Restaurant, Seneca, KS

FOREWORD

Comparison of Heart of America Cows with Kansas Cows - 1998

Item	HOA	KS
No. of herds	1,199	373
No. of cows/herd	99	96
Milk, lb	18,526	19,259
Fat, lb	672	698
Protein, lb	597	614
IOFC, $	1,638	1,482
Milk price*, $	14.68	14.19

*After subtracting hauling cost.

Members of the Dairy Commodity Group of the Department of Animal Sciences and Industry are pleased to present this Report of Progress, 1999. Dairying continues to be a viable business and contributes significantly to the total agricultural economy of Kansas. 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 began business on January 1, 1995, by combining three labs into one. It tested more than 137,000 cows per month from Kansas, Nebraska, Oklahoma, Arkansas, North Dakota, and South Dakota during 1998. A comparison of Kansas DHIA cows with all those in the Heart of America DHIA program for 1998 is illustrated above.

Most of this success occurs because of better management of what is measured in monthly DHI records. In addition, use of superior, proven sires in artificial insemination (AI) programs shows average predicted transmitting ability (PTA) for milk of all Holstein AI bulls in service (August, 1999) to be +2,015 lb (pounds) compared to non-AI bulls whose average PTA was more than 1,000 lb of milk less. More emphasis should be placed on furthering the DHIA program and encouraging use of its records in making management decisions.

The excellent functioning of the Dairy Teaching and Research Center (DTRC) is due to the special dedication of our staff. Appreciation is expressed to Richard K. Scoby (Manager, DTRC); Donald L. Thiemann (Asst. Manager, DTRC); Michael V. Scheffel (Research Assistant); Daniel J. Umsheid; Charlotte Boger; Lesa Reves; Shannon Taylor; and William P. Jackson. Special thanks are given to Betty Hensley and 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 Council (LMIC), a philanthropic organization dedicated to furthering academic and research pursuits by the Department (more details about the LMIC are found at the end of this publication).

J. S. Stevenson, Editor
1999 Dairy Day Report of Progress

CONTENTS

EFFECTS OF PROCESSING AND FAT REMOVAL ON THE VALUE OF COTTONSEED IN DIETS FOR LACTATING DAIRY COWS

M. J. Meyer, J. E. Shirley, E. C. Titgemeyer, M. V. Scheffel, and A. F. Park

Summary

Eighteen Holstein cows were used in six simultaneous 3×3 Latin squares to determine the value of extruded-expelled cottonseed meal with lint as a replacement for whole cottonseed in diets for lactating dairy cows. Diets were: 1) WCS=whole cottonseed; 2) EC+T=extruded-expelled cottonseed meal with tallow; and 3) EC=extruded-expelled cottonseed meal. Diets were formulated to contain 17.5% CP and 40% RUP. Tallow or shelled corn was used to balance energy across diets. No differences were observed in dry matter intake, milk production, or feed efficiency among diets. Cows fed EC produced milk with a slightly higher protein percentage. Feed costs per cwt of milk were $4.17, $4.19, and $4.11 for WCS, EC+T, and EC, respectively. Extruded-expelled cottonseed meal with lint can replace whole cottonseed in diets for lactating dairy cows, if the diet is balanced for energy with either corn grain or tallow.

(Key Words: Extruded Cottonseed, Tallow, Cottonseed, Lactating Cows.)

Introduction

Extruded-expelled cottonseed meal was compared to whole cottonseed in diets for lactating cows under heat stress conditions during the summer of 1998. Cows fed extruded-expelled cottonseed performed as well as those fed whole cottonseed, even though dietary fat was not equalized as dietary amounts of extruded-expelled cottonseed were increased and amounts of whole cottonseed decreased. The amount of soybean meal was adjusted to maintain dietary crude protein (CP) between 17.5 and 18%, but the fat content of the diets decreased from 5.1% to 4.2%, and the ruminally undegradable protein (RUP) increased from 36% to 40% as extruded-expelled cottonseed was added. The lack of differences in response indicated that the additional fat supplied by whole cottonseed did not improve performance. However, milk production in this study was relatively low (approximately 55 lb per cow per day), and dry mater intake was depressed by the heat stress conditions. Thus, the advantage of increased dietary fat in whole cottonseed may not have been realized under the conditions of the study. The purpose of this study is to further evaluate the value of extruded-expelled cottonseed meal as a replacement for whole cottonseed in diets for high-producing dairy cows.

Procedures

Eighteen Holstein cows were used in six 3×3 Latin squares. Cows were individually fed diets typical of those used by commercial dairies with all the cereal grain supplied as corn. The following diets were compared: 1) whole cottonseed (17.5% CP:40% RUP); 2) extruded-expelled cottonseed meal plus tallow (17.5% CP:40% RUP); and 3) extruded-expelled cottonseed meal (17.5% CP:40% RUP).

All diets were fed as a total mixed ration. Cows were fed each diet for 28 days, and feed intake and milk production were measured daily. Milk samples were analyzed weekly for milk composition; milk protein, fat, lactose, solids-not-fat, MUN and somatic cells being measured by the Heart of America DHI Laboratory, Manhattan, KS. Cows were weighed on 2 consecutive days at the beginning of period 1 and on the last 2 days of each period thereafter. Body condition was scored on one of each of the dates when body weights were obtained.

Results and Discussion

Diet components and the chemical composition of the experimental diets are shown in Tables 1 and 2, respectively. Diets were formulated to be isocaloric with the sources of calories being tallow in EC+T and corn grain in EC to equal the caloric value of whole cottonseed. Diets also were formulated to contain 17.5% CP with 40% of the protein being RUP. Because RUP and CP were balanced, responses should provide a meaningful evaluation of the nutritional value of the cottonseed oil removed during the extrusion-expeller process. The actual CP contents of the diets (Table 2) differed as did the RUPs as a percentage of CP. However, the NE_L values were similar between WCS and EC, whereas NE_L in EC+T was greater because solvent soybean meal had a higher NFC content than did the expeller soybean used in the WCS diet as a source of RUP. The NFC contents of diets WCS and EC were consistent with expectations, whereas the content was higher than expected for EC+T.

Responses of the cows to the experimental diets are shown in Table 3. Dry matter consumption was similar across diets, whereas milk production was numerically higher from cows fed diets containing EC+T and EC. Cows fed EC produced milk with higher ($P<.05$) percentages of protein and solids-not-fat. Cows fed WCS had less ($P<.05$) milk-urea nitrogen than cows fed EC+T. These results are consistent with the RUP content of the diets. The diets yielded similar efficiencies (lb of milk produced per lb of dry matter consumed). An economic analysis (Table 4) of the diets shows that feed cost per cwt of milk produced was less for cows fed EC than for cows fed WCS or EC+T.

In summary, extruded-expelled cottonseed meal with lint can replace whole cottonseed in diets for high-producing dairy cows if the diets are balanced for energy with either tallow or corn grain.

Table 1. Compositions of Experimental Diets as Percent of Dry Matter

	Diets[1]		
Ingredient	WCS	EC+T	EC
	----- % of dry matter -----		
Alfalfa hay	27.1	26.8	23.8
Corn silage	20.0	19.9	16.9
Whole cottonseed	9.7	-	-
Extruded cottonseed	-	9.8	9.9
Ground corn	28.5	28.0	32.4
Soybean meal, 48%	1.0	8.0	8.0
Expeller soybean meal	9.1	1.5	2.0
Soy hulls	-	-	3.0
Wet molasses	1.0	1.0	1.0
Tallow	-	1.5	-
Vitamins/minerals premix	3.6	3.6	3.0

[1]WCS = 5.4 lb of whole cottonseed; EC+T = 5.5 lb of extruded-expelled cottonseed meal, 0.8 lb of tallow; and EC = 5.5 lb of extruded-expelled cottonseed meal.

Table 2. Chemical Compositions of Experimental Diets

	Diets[1]		
Ingredient	WCS	EC+T	EC
Crude protein, %	17.7	16.2	17.0
RUP, % of CP	42.2	39.8	38.0
NE_L, Mcal/lb	0.75	0.78	0.74
Fat, %	5.56	5.73	4.27
NDF, %	31.5	30.7	30.7
ADF, %	21.7	21.4	21.5
NFC, %	36.7	40.1	40.6

[1]WCS = 5.4 lb of whole cottonseed; EC+T = 5.5 lb of extruded-expelled cottonseed meal, 0.8 lb of tallow; and EC = 5.5 lb of extruded-expelled cottonseed meal.

Table 3. Responses of Lactating Cows to Experimental Diets

	Diets[1]			
Ingredient	WCS	EC+T	EC	SE[2]
DMI, lb/day	59.0	59.7	59.1	1.01
Milk, lb/day	77.5	80.7	78.6	2.18
ECM[3], lb/day	77.4	79.4	78.3	2.35
Efficiency, milk/feed	1.32	1.32	1.33	0.03
Milk fat, %	3.56	3.61	3.50	0.06
Milk protein, %	2.98[a]	3.01[a]	3.06[b]	0.01
SNF, %	8.53[a]	8.56[a]	8.63[b]	0.02
MUN, mg/dL	15.17[a]	16.12[b]	15.96[ab]	0.28
Change in body wt., lb	-12.85	-18.39	-15.82	7.50

[1]WCS = 5.4 lb of whole cottonseed; EC+T = 5.5 lb of extruded-expelled cottonseed meal, 0.8 lb of tallow; EC = 5.5 lb of extruded-expelled cottonseed meal.
[2]Standard error of the mean.
[3]Energy corrected milk.
[a, b]Means not bearing a common superscript differ ($P<0.05$) within row.

Table 4. Production Costs Associated with Experimental Diets

	Diets[1]		
Item	WCS	EC+T	EC
DMI, lb/day	59.0	59.7	59.1
Cost/lb dry matter[2], $	.0547	.0567	.0547
Feed cost/head/day, $	3.23	3.38	3.23
Milk yield, lb/day	77.5	80.7	78.6
Feed cost/cwt milk[3], $	4.17	4.19	4.11

[1]WCS = 5.4 lb of whole cottonseed; EC+T = 5.5 lb of extruded-expelled cottonseed meal, 0.8 lb of tallow; EC = 5.5 lb of extruded-expelled cottonseed meal.
[2]Based on NE Kansas prices. Shelled #2 corn, $78.6/ton; 48% SBM, $148/ton; Tallow, $360/ton; Linted whole cottonseed, $160/ton; Alfalfa hay (170 RFV), $80/ton; Extruded-expelled cottonseed meal, $148/ton; Vitamin/Mineral premix, $280/ton; Soy hulls, $90/ton; Corn silage, $24.5/ton; Wet molasses, $138/ton; SoyBest expeller soybean meal, $186.00/ton.
[3]Feed cost to produce of 100 lb of milk.

EFFECTS OF RUMENSIN AND BOVATEC ON GROWTH, FEED INTAKE, AND FEED EFFICIENCY IN DAIRY CALVES

J. A. Isch, J. E. Shirley, M. V. Scheffel, E. C. Titgemeyer, and E.C. Thomas.

Summary

One hundred Holstein heifers were used to examine the effects of monensin (Rumensin®) and lasalocid (Bovatec®) included in calf starter and grower diets. Heifers were assigned alternately at birth to a starter feed containing either Rumensin (28 g/ton, 90% dry matter basis) or Bovatec (40 g/ton, 90% dry matter basis). The Bovatec group was switched to a starter feed containing 28 g Bovatec/ton (90% dry matter basis) at 6 weeks of age. Both groups were switched at 8 weeks of age to grower diets designed to deliver 100 mg/head/day of either Rumensin or Bovatec. No treatment differences were observed between birth and 8 weeks of age. Heifers were moved from individual hutches at 8 weeks of age to group pens (five heifers/pen) and remained on the same treatment for the next 84 days. During this 84-day period, heifers receiving Rumensin gained more weight at a faster rate and tended to be more efficient than heifers fed Bovatec. No differences were observed in feed intake, skeletal growth as measured by hip height, or body condition score.

(Key Words: Calves, Replacement Heifers, Rumensin, Bovatec.)

Introduction

Dairy heifers often experience a reduction in rate of gain for the first week or two after moving from individual calf hutches to group pens. Various techniques have been tried to overcome this loss, including blending starter and grower feeds and delaying movement until heifers are consuming 5 lb of feed per day. Stress-induced reduction in feed consumption or decreased efficiency in feed utilization may be factors explaining this decrease in growth rate. Inclusion of ionophores in the starter feed offers a potential means of alleviating this reduction in gain.

Both Rumensin® (monensin) and Bovatec® (lasalocid) have claims for increased rate of weight gain in dairy replacement heifers. Additional claims of these ionophores include control and prevention of coccidiosis, and improved feed efficiency in calves and improved feed efficiency in cattle fed in confinement for slaughter. Little information is available that compares concurrently the efficacy of each ionophore in heifers from birth to 20 weeks of age. This period includes the transition from individual hutches to group pens. The objective of this study was to determine the efficacy for preventing and controlling coccidiosis and effects on feed intake, weight gain, hip height, and feed efficiency, when these ionophores were included in the diet beginning at 1 to 3 days of age.

Procedures

One hundred female Holstein calves from the Kansas State University dairy herd were utilized in this study, which consisted of Phase I (birth to 8 weeks of age) and Phase II (8 to 20 weeks of age). Calves were assigned alternately at birth to treatment diets containing either Rumensin or Bovatec. Calves were paired based on birth date, except for the final two pairings. This occurred because two calves died (one on each treatment) and were replaced to bring the total number of heifers to 100 (50/treatment). Calves were moved from the maternity area to individual hutches within 48 hours after birth and offered a starter feed (pelleted) containing either Rumensin (28 g/ton, 90% dry matter basis) or Bovatec (40 g/ton, 90% dry matter basis) along with whole milk (4% of body weight). Whole milk was fed twice daily, and starter feed was fed once daily. The amounts of starter feed fed and consumed were recorded daily. Feed refusal was weighed before each new daily allocation. One measured tablespoon of wet molasses was distributed over the top of the daily starter feed allocation to stimulate intake. Calves were weaned when they consumed 2 lb of starter feed for 3 consecutive days. If this level of intake was not achieved by 36 days of age, milk offered was reduced by 50% to stimulate starter feed intake. The starter pellets (Table 1) were manufactured at the Grain Science Feed Mill located on the Kansas State University campus. Each batch was sampled and shipped to Elanco Animal Health (Greenfield, IN) for Rumensin compliance analysis or Hoffman-LaRoche (Belvidere, NJ) for Bovatec compliance analysis before they were used in the study. Forages were sampled weekly and composited monthly, and grain mixes were sampled by batch for analysis. Silage was analyzed weekly for dry matter, and the amount fed adjusted accordingly. The primary source of protein in the Phase II diets was alfalfa hay (21% CP) offered in a TMR with corn silage and a grain mix containing ground corn and a mineral and vitamin premix. The ionophores were mixed with ground corn and offered as a topdressing.

Table 1. Calf Starter-Pellet Composition

Ingredient	% of Dry Matter
Cracked corn	54.5
Rolled oats	20.1
Molasses	3.9
Soybean meal	19.8
Mineral-vitamin premix	1.6

Body weight and hip height measurements were obtained within 24 hours after birth, at weaning, and when calves were moved from the hutches to the group pens (8 weeks ± 3 days of age). This was done on a Wednesday after group pen daily feed refusal was determined. Group pen feed offered was recalculated to include the new addition (five) to the pen. Twenty-two group pens were utilized in Phase II. Eight pens for each treatment contained five heifers, two pens contained four heifers and one pen contained two heifers. The average number of days required to fill the Bovatec pens was 25 (range 14 to 35), and the average number required to fill the Rumensin pens was 19 (range 14 to 35). The first calves entered Phase II on February 25, 1998 and the last calves entered Phase II on October 25, 1998 for both treatment groups. Once a heifer entered a pen, it remained in there until the last calf entering the same pen completed 84 days. The average days in group pens were 98.1 and 94.6 for Bovatec and Rumensin groups, respectively, and were not significantly different.

Treatment pens were paired based on the date they were filled. Because alternate calves were assigned to treatments at birth, the average age of calves in paired pens was similar. Pens were arranged in two rows, and treatment groups were assigned to alternating pens to reduce location effect. The amount of TMR fed was based on the number of calves per pen and the average weight of calves within the pen plus 14 lb of body weight per calf (projected gain in 7 days). Individual calf weights were obtained every Tuesday, and the amount of TMR fed was adjusted every Wednesday. Paired pens received the same amount of TMR per head based on the average weight of heifers in the heaviest pen to ensure that sufficient feed was available to achieve the desired rate of gain. The ionophores were mixed with finely ground corn at the rate of 200 g/ton and fed as a topdressing to deliver 100 mg/head/day (1 lb of topdressing per head per day).

Heifers were weighed within 24 hr of birth; at weaning; when moved from hutches to group pens; and on days 28, 56, and 84 following movement into group pens. Hip height was measured within 24 hr of birth, when heifers were moved to group pens; and at the end of the trial. Feces of individual calves in hutches were scored daily using the scale of: 1 = normal, solid; 2 = with consistency of partially melted soft-serve ice cream; 3 = moderate scours with consistency of pancake batter, spread out without firm parts; 4 = primarily liquid with consistency of water; and 5 = bloody. After calves were moved to group pens, a fecal score was determined weekly for the pen. All heifers were observed daily, and their health conditions were recorded along with appropriate follow-up observation and therapy.

Results and Discussion

The responses of dairy calves to Rumensin or Bovatec inclusion in starter feed (birth to 8 weeks of age) are shown in Table 2. The average daily gain and dry matter intake were lower than expected based on previous experience and probably were due to the pelleted feed used in the study. The low intakes of both starter feeds reduced the average intakes of Rumensin and Bovatec to 26 and 37 mg per head per day, respectively, during the 8-week period. No differences were observed in performance traits measured. Further, none of the calves experienced coccidiosis, and fecal scores for both groups averaged less than 2.

The responses of dairy heifers during Phase II (8 to 20 weeks of age) of the study are shown in Table 3. Average daily gain was greater (*P*<.01) for heifers receiving Rumensin than for those fed Bovatec. Dry mater intake and lbs. of gain per lb of feed were similar between the two treatments. The diets in Phase II were formulated to provide sufficient protein to support 2 lb of daily gain. The reason for this formulation was to test the ability of the ionophores to improve energy efficiency through their effects on rumen fermentation. Additional protein was included to ensure that it was not limiting.

Exposure to this type of grower diet without a transition period probably accounted for the slow rate of gain during the first 28 days after calves were moved from hutches to group pens. Calves fed Rumensin gained faster (*P*<.05) than those fed Bovatec during this period. These results agree with the concept that Rumensin improves rate of gain when added to high forage diets. The use of ionophores in starter and grower diets offer a convenient method to control coccidiosis and potentially improve feed efficiency. Further studies with a more palatable starter feed are warranted.

Table 3. Effect of Ionophores on Performance of Dairy Heifers from Birth to 8 Weeks of Age (Phase I)

	Treatment			
Item	Bovatec	Rumensin	SEM	P-Value
Birth wt, lb	79.5	79.5	1.4	.98
Weaning wt, lb	111	108	1.9	.28
Weight at 8 weeks, lb	132	131	2.27	.72
Days to weaning	40.6	41.0	.58	.70
Days to weaning weight	43.6	43.2	.17	.07
Days in hutches	56.4	56.9	.24	.10
Daily gain, lb				
Birth to weaning	.72	.66	.03	.16
Birth to 8 weeks	.92	.89	.03	.50
Daily intake (DM), lb	1.87	1.86	.04	.86
Gain/feed	.50	.48	.01	.37
Hip height, inches				
Birth	30.4	30.2	.20	.52
Weaning	32.9	33.1	.23	.58
8 weeks	34.1	34.2	.23	.81

Table 3. Effects of Ionophores on Performance of Dairy Heifers from 8 to 20 Weeks of Age (Phase II)

	Treatment			
Item	Bovatec	Rumensin	SEM	P-Value
Hip height, inches				
56 days of age	34.1	34.2	.32	.75
140 days of age	38.2	38.4	.16	.37
Body weight, lb				
56 days of age	130	133	3.07	.60
84 days of age	166	174	3.48	.12
112 days of age	216	229	3.11	.01
140 days of age	267	282	3.90	.02
Daily gain				
56-84 days of age	1.28	1.49	.06	.03
56-112 days of age	1.53	1.73	.03	.001
56-140 days of age	1.62	1.78	.02	.0006
Daily intake (DM), lb	7.04	7.05	.08	.90
Gain/feed	.24	.26	.009	.22
Average days in pen	98	95	1.4	.11

EXTRUDED-EXPELLED COTTONSEED MEAL WITH LINT AS A SOURCE OF RUMEN UNDEGRADABLE PROTEIN FOR LACTATING DAIRY COWS

M. J. Meyer, J. E. Shirley, E. C. Titgemeyer, M. V. Scheffel, and A. F. Park

Summary

Twenty-four pluriparous Holstein cows were used in six 4×4 Latin squares to evaluate the value of extruded-expelled cottonseed meal (EECM) with lint as a source of rumen undegradable protein (RUP) for lactating dairy cows. Cows were fed diets typical of those used by commercial dairies with all the cereal grain supplied as corn. Tallow was used to balance the fat level across diets. Experimental diets were: solvent soybean meal (16% CP:35% RUP)=SBM 16-35; solvent soybean meal (18% CP:35% RUP)= SBM 18-35; extruded-expelled cottonseed meal (16% CP:40% RUP)=EC16-40; bloodmeal/fishmeal (16% CP:40% RUP)=BMFM 16-40. Average milk production was approximately 82 lbs and did not differ among treatments. Cows fed BMFM 16-40 consumed less dry matter than cows fed the other diets and were more efficient in converting feed to milk. No difference was observed in body weight gain among treatments. Percentages of milk fat and protein were similar, but percentage of lactose was less in milk from cows fed BMFM 16-40. Urea nitrogen was highest in milk from cows fed SBM 18-35. Increasing RUP from 35 to 40% of the dietary protein tended to depress dry matter intake with no effect on milk production, whereas efficiency of milk production increased. The casein fraction of milk protein was not affected by diet, but the nonprotein nitrogen fraction was greater in milk from cows fed SBM 18-35. Feed costs/cwt milk were $4.24, $4.29, $3.98 and $5.18 for SBM 16-35, SBM 18-35, EC 16-40, and BMFM 16-40, respectively, based on commodity prices in northeast Kansas. Extruded-expelled cottonseed meal with lint is an acceptable source of rumen undegradable protein for lactating dairy cows.

(Key Words: Cottonseed Meal, Rumen Undegradable Protein, Lactating Cows.)

Introduction

Extruded-expelled cottonseed meal (EECM) is obtained by passing whole cottonseed through an extruder (exit temperature of 220 to 260°F) and an expeller. The resultant product contains approximately 7.5% fat and 26% protein on a dry matter basis. Approximately 50% of the protein in EECM is undegradable in the rumen. The EECM can be purchased commercially for $12.00 to $15.00 per ton less than whole cottonseed and approximately $500.00 per ton less than fishmeal and bloodmeal in central and northeast Kansas. Thus, it has the potential to significantly reduce feed cost.

The EECM with lint and hulls was evaluated as a feedstuff for lactating dairy cows during the summer of 1998. The product compared favorably with whole cottonseed when substituted in the diet on a pound for pound basis for whole cottonseed. Milk yields were relatively low (<60 lb/day) because of the high ambient temperature; thus, the values of the additional fat in whole cottonseed and the rumen undegradable protein (RUP) in EECM were not obvious. This information is needed to establish its place in dairy diets as well as its economic value. The purpose of this study was to further evaluate the comparative responses of high-producing cows to EECM and standard protein sources.

Procedures

Twenty-four Holstein cows were used in six, simultaneous 4×4 Latin squares with 21-day periods. Cows were fed individually diets typical of those used by commercial dairies with all the cereal grain supplied as corn. Alfalfa and corn silage were the forage sources. The following diets were compared: 1) solvent soybean meal, SBM (16% crude protein, CP:35% RUP); 2) solvent SBM (18% CP:35% RUP); 3) extruded cottonseed meal, EC (16% CP:40% RUP); and 4) bloodmeal/fishmeal (BMFM, 16% CP:40% RUP).

Cows were provided ad libitum access to a total mixed ration that was fed twice daily. Cows were fed each diet for 21 days, and individual feed intake and milk production were measured daily. Milk samples (a.m. and p.m. composite) were analyzed weekly for milk composition; protein, fat, lactose, solids-not-fat, milk urea nitrogen (MUN), and somatic cells were measured by the Heart of America DHI Laboratory, Manhattan, KS. Cows were weighed immediately after the a.m. milking on 2 consecutive days at the beginning of period 1 and on the last 2 days of each period thereafter. Body condition was scored at the beginning of period 1 and on the last day of each period thereafter. Blood samples were collected from the tail vein during the last week of each period, and the plasma was analyzed for concentrations of glucose, total amino acids, and urea. Milk samples were collected from 12 cows (three per diet) during the last week of each period to evaluate the effect of diet on milk protein fractions.

Results and Discussion

The experimental diets (Table 1) were formulated to be isocaloric, with EECM and BMFM substituted for SBM. Soy hulls were used to balance ADF and NDF, and tallow was used to balance fat across diets. Diets SBM 16-35, EC 16-40 and BMFM 16-40, were formulated to be isonitrogenous (Table 2); however, we used a crude protein value (DM basis) of 29% for EECM and the actual value was 26%. Therefore, the EC 16-40 diet was 14.8% crude protein instead of the projected 16%.

Cows fed the BMFM 16-40 consumed less (P<.05) dry matter, produced the same amount of milk, but were more (P<.05) efficient in converting feed to milk than cows fed the other diets (Table 3). No difference was observed among diets in milk fat, protein and solids-not-fat but the BMFM diet depressed (P<.05) lactose percentage. The urea nitrogen concentration in milk (MUN) generally is used as a criterion to evaluate the degradability of protein in the rumen. Protein degraded in the rumen contributes to the rumen ammonia pool, which in turn, influences the amount of ammonia moving from the rumen into the blood stream and subsequently converted to urea in the liver. The urea moves from the liver into the blood stream and leaves the body via the urine and milk. The concentration in milk is highly correlated (R^2=.82) with the concentration in the blood. Conversely, protein not degraded in the rumen does not contribute to the rumen ammonia pool. Milk from cows fed EECM contained less (P<.05) urea nitrogen than milk from cows fed the two SBM diets and was numerically less than that of cows fed the BMFM diet.

The amount of nitrogen contributed by livestock waste is a major environmental concern. Surplus dietary protein increases the amount of nitrogen contained in livestock waste (urine and feces). The question is: what level and degradability of protein should diets for lactating dairy cows contain to meet needs for maintenance, milk, growth, and reproduction. Comparing the production of cows fed SBM 16-35 to that of cows receiving EC 16-40 and BMFM 16-40 shows no apparent production benefit from diets with increased RUP. An analysis of the difference between the response of cows fed SBM 16-35 and the average response of cows fed BMFM 16-40 and EC 16-40 is shown in Table 4. These data represent the difference in production responses by cows receiving diets with 35% RUP and 40% RUP. Milk production and energy-corrected milk production were similar between the two groups, even though cows receiving the 40% RUP diets consumed less dry matter. Thus, cows fed the 40% RUP diet were more (*P*<.01) efficient.

The effects of level and source of protein on the distribution of milk nitrogen are shown in Table 5. These data are based on only 12 of the 24 cows used in the study. Milk protein content was determined by two analytical methods: Heart of America DHIA (DHIA-Prot) and the Rowland-Kjeldahl procedure (RK-Prot). Correlation analysis showed a correlation coefficient of .987 (*P*<.001), indicating a strong, highly significant relationship between the two analyses. Although cows fed SBM 18-35 received a higher level of dietary crude protein, their total percentages of milk protein, casein protein, or whey protein were not different than those of cows fed SBM 16-35. However, cows fed SBM 18-35 did have a higher fraction of nonprotein nitrogen (NPN). The NPN fraction of milk is analogous to MUN content, so this response is not surprising. No significant differences occurred in the content of total protein, casein protein, whey protein, or NPN between cows fed BMFM 16-40 and EC 16-40. These results indicate that the bypass protein in EECM is comparable in quality to that in the fishmeal and bloodmeal combination.

Production costs associated with the four diets are summarized in Table 6. Using northeast Kansas market prices for all diet ingredients, cost per pound of dry matter was determined. The relatively high cost of fishmeal and spray-dried blood meal resulted in BMFM 16-40 being the least economically favorable diet to feed. This is indicated by the feed cost per hundred weight of milk, which takes into consideration intake, feed cost, and milk yield.

In summary, the extruded cottonseed product used in this study appears to be an effective source of ruminally undegradable protein. When compared to cows fed a diet supplemented with fishmeal and bloodmeal, cows fed a diet with EECM showed no differences in milk production, production of ECM, or milk casein protein content. Economic analysis indicated that the extruded cottonseed product is a less expensive source of RUP than a combination of fishmeal and bloodmeal.

Table 1. Compositions of Experimental Diets

	Diets[1]			
Ingredient	SBM 16-35	SBM 18-35	EC 16-40	BMFM 16-40
	------------ % of dry matter ------------			
Alfalfa hay	25.2	25.2	25.6	25.4
Corn silage	20.2	20.2	20.3	20.2
Extruded cottonseed	-	-	8.4	-
Shelled corn	33.6	28.4	34.2	35.6
Solvent SBM, 48%	9.7	14.7	5.7	3.6
Soy hulls	6.0	6.0	-	6.0
Wet molasses	1.0	1.0	1.0	1.0
Tallow	1.0	1.0	1.0	1.0
Vitamin/mineral premix	3.6	3.6	3.7	3.2
Fishmeal	-	-	-	3.2
Bloodmeal	-	-	-	.8

[1]SBM 16-35 = 5 lb of SBM, 16% CP, 35% RUP; SBM 18-35 = 8 lb of SBM, 18% CP, 35% RUP; EC 16-40 = 5 lb of extruded expelled cottonseed meal, 16% CP, 40% RUP; BMFM 14-40 = 1.8 lb of fishmeal, 0.4 lb bloodmeal, 16% CP, 40% RUP.

Table 2. Chemical Compositions of Experimental Diets

	Diets[1]			
Ingredient	SBM 16-35	SBM 18-35	EC 16-40	BMFM 16-40
Crude protein, %	15.3	17.0	14.8	16.5
RUP, % of CP	36.7	40.0	40.7	41.7
NE_L, Mcal/lb	0.77	0.77	0.78	0.77
Fat, %	4.71	4.52	4.95	4.67
NDF, %	29.0	28.3	29.2	28.6
ADF, %	19.0	19.2	20.2	18.8
NFC, %	40.9	40.2	42.8	43.1

[1]SBM 16-35 = 5 lb of SBM, 16% CP, 35% RUP; SBM 18-35 = 8 lb of SBM, 18% CP, 35% RUP; EC 16-40 = 5 lb of extruded expelled cottonseed meal, 16% CP, 40% RUP; BMFM 14-40 = 1.8 lb of fishmeal, 0.4 lb of bloodmeal, 16% CP, 40% RUP.

Table 3. Responses of Lactating Cows to Protein Sources

	Diets[1]				
Item	SBM 16-35	SBM 18-35	EC 16-40	BMFM 16-40	SE[2]
Daily intake (DM), lb	65.2[a]	65.2[a]	64.5[a]	61.7[b]	1.2
Milk, lb/day	80.7	82.6	81.9	81.8	2.1
ECM[3], lb/day	82.3	84.8	84.0	84.2	2.1
Efficiency, milk/feed	1.24[a]	1.27[a]	1.27[a]	1.33[b]	.01
Milk fat, %	3.58	3.61	3.62	3.63	.05
Milk protein, %	3.24	3.26	3.22	3.26	.01
Lactose, %	4.87[a]	4.88[a]	4.90[a]	4.82[b]	.01
SNF, %	8.84	8.88	8.85	8.80	.03
MUN, mg/dL	12.5[b]	16.5[a]	11.6[c]	12.1[bc]	.21
Change in BCS	0.09	0.18	0.08	0.09	.06
Change in body wt., lb	2.6	11.8	-7.1	6.4	14.3

[1]SBM 16-35 = 5 lb of SBM, 16% CP, 35% RUP; SBM 18-35 = 8 lb of SBM, 18% CP, 35% RUP; EC 16-40 = 5 lb of extruded expelled cottonseed meal, 16% CP, 40% RUP; BMFM 14-40 = 1.8 lb of fishmeal, 0.4 lb of bloodmeal, 16% CP, 40% RUP.

[2]Standard error of the mean.

[3]Energy-corrected milk.

[a,b,c]Means with uncommon superscript differ ($P<0.05$) within row.

Table 4. Comparison of 35% and 40% RUP Diets

Item	Estimated Difference[1]	SE[2]	P-Value
Daily intake (DM), lb	-0.97	.70	.004
Milk, lb/day	+0.50	1.19	.36
ECM[3], lb/day	+0.79	1.19	.15
Efficiency, milk/feed	+0.058	.014	.0002
Milk fat, %	+0.048	.061	.43
Milk protein, %	+0.005	.018	.78
MUN, mg/dL	-0.65	.26	.014

[1]Mean response of cows fed SBM 16-35 minus that of cows fed EC 16-40 and BMFM 16-40. Negative value indicates mean response of cows fed SBM 16-35 was greater than that of cows fed EC 16-40 and BMFM16-40.
[2]Standard error of the difference.
[3]Energy-corrected milk.

Table 5. Diet Effects on Milk Nitrogen Distribution

	Diets[1]				
Item	SBM 16-35	SBM 18-35	EC 16-40	BMFM 16-40	SE[2]
DHIA-Prot[3], %	3.23	3.28	3.23	3.24	.03
R-K-Prot[4], %	3.29	3.34	3.29	3.28	.03
Casein protein, %	2.99	3.03	2.99	2.98	.03
Whey protein, %	0.30	0.31	0.30	0.30	.005
NPN[5], %	0.015[a]	0.017[b]	0.015[a]	0.015[a]	.0002

[1]SBM 16-35 = 5 lb of SBM, 16% CP, 35% RUP; SBM 18-35 = 8 lb of SBM, 18% CP, 35% RUP; EC 16-40 = 5 lb of extruded expelled cottonseed meal, 16% CP, 40% RUP; BMFM 14-40 = 1.8 lb of fishmeal, 0.4 lb of blood meal, 16% CP, 40% RUP.
[2]Standard error of the mean.
[3]Percent milk protein determined by Heart of America DHIA, Manhattan, KS.
[4] Percent milk protein determined by Rowland-Kjeldahl procedure.
[a,b]Means with uncommon superscript differ (*P*<0.05) within row.

Table 6. Production Costs Associated with Each Diet

	Diets[1]			
Item	SBM 16-35	SBM 18-35	EC 16-40	BMFM 16-40
Daily intake (DM), lb	65.2	65.2	64.5	61.7
Cost/lb dry matter[2], $	.0525	.0543	.0505	.0687
Feed cost/head/day, $	3.42	3.54	3.26	4.24
Milk yield, lb/day	80.7	82.6	81.9	81.8
Feed cost/cwt. milk[3], $	4.24	4.29	3.98	5.18

[1]SBM 16-35 = 5lb of SBM, 16% CP, 35% RUP; SBM 18-35 = 8 lb of SBM, 18% CP, 35% RUP; EC 16-40 = 5lb of extruded cottonseed meal, 16% CP, 40% RUP; BMFM 14-40 = 1.8lb of fishmeal, 0.4lb of bloodmeal, 16% CP, 40% RUP.
[2]Based on NE Kansas prices. Shelled #2 Corn, $78.6/ton; 48% SBM, $148/ton; Fishmeal, $980/ton; Spray-dried blood meal, $806/ton; Tallow, $360/ton; Alfalfa hay (170 RFV), $80/ton; Extruded cottonseed meal, $148/ton; Vitamin/Mineral premix, $280/ton; Soy hulls, $90/ton; Corn silage, $24.5/ton; Wet molasses, $138/ton.
[3]Feed cost to produce 100 lb of milk.

EFFECT OF PROTEIN LEVEL IN PREPARTUM DIETS ON POSTPARTUM PERFORMANCE OF DAIRY COWS

A. F. Park, J. E. Shirley, E. C. Titgemeyer, M. V. Scheffel, and M. J. Meyer

Summary

Seventy-five Holstein cows were used in a randomized complete block design to determine the level of dietary protein required to support metabolic functions and maintain body reserves during the periparturient period and subsequent lactation. Cows fed the 14.7% protein diet prepartum had a more ideal body condition score during the entire prepartum and postpartum periods. During the first 90 days of lactation, few consistent differences occurred among prepartum diets for milk production, but the response to rbST was greatest for cows fed 11.7, 13.7 or 14.7% protein prepartum. Full 305-day lactation records showed the most milk, fat, and protein for cows consuming 13.7 or 14.7% protein prepartum. Results of our study indicate that using 13.7 to 14.7% crude protein with approximately 45% undegradable protein in the close-up diet for dairy cattle produces beneficial outcomes during the subsequent lactation.

(Key Words: Prepartum, Protein, Dairy Cows.)

Introduction

The last 28 days prepartum and the first 28 days postpartum (periparturient period) may be the most critical times in a dairy cow's production cycle. The 28-day prepartum period is characterized by rapid growth of the fetus, metabolic transitions to support lactation, and ruminal adaptation to a dramatic change in diet ingredients to support lactation. Failure to meet the needs of the cow during this period results in health disorders after calving that negatively affect dry matter intake, peak milk yield, and total lactational yield. The protein needs of the cow during this time are not well defined, and the information available presents a conflicting view regarding the level of dietary protein and ratio of rumen degradable protein (RDP) to undegradable protein (RUP) necessary to support the rapidly developing fetus and maintain labile protein reserves sufficient to support metabolic systems immediately postpartum. Clearly, transition diets must meet the rumen microbial needs for energy and protein at a time when the cow's metabolic needs are increasing.

The objective of this study was to determine the level of dietary protein required to supply amino acids to support metabolic functions and maintain body protein reserves during the periparturient period.

Procedures

Seventy-five multiparous Holstein cows were used. Diets were formulated to provide surplus energy (.72 Mcal/lb) and five levels of protein. Experimental diets were: 1) 9.7% crude protein (CP) or negative control (supplied less protein than required to support normal rumen microbial needs); 2) 11.7% CP supplied sufficient protein to meet rumen microbial needs; 3) 13.7% CP, protein above 11.7% was RUP; 4) 14.7% CP, protein above 11.7% was RUP; and 5) 16.2% CP, protein above 11.8% was RUP. Expeller soybean meal was substituted for solvent soybean meal to increase the RUP, while maintaining a similar amino acid profile. Cows were housed in a tie-stall barn to accommodate accurate measurements of individual dry matter intake. Treatments were initiated 28 days prior to projected calving date and terminated at parturition. Cows were fed the same total mixed ration (TMR) after parturition, remained in the tie-stall barn until 90 days in milk, and then were moved to a freestall facility. Daily milk production and feed consumption were measured during the first 90 days postpartum, and milk samples (a.m./p.m. composite) were obtained weekly and analyzed for milk composition; milk protein, fat, lactose, solids-not-fat, MUN, and somatic cells were measured by the DHI Laboratory, Manhattan, KS. Body condition was scored at the beginning of the study and weekly thereafter. Body weight was measured on 2 consecutive days at the beginning of the study; weekly thereafter; and on days 1, 2, 27, 28, 59, 60, 89, and 90 postpartum. Urine ketones were measured daily beginning 10 days prepartum and ending on day 28 postpartum. Blood samples were obtained from the tail vein on days 28, 21, 10, 5, 3, and 1 prepartum and days 3, 7, 15, 20, 25, 60, and 90 postpartum. Urine samples were collected on the same days as blood samples. Health status and treatments were recorded daily while cows were in the tie-stall barn. Udder edema scores were recorded daily until parturition and then daily for 21 days postpartum. Calves were weighed within 6 hr after birth. Hay and corn silage samples were collected weekly and composited monthly for analysis. Grain mix and topdressing were sampled by batch and composited monthly for analysis. Corn silage dry matter was determined weekly, and the amount fed was adjusted to provide the appropriate dry matter.

Results and Discussion

Compositions of the experimental diets are shown in Tables 1 and 2. Soyplus (mechanical extracted SBM) was substituted for solvent SBM to increase the RUP content of the diets, and corn grain was replaced by SBM as the percentage of CP in the diets increased. The problem these substitutions created was that the nonstructural carbohydrate (NSC) component of the diet decreased from 42% to 31% as dietary protein increased. However, the NSC contents of all diets should have been adequate to support rumen function. Dietary fat ranged from 3.1% to 3.9% and should not have had a major influence on performance.

Prepartum performance responses of cows to the experimental treatments are shown in Table 3. Cows fed 14.7% protein consumed the most dry matter (35.9 lb/day), whereas cows fed 16.2% protein consumed the least (32.1 lb/day). All cows gained weight and condition from day 28 prepartum until parturition. Energy balance was lowest for cows fed 16.2% protein, and they gained the least amount of weight. Differences were observed in udder edema scores and urine ketones across treatments. Edema scores and urine ketones were lowest for cows fed intermediate levels of protein, and cows fed the diets at either extreme had greater edema scores and urine ketones. No differences were observed in calving difficulty or calf birth weights across treatments. Three cows out of the 75 were treated for milk fever, one fed 11.7% protein and the other two fed 13.7% protein.

All cows were switched to the same TMR after calving. Dry matter intake varied across treatments (Table 4) during the first 90 days postpartum. Cows fed 11.7% protein prepartum had greater intakes during the first of 90 days of lactation. Average production and composition of milk also were affected by treatment during the first 90 days of lactation. Cows fed 11.7 or 14.7% protein prepartum produced more milk and along with those fed 13.7% protein prepartum had a tendency for higher milk protein percentages. Cows fed 14.7% protein prepartum had greater fat yield and lactose yield but a lower MUN value and somatic cell count.

Recombinant bovine somatotropin (rbST) was administered to cows during the ninth week of lactation, and the response was measured in each treatment. Cows fed intermediate levels of protein prepartum (11.7 to 14.7%) responded similarly to rbST with respect to milk yield, whereas cows fed 16.2% protein prepartum did not respond, and those fed 9.7% protein prepartum showed a slight response. Complete lactation milk production data revealed that cows fed 13.7 or 14.7% protein prepartum had the highest 305-day milk production, cows fed 11.7% protein prepartum were intermediate, and those fed 9.7 or 16.2% protein prepartum produced the least. The cows fed 13.7 or 14.7% protein prepartum also tended to produce the most milk fat and protein.

NRC (1989) recommends that dry cow diets contain 11.8% CP. Results from our study support this recommendation based on the first 90 days of lactation. However, based on full lactation, cows fed 13.7 or 14.7% protein prepartum produced more milk, milk fat, and milk protein than those fed lower levels of protein (9.7 or 11.7%). Cows fed the greatest level of protein consumed less feed prepartum and had the lowest milk production. Although cows fed only 9.7% protein had feed intakes similar to those of cows fed more protein, they produced less milk than cows fed intermediate levels of protein. Much of the difference in whole lactation performance seemed to be in response to rbST. Intermediate levels of protein prepartum (13.7 or 14.7%) seemed to maximize the response to rbST, presumably by maximizing body reserves that were subsequently mobilized to support lactation.

Table 1. Compositions of Experimental Diets

	Prepartum Diets (% protein)					
Ingredient	9.7	11.7	13.7	14.7	16.2	Postpartum
	))))))))))))))))) % of DM)))))))))))))))))					
Alfalfa hay	15.00	15.00	15.00	15.00	15.00	28.35
Prairie hay	20.00	20.00	20.00	20.00	20.00	-
Corn silage	30.00	30.00	30.00	30.00	30.00	20.49
Corn grain	32.42	27.74	23.06	17.88	12.69	21.48
Whole cottonseed	-	-	-	-	-	9.56
Soybean meal	-	4.68	9.36	4.36	-	20.07
Soyplus®	-	-	-	9.36	19.73	-
Limestone	.60	.60	.60	.60	.60	2.70
Dicalcium phosphate	.74	.74	.74	.74	.74	1.80
TM salt	.50	.50	.50	.50	.50	.65
Mg oxide	.50	.50	.50	.50	.50	.45
Vitamin ADE premix	.12	.12	.12	.12	.12	.20
Vitamin E premix	.08	.08	.08	.08	.08	.035
Se premix	.04	.04	.04	.04	.04	.035

Table 2. Nutrient Compositions of Experimental Diets

	Prepartum Diets (% protein)					
Item	9.7	11.7	13.7	14.7	16.2	Postpartum
Crude protein, %	9.7	11.7	13.7	14.7	16.2	18.2
ADF, %	23.3	23.6	23.4	24.2	24.6	19.9
NDF, %	36.6	37.3	37.2	38.0	39.5	30.9
NE_L, Mcal/lb	.71	.72	.70	.70	.70	.78
Calcium, %	.42	.43	.45	.46	.46	.66
Phosphorus, %	.34	.38	.40	.41	.41	.53

Table 3. Effects of Prepartum Protein Level on Prepartum Responses

	Prepartum Dietary Protein, %					
Item	9.7	11.7	13.7	14.7	16.2	SEM
Dry matter intake, lb/day	34.50	35.10	34.30	35.90	32.10	1.3
Body weight initial, lb	1500	1485	1470	1472	1500	15
Body weight final, lb	1562	1559	1550	1558	1561	15
BCS initial	2.88	2.97	3.04	2.95	2.96	0.06
BCS final	3.13	3.10	3.19	3.34	3.05	0.06
Energy balance, Mcal/day	4.80	5.20	4.10	4.90	2.50	0.90
Edema score[1]	1.47	1.48	1.43	1.33	1.47	0.12
Urine ketone, mg/dL[2]	0.55	0.05	0.00	0.00	0.15	0.21
Calving difficulty score	1.33	1.53	1.00	1.07	1.07	0.13

[1]Cubic response (P<.05).
[2]Quadratic response (P<.01).

Table 4. Effects of Prepartum Protein Level on Responses during the First 90 Days Postpartum

	Prepartum Dietary Protein, %					
Item	9.7	11.7	13.7	14.7	16.2	SEM
Dry matter intake, lb/day[1]	53.80	57.20	54.30	55.00	53.90	2.0
Milk yield, lb/day[1]	86.10	87.00	83.00	87.10	85.90	4.2
Milk protein, %[2]	3.04	3.11	3.10	3.09	2.99	.05
Milk fat yield, lb/day[3]	3.17	3.11	2.98	3.24	3.11	.13
Lactose yield, lb/day[4]	4.30	4.26	4.04	4.34	4.21	.20
Milk urea nitrogen, mg/dL[5]	17.04	15.72	16.04	15.35	15.21	.43
Somatic cell score, X 1000[6]	419	279	359	134	399	120
Response to rbST, lbs[6]	1.4	3.1	4.7	5.3	-.2	1.8

[1]Quartic response (P<.05). [2]Quadratic trend (P=.06). [3]Cubic response (P<.05).
[4]Quartic response (P<.01). [5]Quadratic response (P<.05). [6]Linear response (P<.05).

Table 5. Full-Lactation Responses Based on 305-Day Lactation

	Prepartum Dietary Protein, %					
Item	9.7	11.7	13.7	14.7	16.2	SEM
ME milk yield, lb[1]	22,517	23,099	23,944	24,280	21,730	941
ME milkfat yield, lb[2]	800	789	843	850	755	33
ME milk protein, lb[3]	687	711	733	750	659	30

[1]Quadratic response trend (P=.06).
[2]Cubic response trend (P=.07).
[3]Quadratic response (P<.05).

EVALUATION OF WET CORN GLUTEN FEED AS AN INGREDIENT IN DIETS FOR LACTATING DAIRY COWS

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M. V. Scheffel, and E. C. Titgemeyer

Summary

Thirty-two Holstein cows were used in two 2×2 Latin squares with 28-day periods to evaluate the effect of including wet corn gluten feed in diets for lactating dairy cows. Wet corn gluten feed (WCGF) was fed to cows housed in freestalls at 20% of the diet dry matter. Cows fed WCGF consumed more dry matter, and produced more milk and more energy-corrected milk than cows fed the control diet. Production efficiency was not different between diets. The percentages of fat and protein in milk were not different between diets, but yields of all milk components were improved by including WCGF in the diet. Body weight and condition score were not affected by treatment. Plasma glucose, total amino acids, and urea nitrogen were similar between cows fed the control and WCGF diets. WCGF is an excellent feed for lactating dairy cows when included in the diet at 20% of the dry matter. Further studies are warranted to determine the upper limits of its dietary inclusion.

(Key Words: Wet Corn Gluten Feed, Lactating Cows, Milk Yield.)

Introduction

Wet corn gluten feed (WCGF) is a potential feedstuff for dairy cows in the upper midwest. Studies conducted with feedlot steers indicated that it improved average daily gain and dry matter intake, reduced acidosis, and had feed efficiency values comparable to those of corn. Dairy producers who have used WCGF have reported increases in milk yield, but limited research findings are available. The objective of this study was to evaluate the effects of WCGF on dry matter intake, milk yield, milk components, and feed efficiency when fed to lactating dairy cows.

Procedures

Thirty-two primaparous cows were used in two 2×2 Latin squares with 28-day periods. Cows were housed and fed in a freestall facility at the Kansas State University Dairy. Four pens each containing eight cows were utilized. Cows were pen fed diets formulated to meet or exceed NRC (1989) nutrient requirements. Diets were formulated to be isonitrogenous and isocaloric. Alfalfa hay and corn silage were the forage sources. Experimental treatments were: 1) control and 2) WCGF constituting 20% of the diet dry matter (Table 1).

Table 1. Experimental Diets

	Diet	
Ingredient	Control	WCGF[1]
	--% of Dry Matter--	
Alfalfa hay	30.0	23.3
Corn silage	15.0	8.3
Shelled corn	31.0	24.4
Soybean meal[2]	5.0	-
Soybean meal[3]	5/.0	10.0
WCGF	-	20.0
Whole cottonseed	9.3	9.3
Wet molasses	1.0	1.0
Min-vit premix	3.7	3.7

[1]Wet corn gluten feed.
[2]Solvent-extracted soybean meal.
[3]Mechanically extracted soybean meal subjected to heat (Soybest®).

Diets were fed free choice twice daily as a total mixed ration. Cows were fed each diet for 28 days, and pen feed intake and individual milk production were measured daily. Milk samples (a.m. and p.m. composite) were analyzed weekly for composition; protein, fat, lactose, solids-not-fat, milk urea nitrogen (MUN) and somatic cells were measured by the Heart of America DHI Laboratory, Manhattan, KS. Cows were weighed and scored for body condition at the beginning and end of each period. Blood samples were collected from the tail vein during the final week of each period, and total amino acids, glucose, and urea nitrogen concentrations in plasma were measured.

Results and Discussion

Cows fed WCGF consumed more ($P<.01$) dry matter and produced more ($P<.05$) milk and more ($P<.01$) energy-corrected milk than cows fed the control diet (Table 2). Production efficiency was not different between diets, but yields of all milk components were improved ($P<.05$) by including WCGF in the diet.

Body weight and condition were not affected by treatment. Plasma glucose, total amino acids, and urea nitrogen were similar between cows fed the control and WCGF diets (Table 3). Interestingly, cows consuming the WCGF had lower milk urea nitrogen (MUN) values, even though blood plasma urea nitrogen (PUN) was not different. Plasma samples were collected approximately 5 hours after feeding and reflect only that point in time, whereas milk values represent an average of PUN values over the entire milking interval.

In summary, WCGF is an excellent feed for lactating dairy cows when included in the diet at 20% of the dry matter. Further studies are warranted to determine the upper limits of its dietary inclusion.

Table 2. Performance of Cows Fed Wet Corn Gluten Feed

	Diet		
Item	Control	WCGF[1]	P-Value
Daily intake (DM), lb	53.63	57.99	.02
Daily intake (DM), % of body wt	3.99	4.33	.02
Milk, lb/day	73.04	78.33	.04
Milk/feed	1.38	1.37	.78
Milk fat, %	3.48	3.46	.84
Milk protein, %	3.15	3.18	.33
Milk lactose, %	5.02	5.05	.02
Milk SNF[2], %	8.93	8.99	.10
MUN[3], Mg/dL	16.07	15.64	.05
ECM[4], lb/day	73.16	78.30	<.01
SCC, ×1000	111	189	.43

[1]Wet corn gluten feed. [2]Solids-not fat. [3]Milk urea nitrogen. [4]Energy-corrected milk.

Table 3. Effect of Wet Corn Gluten Feed on Plasma Metabolites

	Diet		
Item	Control	WCGF	P-Value
Glucose, mg/dL	71.32	72.90	.24
Total amino acids, mM	2.49	2.54	.24
Urea nitrogen, mg/dL	17.34	16.82	.55

THE USE OF SOMATIC CELL COUNTS TO IDENTIFY COWS WITH SUBCLINICAL MASTITIS AT CALVING

J. M. Sargeant[1], J. E. Shirley, B. J. Pulkrabek, M. E. Scheffel, and A. F. Park

Summary

The dynamics of somatic cell counts during the first 10 days in milk were compared among udder quarters of cows with intra-mammary infection at the time of calving and those with no infection present. The study group consisted of 81 cows calving at the Kansas State University dairy research herd between July of 1998 and February of 1999. Cows with an intramammary infection had greater, average, somatic cell counts at calving, and this difference continued throughout the 10-day period. Using a breakpoint of 1,000,000 somatic cells/ml at calving to select animals for culture would have correctly selected 81% of the quarters that were actually infected with major mastitis pathogens.

(Key Words: Somatic Cell Count, Intramammary Infection, Calving.)

Introduction

Mastitis is the most costly disease of dairy cattle because of economic losses from reduced milk production, treatment costs, increased labor, milk withheld following treatment, premature culling, and decreased genetic improvement. Clinical mastitis is characterized by abnormal milk, with or without additional signs of illness. Subclinical mastitis is defined by intramammary bacterial infection without signs of abnormal milk or illness, therefore, and may, be more difficult to recognize. The pathogens that cause mastitis may be classified as those that are contagious in nature and primarily spread from cow to cow and those that are acquired from the environment. The risk period for new infection varies with the pathogen involved. New infections with contagious pathogens are more likely to occur during the milking period, and new infections with environmental pathogens are more likely to occur during involution of the udder during the early dry period (particularly the environmental *Streptococcus* ssp.) and during the period surrounding calving (*E. coli*).

Over the past decades, tremendous advances have been made in udder health management. Control measures include the use of pre- and postmilking teat dipping, dry cow therapy, segregation and culling strategies for chronically infected animals, and environmental control during the dry cow and calving periods. Each of these control measures is aimed at the management of specific pathogens. Postmilking teat dipping is aimed at preventing new infections during the milking period, and dry cow therapy is used to cure infections present at the time of dry-off and to prevent new infections during the early dry period. Environmental control during the dry period and calving period is targeted primarily at preventing new infections with environmental (*Streptococcus* spp.) and coliform bacteria (e.g., *E. coli, Klebsiella*), respectively. Therefore, the status of intramammary infections at calving and the specific pathogen implicated would provide a means of monitoring the effectiveness of existing udder control programs and assessing the usefulness of new mastitis control strategies.

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Bacteriological culture is the standard for identifying subclinical infection. However, logistic and financial considerations involved in sampling all cows at the time of calving have precluded widespread adoption of this strategy in the dairy industry. If an effective means to identify fresh cows at a high risk of having intramammary infections could be found, it would increase the efficiency and perhaps the adoption of this management aid. Previous studies have examined the usefulness of somatic cell count (SCC) results from DHI sampling as a means of identifying potentially infected cows. However, this strategy has proven to have limited use, because routine testing is performed on composite samples rather than samples from individual udder quarters. In addition, samples are obtained on a monthly basis from cows that are at least 5 days in milk. This means that cows are sampled for the first time between 5 and 35 days, which in some cases may be too late after calving to provide meaningful information.

A recent study of Dutch Holstein cows reported that SCC evaluation of quarter milk samples during the early postcalving period might be an effective means of identifying high-risk cows for further bacteriological examination. Many DHI organizations will provide SCC evaluations on milk samples submitted by producers, potentially allowing information to be obtained for cows at any stage of lactation. Therefore, the potential exists to use SCC to select cows (or quarters) for further culture analysis. If validated, such sampling would provide the necessary information on which pathogens were present in the herd at calving to monitor udder health programs for dry cows. At the same time, the selective nature of the sampling would reduce the number of noninfected cows subjected to the time and expense of milk culturing.

The objectives of the present study were to examine the use of SCC as a means of identifying intramammary status at calving and to identify the ideal sampling times to maximize the ability to identify infected cows for further bacteriological examination.

Procedures

The study group consisted of multiparous cows calving at the Kansas State University dairy. Milk samples for bacteriological culture were collected from each udder quarter of each cow during the first 12 hours after calving. In addition, quarter samples were collected once daily for 10 days at the morning milking for SCC evaluation. Somatic cell count evaluations were performed by the Heart of America DHI, Manhattan, KS.

The milk samples for bacteriological culture were frozen immediately after collection and sent weekly to the diagnostic laboratory at Kansas State University. After the samples were thawed, a swab was used to plate the milk on blood agar and MacConkey agar. Plates were incubated aerobically at 37°C and examined for growth 24 and 48 hrs later. Colonies were identified using standard laboratory procedures for mastitis pathogens.

The dynamics of SCC during the first 10 days in milk for quarters with and without intramammary infection at the time of calving were compared and analyzed statistically using analysis of variance for repeated measures. The usefulness of SCC for determining infection status was evaluated further using break-point analysis. For SCC to be useful as an aid in determining intramammary infection at calving, the majority of quarters with intramammary infection also must have high SCC. Therefore, hypothetical break points were created for selecting quarters based on their SCC for culture analysis. This information was combined with the actual culture results to determine the percentage of infected and noninfected animals above each break point. Because the majority of udder control programs are targeted towards the control of major mastitis pathogens, the infected cows were classified further as having major or minor pathogens.

Results and Discussion

A total of 81 cows was included in the study. All of the cows calved between July 15, 1998 and February 19, 1999. One cow died 5 days after calving, and four cows that calved had only three functional quarters. Of the 324 quarters cultured, 78 were infected with one bacterium, and four were infected with two bacteria. The most frequently identified bacteria were nonhemolytic *Staphylococcus* spp. The significance of these bacteria for udder health is still unclear. Of the 23 major mastitis pathogens identified, 17% were contagious in nature (*Staphylococcus aureus*), and 83% were environmental pathogens (environmental *Streptococcius* spp., *E. coli,* or *Klebsiella*). The relative frequency of different pathogens would be expected to differ among herds, depending on factors such as the area, management, and udder health programs.

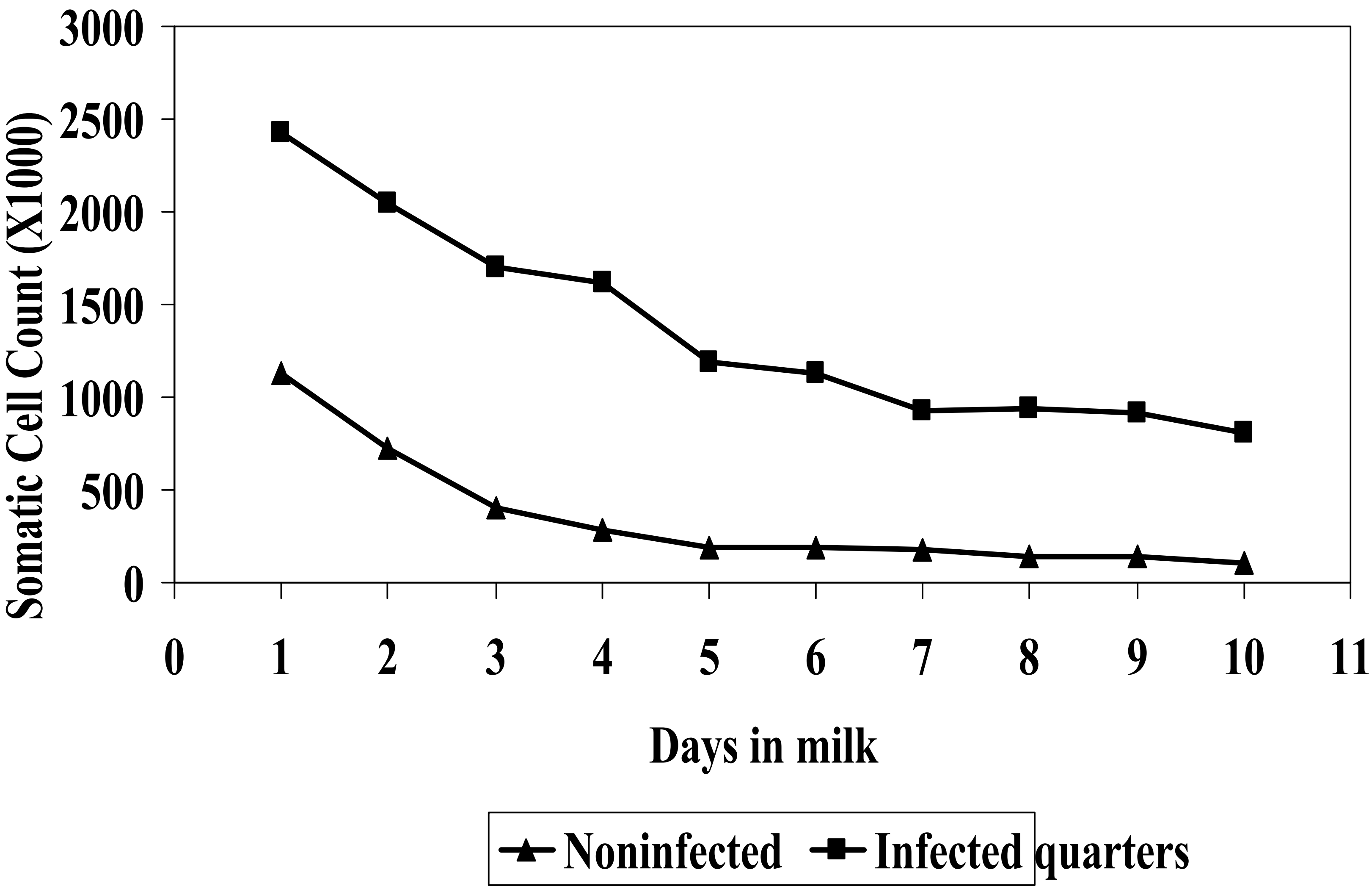
Figure 1 shows average SCC by days in milk for infected and noninfected quarters. Average SCC decreased during the first 10 days in milk in both groups. Quarters that were infected with any pathogen at the time of calving had an average SCC of 2,666,000 compared to an average SCC of 1,211,000 in noninfected quarters. Infected cows had greater (P<0.001) average SCC throughout this period, and the count did not decline (P<0.001) as quickly over time as that for the noninfected quarters.

Despite significant differences in the average SCC between infected and noninfected quarters, considerable variation existed in the SCC of individual quarters. Table 1 shows the percentages of quarter milk samples exceeding SCC break points of 250,000, 500,000, or 1,000,000 cells/ml for quarters infected with major pathogens, quarters infected with minor pathogens, and culture negative quarters at calving and at 5 and 10 days in milk. Based on these results, if one were to sample all quarters of all cows for SCC at the time of calving and use a break point of 250,000 cells/ml to further select quarters for milk culture, one would correctly select all of the quarters infected with major pathogens. However, using this criterion also would result in large numbers of noninfected quarters being selected for culture, increasing the cost and lessening the efficiency. Using a more stringent break point of 1,000,000 cells/ml to select quarters for culture would correctly select 81% of the quarters actually infected with major pathogens and only 32% of the noninfected quarters. The use of this break point seemed to be the most efficient sampling strategy.

Table 1. Percentages of Quarter Milk Samples with an SCC 250,000, 500,000, or 1,000,000 Cells/ml in Quarters Infected with Major Pathogens, Quarters Infected with Minor Pathogens, and Culture Negative Quarters at Calving and 5 and 10 Days in Milk

Item	Calving	Day 5	Day 10
Break point of 250,000 cells/ml			
Major pathogen	100	65	45
Minor pathogen	76	38	31
Not infected	82	11	9
Break point of 500,000 cells/ml			
Major pathogen	88	53	35
Minor pathogen	67	29	24
Not infected	54	6	4
Break point of 1,000,000 cells/ml			
Major pathogen	81	24	25
Minor pathogen	50	18	13
Not infected	32	4	2

Figure 1. Average Somatic Cell Count by Days in Milk for Infected and Noninfected Quarters.



PERFORMANCE OF LACTATING DAIRY CATTLE HOUSED IN A FOUR-ROW FREESTALL BARN EQUIPPED WITH THREE DIFFERENT COOLING SYSTEMS

M. J. Brouk, J. F. Smith, J. P. Harner III[1],
B. J. Pulkrabek, D. T. McCarty, and J. E. Shirley

Summary

Ninety-three multiparous Holstein cows averaging 130 days in milk (DIM) were utilized to evaluate three cooling treatments installed in separate pens of a four-row freestall barn in northeast Kansas during the summer of 1999. Treatments were: 1) a double row of 36-inch fans spaced at 24-ft intervals over the freestalls; 2) a single row of 36-inch fans spaced at 24-ft intervals over the freestalls and over the cow feed line; and 3) a double row of 36-inch fans spaced at 24-ft intervals over the freestalls and a single row over the feed line. Each pen was equipped with identical sprinkler systems over the cow feed line. The 85-day study evaluated milk production, body condition score, respiration rate, and feed intake of cows cooled with the systems. Cows cooled with fans over the freestalls and feed line produced more ($P<$ .05) milk (98.8 vs 93.9 lb/cow/day) than those cooled with fans only over the freestalls. Milk production was similar for cows cooled with fans over the freestalls and feed line, and doubling the number of fans over the freestalls had no apparent advantage. Cows in all treatments consumed similar amounts of feed, and those cooled only by fans over the freestalls tended to gain more body condition than cows in the other two treatments. Estimated increase in net income realized from using these cooling systems ranged from $3,500-6,100/year/pen.

(Key Words: Environmental Stress, Heat Stress, Milk Production.)

Introduction

Many Kansas dairies have chosen four-row freestall barns for cow housing. Freestall barns provide shade to protect dairy cattle from most of the sun's rays. However, cattle still experience heat stress when the temperature-humidity index exceeds 72. Without additional cooling, cattle in four-row freestall barns will experience heat stress during the summer months in Kansas. Cows lose heat to the environment mostly by evaporation. Evaporation in the lungs helps cool the cow, and as respiration rate increases, greater evaporation occurs. However, the cow's ability to control heat stress in this manner is limited, and other methods of cooling can reduce the negative effects of heat stress. The purpose of this study was to evaluate the effectiveness of three different cooling systems installed in a four-row freestall barn.

Procedures

Ninety-three multiparous Holstein cows averaging 130 days in milk (DIM) were assigned to one of three cooling treatments. Cows were blocked by lactation number, DIM, and production. Cows were housed in each of three identical 100-cow pens on a commercial dairy farm equipped with 84 freestalls per pen (Table 1). The barn was 100 ft in width and 420 ft in length. The sidewall height was 12 ft, and the roof had a 4/12 slope.

Treatment one (2S) was located in the southeast quarter of the building and had a

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double row of fans (14 36-inch-diameter circulation fans with 0.5 horsepower motors) mounted every 24 ft over the freestalls. Each fan had an air delivery rate of 10,000-11,500 cfm and was angled down at 30°.

Treatment two (F+S) was located in the southwest quarter of the building and had a row of fans (seven 36-inch-diameter circulation fans with 0.5 horsepower motors) mounted over the freestalls and another row (seven 36-inch-diameter circulation fans with 0.5 horsepower motors) over the feed line. Both rows of fans were angled downward at 30° and had the same air delivery rate as those listed above.

Treatment three (F+2S) was located in the northwest quarter of the building and had a double row of fans (14 36-inch-diameter circulation fans with 0.5 horsepower motors) mounted every 24 ft over the freestalls and a row of fans (seven 36-inch-diameter circulation fans with 0.5 horsepower motors) mounted over the feed line. The angle and air delivery rate were the same as described above.

Each pen was equipped with similar sprinkler systems consisting of 2.5 gal/hr nozzles spaced every 78 inches on center at a height of 8 ft above the headlocks. Sprinklers were on a 15-minute cycle, with 3 minutes on and 12 minutes off. They were activated when the temperature was above 75°F. The designed application rate was .04 inches/sq ft of surface area, which consisted of 12 sq ft/headlock or 24-inch feeding space. Total application rate was 50 gal/ cycle.

Fans of all treatments were activated when the temperature was above 70°F both day and night.

Cows were fed the same total mixed ration three or four times daily for 105% of ad libitum intake. Amounts fed and refused were recorded daily. Intake data were collected on a pen basis and included 69 additional cows in each pen. Cows were milked 3× and had similar access to water. Animals eligible for rbST were injected at 14-day intervals throughout the trial. Daily milk production was measured for a 24-hour period every 2 weeks throughout the trial. Respiration rates were measured four times during periods of heat stress. Rates were taken in the morning and again in the afternoon on 50 cows/pen.

Results and Discussion

Initial treatment averages (Table 2) for DIM and milk production were not different. Cows cooled with the F+S system produced 4.5 lb more (P<.05) milk than those in the 2S system, and those under the F+2S system were intermediate. Dry matter intake was numerically similar for all treatments. All cows increased body condition during the trial. Cows under the 2S system tended to gain more condition than the F+S cows. This likely was due to similar intakes, but lower production in the 2S treatment.

Respiration rates both morning and afternoon (Figure 1) were greatest for cows in the 2S treatment but followed similar trends for cows in the other treatments. Respiration rates increased 10 to 14% during the afternoon. Cows housed in the F+S system had the lowest percentage increase. The smaller percentage increase in respiration rate and increased milk production resulting from the F+S system indicate that it was the most effective system in reducing heat stress of dairy cattle.

An economic analysis of the three systems is shown in Table 3. Based on the assumption that post-peak milk production normally declines 5% each month and that without any heat stress control measures other than shade, milk production would decline an additional 20% during the summer months, these methods of heat abatement will increase gross farm income $8,157 to $11,647/pen/yr or $81.57 to $116.47/cow/yr. Net income, after all capital investment, operational, and increased feed costs have been removed, would increase from $35.82 to $64.04/cow/yr. The average Kansas dairy farm could increase annual net farm income by $3,582 to $6,404 by utilizing one of these systems. This profit would pay for the entire investment in less than 2 years.

Conclusions

The results of this study clearly show that cooling cows can pay big dividends. The systems implemented in this study are cost effective and available to any Kansas dairy producer. Based on the results presented, four-row freestall barns are cooled most effectively when sprinklers are used on the feed line and rows of fans are placed on both the feed line and over the freestalls. Design criteria presented here have been effective in reducing the effects of heat stress in four-row freestall barns. Recommendations on deviations from these design criteria require additional study.

Table 1. Description of a Four-Row Freestall Barn and Cooling Treatments[1]

	Cooling System[2]		
Item	2S	F+S	F+2S
Sprinklers			
Location	feed line	feed line	feed line
Nozzle rating, gallons/hr	25	25	25
Nozzle type	180°	180°	180°
Cycle	on - 3 min	on - 3 min	on - 3 min
	off - 12 min	off - 12 min	off - 12 min
Height, ft	8	8	8
Fans			
Rows over freestalls	2	1	2
Rows over feed line	0	1	1
Number per row	8	8	8
Total number	16	16	24
Spacing, ft	24	24	24
Diameter, inches	36 (½ hp)	36 (½ hp)	36 (½ hp)
Airflow, cfm/stall	1,900	950	1,900
Airflow/headlock, cfm/head	0	800	800

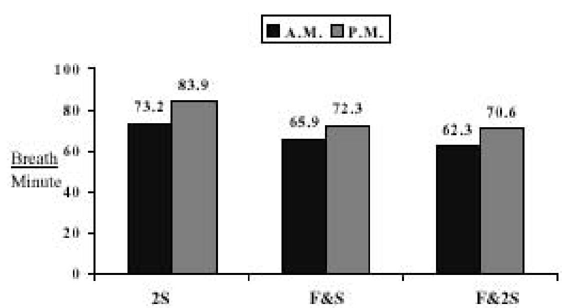
[1]Building description: building type, 4 row; orientation, east-west (2% slope to west); dimensions, width (100 ft), length (420 ft), sidewall height (12 ft), roof slope (4/12); and configuration, 4 pens with 84 stalls per pen and 100 headlocks per pen.

[2]2F = two rows of fans over freestalls, F+S = one row of fans over the feed line and one row of fans over the freestalls, and F+2S=one row of fans over the feed line and two rows of fans over the freestalls.

Table 2. Milk Yield, Body Condition, and Feed Intake of Dairy Cows Housed in a Four-Row Freestall Barn with Three Different Cooling Systems

	Cooling System[1]			
Item	2S	F+S	F+2S	SEM
Initial milk, lb	114.5	115.5	114.8	3.8
Initial days in milk	131	128	131	10.1
Average milk, lb	93.9[x]	98.8[y]	96.5[xy]	2.5
Dry matter intake, lb	55.6	56.2	56.3	-
Change in body condition	+.52	+.39	+.21	.14

[x,y]Means with uncommon superscripts differ (P<0.05).
[1]2S = two rows of fans over freestalls, F+S = one row of fans over the feed line and one row of fans over the freestalls, F+2S = one row of fans over the feed line and two rows of fans over the freestalls, and SEM = standard error of mean.



2S = two rows of fans over freestalls, F&S = one row of fans over the feedline and one row of fans over the freestalls and F&2S = one row of fans over the feedline and two rows of fans over the freestalls.

Figure 1. Average Respiration Rates of Cows Cooled with Three Different Spray and Fan Systems in a Four-Row Freestall Barn.

Table 3. Economic Analysis of Three Cooling Systems Installed in a Four-Row Freestall Barn

	Cooling System[1]		
Item	2S	F+S	F+2S
Beginning (6/12/99) milk production (lb/cow/day)	114.5	115.9	114.8
Estimated milk production w/o cooling (lb/cow/day)	85.1	86.2	85.3
Average milk production w/ cooling (lb/cow/day)	93.9	98.4	96.5
Cooling response (lb/cow/day)	8.8	12.2	11.2
Total extra income due to cooling ($/pen)	8,157	11,368	10,364
Fixed and installation cost of fans ($/pen)	7,072	7,072	10,608
Fixed and installation cost of sprinkler ($/pen)	500	500	500
Total fixed cost of cooling systems ($/pen)	7,572	7,572	11,108
Annual fixed fan cost ($/pen/yr)	1,010	1,010	1,515
Annual fixed sprinkler cost ($/pen/yr)	100	100	100
Total cost of electricity for fans ($/pen/yr)	890	890	1,335
Total electricity cost per stall ($/stall/yr)	10.60	10.60	15.90
Total sprinkler water usage (gal/pen/yr)	171,520	136,000	119,580
Cost of water for sprinklers ($/pen/yr)	274.43	217.61	191.33
Water cost per stall ($/stall/yr)	3.27	2.59	2.28
Variable cooling cost for water and electricity ($/pen/yr)	1,165	1108	1,527
Additional feed cost per cow ($/cow/day)	0.24	0.33	0.30
Additional feed cost per pen ($/pen/year)	1,694	2,361	2,152
Interest rate if money was invested (%)	8.00	8.00	8.00
Return on money if invested ($/yr)	606	606	889
Gross income due to cooling system ($/pen/yr)	$8,157	$11,368	$10,364
Total operating and feed cost ($/pen/yr)	$4,575	$5,185	$6,183
Net income due to cooling system ($/yr/pen)	$3,582	$6,183	$4,180
Net income per stall due to cooling ($/stall/yr)	$43	$74	$50
Additional income per day due to heat abatement (per stall)	0.51	0.88	0.59

[1]2S = two rows of fans over freestalls, F+S = one row of fans over the feed line and one row of fans over the freestalls, and F+2S = one row of fans over the feed line and two rows of fans over the freestalls.

Assumptions:

- 84 cows or stalls per pen
- Calculations over a 85 days of heat stress
- Milk price = $13/cwt
- Rural water cost = $1.60/1000 gal
- 20% reduction in milk production with no cooling

Dairy Day 1999

PERFORMANCE OF LACTATING DAIRY CATTLE HOUSED IN TWO-ROW FREESTALL BARNS EQUIPPED WITH THREE DIFFERENT COOLING SYSTEMS

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B. J. Pulkrabek, D. T. McCarty, and J. E Shirley

Summary

One hundred fifty-nine Holstein cows (66 primiparous and 93 multiparous) were assigned to each of three different cooling systems installed in two-row freestall barns on a northeast Kansas dairy. One barn was equipped with a row of five 48-inch fans mounted every 40 ft over the freestalls and a row of 10 36-inch fans mounted every 20 ft over the cow feed line. Another barn was equipped with five 48-inch fans mounted over the freestalls. Both of these barns were also equipped with identical sprinkler systems mounted over the feed line. The third barn was equipped with a row of five 48-inch fans mounted over the freestalls. In addition to the sprinklers over the feed line, additional sprinklers were mounted on the back alley of the third barn. Data were collected for an 85-day period to evaluate the three systems under heat stress during the summer of 1999. Cows cooled with these three systems produced similar amounts of milk and consumed nearly equal amounts of feed. Summer heat stress generally reduces milk production 20%, if cooling systems are not installed. Based on this estimated loss, these systems returned over $10,000/pen/year above ownership and operational cost. These results indicated that effective cooling in a two-row freestall barn includes a sprinkler system on the feed line and properly sized and spaced fans over the freestalls.

(Key Words: Environmental Stress, Heat Stress, Milk Production.)

Introduction

Properly designed, two-row, freestall barns can provide maximum natural ventilation because of the reduced building width compared to four- and six-row barns. Increased natural air flow can help keep cows cooler during the summer. However, cows will still experience heat stress, so other measures generally are applied in these facilities. The purpose of this study was to evaluate the use of fans and additional sprinkler area upon the performance of dairy cattle.

Procedures

One hundred fifty-nine Holstein cows were blocked by lactation number, milk production, and days in milk (DIM) and assigned to each of three cooling treatments. A commercial dairy in northeast Kansas constructed three identical two-row freestall barns. The barns were similar in dimensions (Table 1) and equipment. Each barn contained a single pen with 100 freestalls and 108 cows. One barn (F+S) was equipped with a row of fans (five 48-inch-diameter circulations fans with 1 horsepower motors) over the freestalls and another row of fans (10 36-inch-diameter circulation fans with 0.5 horsepower motors) over the cow feed line. Fans were angled down at 30°. Fans over the stalls produced an estimated air flow of 1,000 cfm/stall, and those mounted over the cow feed line produced an estimated air flow of 900 cfm/headlock. Barns two (S) and three (S+) were equipped with a row of fans (five 48-inch-diameter circulations fans

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with 1 horsepower motors) over the freestalls that were angled as above. Treatments F+S and S both had a similar sprinkler system installed on the feed line. The sprinkling system consisted of 2.5 gal/hr nozzles spaced every 78 inches on center mounted at a height of 8 ft on the feed line. Sprinklers were on a 15-minute cycle, with 3 minutes on and 12 minutes off. They were activated when the temperature was above 75EF. The designed application rate was 0.04 inches/sq ft of surface area, which consisted of 12-sq ft/headlock or 24-inch feeding space. Total application rate was 25 gal/cycle. Treatment S+ had a similar sprinkler system to that of F+S and S, except that an additional line was installed on the rear alley of the barn. Sprinkler nozzles were spaced 156 inches on center and the total application rate was 35 gal/cycle. The system was activated as described above.

Fans for all treatments were activated both day and night when the temperature was above 70EF. When wind speed was greater than 15 mph, fans in all barns were switched off manually.

Amounts fed and refused for each pen were recorded daily for each pen. Cows were fed twice daily for 105% of ad libitum intake. Intake data were collected on a pen basis and included the treatment cows plus an additional 55 cows that were not part of the study. Cows were milked 2×, and daily milk production was measured for a 24- hr period every 2 weeks. Animals eligible for rbST were injected on 14-day intervals throughout the study. Respiration rates were measured four times during the study in periods of heat stress. Rates were estimated in the morning and again in the afternoon from 50 cows/pen.

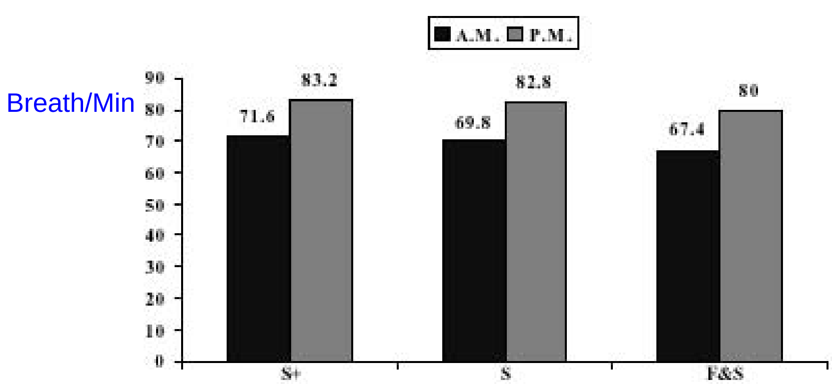
Results and Discussion

Milk production and days in milk did not differ among treatments at the beginning of the study (Table 2). Average milk production was similar during the trial as well as intake. First-lactation cows (Table 3) had lower milk production at the start and during the trial than older cows. However, neither heifers nor cows differed in treatment response. Respiration rates (Figure 1) were similar and increased 16 to 18% from morning to afternoon.

The economic analysis (Table 4) demonstrates that cooling systems are both economical and effective. Based on the assumptions presented, net income after expenses was $10,000 to $12,000/pen/year. This could amount to $100 to $120 per cow/year. These cooling systems are important to the profitability of Kansas dairies.

Conclusions

These results indicated that an effective cooling system for a two-row freestall barn would include fans over the freestalls and a sprinkler line over the feed line. Installing additional fans or sprinkler area did not increase milk production in this study.



F&S = one row of fans over cow feed lane and one row of fans over freestalls,
S = one row of fans over freestalls,
S+ = one row of fans over freestalls and additional sprinkler lines.

Figure 1. Average Respiration Rates of Cows Cooled with Three Different Spray and Fan Systems in Two-Row Freestall Barns.

Table 1. Descriptions of Two-Row Freestall Barns and Cooling Systems[1]

	Cooling System[2]		
Item	F+S	S	S+
Sprinklers			
Location	feed line	feed line	feed line & north alley
Nozzle rating, gal/hr	25	25	25
Nozzle type	180°	180°	180°
Cycle, gal/15 min	25	25	35
Height, ft	8	8	8
Fans			
Rows over freestalls	1	1	1
Rows over feed line	1	0	0
Number/ row stalls	5	5	5
Number/feed line	10		
Total number	15	5	5
Spacing:			
freestalls, ft	40	40	40
feed line, ft	20	—	—
Diameter:			
freestalls, inches	48 (1 hp)	48 (1 hp)	48 (1 hp)
feed line, inches	36 (½ hp)	—	—
Airflow, cfm/stall	1,000	1,000	1,000
Airflow/headlock, cfm/head	900	0	0

[1]Building description: building type, 2-row; orientation, east-west (2% slope to west); dimensions, width (40 ft), length (220 ft), sidewall height (12 ft), and roof slope (2/12); and configuration, 1 pen with 100 stalls per pen and 110 headlocks per pen.

[2]F+S = one row of fans over the feed line and one row of fans over the freestalls; S = one row of fans over the freestalls; and S+ = one row of fans over freestalls and additional sprinkler lines.

Table 2. Milk Yield, Body Condition Change, and Feed Intake of Dairy Cows Housed in Two-Row Freestall Barns Equipped with Three Different Cooling Systems

	Cooling System[1]			
Item	F+S	S	S+	SEM
Initial milk, lb	86.9	87.2	88.2	3.5
Initial days in milk	115	114	114	7
Average milk, lb	80.8	80.3	79.5	1.7
Dry matter intake, lb	49.9	49.8	49.6	-
Change in body condition	+.26	+.31	+.28	.04

[1]F+S = one row of fans over feed line and one row of fans over freestalls; S = one row of fans over freestalls; S+ = one row of fans over freestalls and additional sprinkler lines. SEM = standard error of mean.

Table 3. Milk Yield and Changes in Body Condition Score of Multiparous and Primiparous Dairy Cows Housed in Two-Row Freestall Barns Equipped with Three Different Cooling Systems

	Cooling System[1]							
	Multiparous				Primiparous			
Item	F+S	S	S+	SEM	F+S	S	S+	SEM
Initial milk, lb	93.1	92.3	93.9	3.0	86.9	87.2	88.2	3.5
Initial days in milk	117	118	118	9	112	111	110	11
Average milk, lb	81.5	81.6	80.5	2.6	80.0	79.0	79.4	2.7
Change in body condition	+.44	+.41	+.27	.06	+.11	+.22	+.25	.07

[1]F+S = one row of fans over feed line and one row of fans over freestalls; S = one row of fans over freestalls; S+ = one row of fans over freestalls and additional sprinkler lines. SEM = standard error of mean.

Table 4. Economic Analysis of Three Cooling Systems Installed in Two-Row Freestall Barns

	Cooling System[1]		
Item	F+S	S	S+
Beginning (6/12/99) milk production (lb/cow/day)	86.9	87.2	88.2
Estimated milk production w/o cooling (lb/cow/day)	64.6	64.8	65.6
Average milk production w/ cooling (lb/cow/day)	80.8	80.3	79.5
Cooling response (lb/cow/day)	16.2	15.5	13.9
Total extra income due to cooling ($/pen)	17,906	17,107	15,401
Fixed and installation cost of fans ($/pen)	6630	2210	2210
Fixed and installation cost of sprinkler ($/pen)	500	500	750
Total fixed cost of cooling systems ($/pen)	7130	2710	2960
Annual fixed fan cost ($/pen/yr)	947	316	316
Annual fixed sprinkler cost ($/pen/yr)	100	100	125
Total cost of electricity for fans ($/pen/yr)	1118	556	556
Total electricity cost per stall ($/stall/yr)	11.18	5.56	5.56
Total sprinkler water usage (gal/pen/yr)	136,573	132,428	210,419
Cost of water for sprinklers ($/pen/yr)	218.5	211.9	336.7
Water cost per stall ($/stall/yr)	2.19	2.12	3.37
Variable cooling cost for water and electricity ($/pen/yr)	1337	768	893
Additional feed cost per cow ($/cow/day)	0.44	0.42	0.38
Additional feed cost per pen ($/pen/year)	3719	3553	3199
Interest rate if money was invested (%)	8.00	8.00	8.00
Return on money if invested ($/yr)	570.40	216.80	236.80
Gross income due to cooling system ($/pen/yr)	$17,906	$17,107	$15,401
Total operating and feed cost ($/pen/yr)	$6,673	$4,954	$4,794
Net income due to cooling system ($/yr/pen)	$11,232	$12,153	$10,607
Net income per stall due to cooling ($/stall/yr)	$112	$122	$106
Additional income per day due to heat abatement (per stall)	1.12	1.22	1.06

[1]F+S = one row of fans over feed line and one row of fans over freestalls; S = one row of fans over freestalls; S+ = one row of fans over freestalls and additional sprinkler lines.

Assumptions:

- 100 cows or stalls per pen
- Calculations over a 85 days of heat stress
- Milk price = $13/cwt
- Rural water cost = $1.60/1000 gal
- 20% reduction in milk production with no cooling
- 5% loss in milk production per month due to increasing days in milk
- Feed cost = $135/ton of dry matter
- Estimated life of fan is 7 years, and that for sprinkler system is 5 years

EFFECTS OF TEMPERATURE AND HUMIDITY ON COW RESPIRATION RATES IN THREE KANSAS AND TWO NEBRASKA FREESTALL BARNS[1]

M. J. Brouk, J. P. Harner III[2], and J. F. Smith

Summary

Temperatures and humidities outside and inside freestall barns and cow respiration rates were monitored on three Kansas and two Nebraska commercial dairy farms during the summer of 1999. All farms had 4-row freestall buildings with different cooling systems. The first Kansas barn could be cooled naturally and mechanically using evaporative cooling pads located on the east and west walls. The second Kansas barn was ventilated naturally by manually lowering the sidewall curtains and without sprinkling or ventilation systems. The third Kansas barn was ventilated naturally and equipped with fans located over the freestalls and feed-line sprinklers. The first Nebraska barn was ventilated naturally and equipped with a sprinkler system over the feed line and fans over the freestalls. The second Nebraska barn was ventilated mechanically using evaporative cooling, fans installed over the freestalls, and a sprinkler system over the feed line. Evaporative cooling did not favorably modify the barn environment. It increased or decreased humidity and offset the effect of a lower barn temperatures, resulting in greater respiration rates of cows and overall less cow comfort than other systems that provided fans or sprinklers or both.

(Key Words: Environmental Stress, Heat Stress, Dairy Cattle.)

Introduction

Heat stress during the summer months reduces milk production. Cows begin to experience milk heat stress when the temperature humidity index (THI) exceeds 72. Dairy cattle produce large amounts of heat from both ruminal fermentation and metabolic processes. As milk production increases, the total amount of heat produced increases. In order to maintain body temperature with the normal range, cows must exchange this heat with the environment. This exchange primarily occurs via the lungs and skin. Under natural conditions and at temperatures below 70°F, more than 50% of the heat is lost via the skin. As the temperature reaches 80°F, only about 25% of the heat is lost through the skin and 75% is lost via the lungs. As the temperature increases above 80°F, a much greater percentage of the heat will be lost through the lungs and a smaller percentage through the skin.

Heat loss via the skin primarily occurs through exchange with the air. The amount of exchange under natural conditions is limited by air temperature, air movement, and relative humidity. Decreasing air temperature or increasing air movement will increase the loss via the skin. However, as temperature rises above 70°F, the temperature differential between the air and normal cow body temperature decreases. As the temperature approaches 103°F, the differential is minimal, and very little heat is lost via

[1]We acknowledge the cooperation of the following dairies who participated in this study: Aspen Dairy, Miller, NE; Wolfden Dairy, Kearney, NE; Tuls Dairy, Liberal, KS; Hamilton County Dairy, Syracuse, KS; and Coolidge Dairy, Coolidge, KS.

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the skin, unless sprinklers are installed. Heat exchange is increased greatly by applying water to the skin. The water evaporates and absorbs the heat that increased the heat exchange between the skin and environment. Thus, at temperatures above 70°F, the use of sprinkler systems increases the amount of heat that is lost through the skin. Losses of heat through the skin are maximized when water is applied and then evaporated. A system that incorporates sprinklers that quickly wet the cow and then shut off while a fan moves large volumes of air around the cow will increase the number of wetting and evaporation cycles. In addition, the barn ventilation system must provide enough air exchange to move the humidity from water evaporation out of the building. Installation of circulation fans and construction of open sidewall barns increase air flow around the cow and building air exchange.

Heat loss through the lungs is accomplished by two methods. Heat is lost by increasing the temperature of the air inhaled and by evaporation of water in the lungs. Air exhaled by a cow will be approximately 100°F and contain greater than 95% relative humidity. The amount of cooling achieved through respiration is limited to the number of breaths per minute and the differences in temperature and relative humidity of the air inhaled and air exhaled. The temperature and humidity of the exhaled air are constant. At temperatures above 70°F, proper building design to maximize heat exchange via the skin and lungs is essential.

Dairy freestall barns generally are designed to maximize natural ventilation. Supplemental cooling systems (fans and sprinkler) are added to help reduce heat stress. The basic concept has been to create air movement via natural and mechanical methods. The addition of sprinkler systems at the feed line allows the cows to take advantage of water evaporation off the body to increase skin heat exchange. Recently, two barns (one in Kansas and one in Nebraska) included an evaporative cooling system in the building design.

Evaporative cooling utilizes water evaporation to reduce the temperature of air. Water absorbs heat as it evaporates and reduces air temperature. However, evaporative cooling also increases the relative humidity of the air. The degree of cooling is influenced by the temperature and relative humidity of the air introduced into the cooling pad, where evaporation occurs. High temperature and low relative humidity will allow for a larger reduction in temperature than high temperature and high relative humidity. Thus, relative humidity may limit the effectiveness of this system. Another possible limitation of an evaporative cooling system for dairy freestall barns is the water vapor produced from dairy cattle respiration. Cows produce large volumes of water vapor and urine, which will increase the relative humidity of the air in the barn. This humidity must be removed by building air exchange. If the humidity is not removed, the heat exchange capacity of the lungs due to evaporation is reduced. To be effective, the evaporative cooling system must increase the heat exchange capacity of the lungs via a lower temperature in the presence of greater relative humidity. This means that either the evaporative cooling system is more energy efficient in the evaporation process than the lung of the cow or that the reduced air temperature would increase the heat loss of the skin more than the increased relative humidity reduced the heat exchange in the lungs. The efficiency of water evaporation is likely similar between the evaporative cooling pad and the cow, because the same laws of physics apply to both. Hence, the potential advantage of evaporative cooling systems would be increased loss of heat through the skin.

The purpose of this study was to monitor temperatures and relative humidities outside and inside five freestall barns with different cooling systems. Respiration rates of cows also were monitored to evaluate their responses to different environmental conditions in the barns.

Procedures

Five freestall barns, three in western Kansas and two in western Nebraska, were monitored during the summer of 1999. Temperatures and relative humidities outside and inside barns were monitored continuously for 672 hr (Kansas, July 21 -August 17, 1999) and 864 hr (Nebraska, July 30 - September 3, 1999). Respiration rates were obtained in the morning (7-8:00 a.m.), afternoon (2-3:00 p.m.), and night (9-10:00 p.m.) from 50 cows per farm on 3 (Kansas dairies) or 2 (Nebraska dairies) different days. All barns were four-row freestall barns but differed in construction and cooling system design.

Barn one (A-KS) was a 106-ft wide, 4-row, freestall barn oriented north-south and located in southwest Kansas. The building was ventilated naturally and mechanically. It had a galvanized uninsulated roof on a 4/12 pitch. Sidewalls were 12.5 ft high. Located in the upper 30 inches of the sidewalls were evaporative pads that ran the length of the building. The lower portion of the sidewall was curtained. Roof fans were located on 12-ft centers along the ridge of the building, and there was no peak opening. The 36-inch fans (11,000 cfm/fan) moved air through the evaporative pads and exhausted through the ridge. A portion of the fans operated when curtains were opened to exhaust heat from the peak of the building. The barn had no sprinkler system along the feed line.

Barn two (B-KS) was a 100-ft wide, 4-row, freestall barn oriented east to west and located in southwest Kansas. The building had a galvanized uninsulated roof on a 3/12 pitch. The ridge opening was 18 inches. Curtain sidewalls were 10 ft high. The building was ventilated naturally and had no sprinkler or mechanical ventilation systems.

Barn three (C-KS) was 100-ft wide, 4-row, freestall barn oriented east to west and located in southwest Kansas. The building had a galvanized uninsulated roof on a 3/12 pitch. The ridge opening was 18 inches. Sidewalls were 11 ft high with a curtain used on the south side. The north side had a 30-inch opening below the eave with the remainder of the wall being solid. The building was ventilated naturally and had sprinkler and mechanical ventilation systems. The sprinkler systems had a spray nozzle located every 88 inches along the feed line. The ventilation system had 48-inch fans (20,000 cfm/fan) over the freestalls on 28-ft centers. The bottom of the sprinkler line and fans were located 7 ft above the floor. The sprinkler and ventilation systems were controlled thermostatically to operate when temperatures exceeded 72°F.

Barn four (D-NE) was a 96-ft wide, 4-row, freestall barn oriented east to west and located in north central Nebraska. The building had a galvanized uninsulated roof on a 3/12 pitch. The ridge opening was 18 inches. Sidewalls were 14 ft high with a 13-ft curtain. The building was ventilated naturally and had sprinkler and mechanical ventilation systems. The sprinkler systems had a spray nozzle located every 21 ft along the feed line. The ventilation system had 36-inch fans (11,000 cfm/fan) over the freestalls on 48-ft centers. The bottom of the sprinkler line and fans were located 8 ft above the floor. The sprinkler and ventilation systems were controlled manually.

Barn five (E-NE) was a 96-ft wide, 4-row, freestall barn oriented east to west and located in north central Nebraska. The building was ventilated mechanically. It had a galvanized insulated roof on a 3/12 pitch. Sidewalls were 12 ft high and solid except for sidewall inlets located on the south and north sides running the length of the building. A high pressure line was located just above the sidewall inlets and sprayed a fine mist of water into the incoming air stream. The inlet was approximately 8 inches wide and located about 9 ft above the floor. Roof fans were located on 12-ft centers in the ridge of the building. The 36-inch fans (11,000 cfm/fan) moved air from the sidewall inlets located on the south and north sides with the exhaust occurring at the ridge. Sprinkler systems were located over the sidewall inlets and feed line. The feed line system used 0.5 gal/min nozzles located every 12 ft. The sidewall inlet system used

1.5 gal/min nozzles located on 6-ft centers. Circulation fans were installed over the free-stalls.

Results and Discussion

Kansas Barns

Inside barn temperatures (Table 1) at the Kansas farms differed (P<.05) with C-KS being highest (80°F) and A-KS the lowest (76°F). Barn relative humidity was greater (P<.05) for A-KS than for B-KS and C-KS (72.1 vs 59.6 and 59.0%). Outside relative humidity was similar for all farms. Outside temperature was greatest (P<0.05) for C-KS and lowest for A-KS. The cooling cells of the A-KS barn reduced ambient temperature 2°F and increased humidity 12.2 units, resulting in an increased THI inside the barn. These differences were significant (P<.05) as compared to the other systems.

Mean respiration rates (Table 2) were greater (P<.05) for cows in A-KS than for cows in B-KS and C-KS (83.5 vs 60.4 and 63.0 breaths/minute). Rates were higher (P<.05) for A-KS cows than for cows in the two other barns during morning, afternoon, and night. Temperature humidity index values before and during measurements of respiration rates were similar in the morning and afternoon periods but differed at night. The evaporative cooling system lowered barn temperature but increased barn humidity, resulting in greater THI values during the entire study period. Greater THI values accounted for greater respiration rates of cows, even though THI values were not greater for the A-KS barn. These results indicate that THI, which does not account for the effects of sprinkler systems or air movement, was not a suitable tool for predicting cow comfort or respiration rates influenced by conditions more than 2 hr prior to their measurement.

Nebraska Barns

Barn temperature, relative humidity, and THI (Table 3) were greater (P<.05) for E-NE than D-NE. The effect of the evaporative cooling system increased THI more (P<.05) than outside temperature changes of the other barn. Outside conditions were similar for both locations. Mean respiration rates and average THI values when respiration rates were assessed were not different between barns. However, respiration rates of cows in the morning were greater (P<.05) for E-NE than for D-NE. Respiration rates of cows in these two barns followed the same trends observed for the barns in Kansas.

Conclusions

These results showed that evaporative cooling increased barn humidity and either lowered or increased barn temperature. In the case of the dairy that showed a reduced barn temperature, sidewall curtains were lowered at night, and the evaporative pad was bypassed during evening hours. Thus, the barn was cooled to near ambient temperature at night. In the case of the other evaporatively cooled barn, curtains were not lowered at night, and the building temperature remained above the outside temperature. Evaporative cooling of freestall barns increased cow respiration rates and did not improve the environmental conditions for cows. Considering the methods by which a cow reduces body temperature, evaporative cooling did not sufficiently reduce air temperature to offset the reduction in evaporative lung cooling due to increased humidity. Additional studies are needed to evaluate system performance based on other management strategies.

Table 1. Comparison of Temperature, Relative Humidity, and THI Outside and Inside Three Freestall Barns in Kansas[1]

	Barns			
Item	A[2]-KS	B[3] - KS	C[4] - KS	SE
Inside barn temperature, °F	76[a]	78[b]	80[c]	.2
Inside barn relative humidity, %	72[b]	60[a]	59[a]	.8
Inside barn THI[1]	73[b]	72[a]	74[c]	.1
Outside temperature, °F	78[a]	78[a]	80[b]	.2
Outside relative humidity, %	60	58	60	.7
Outside THI[1]	72[a]	72[a]	73[b]	.1
Temperature difference[5], °F	-2[a]	0[b]	0[c]	.2
Relative humidity difference[5], %	12[b]	1[a]	-1[a]	.8
THI[1] difference[5]	1[c]	0[a]	1[b]	.1

[1]THI = Temperature humidity index. Data were collected from July 30 through September 3, 1999. THI = temperature, °F - (.55 - .55 × percent relative humidity/100) × (temperature, °F - 58).
[2]A-KS = 4-row Kansas freestall barn with evaporative cooling.
[3]B-KS = 4-row Kansas freestall barn without any cooling system.
[4]C-KS = 4-row Kansas freestall barn with freestall fans and a feed-line sprinkler system.
[5]Inside barn minus outside.
[a,b,c]Means within the same row with unlike superscripts differ ($P<.05$).

Table 2. Respiration Rate of Dairy Cows and Freestall Barn THI at Three Dairy Farms in Kansas at Different Periods of the Day[1]

	Barns			
Item	A[2]-KS	B[3]- KS	C[4]- KS	SE
Morning respiration rate, breaths/min	74[a]	58[b]	63[b]	3
Afternoon respiration rate, breaths/min	93[b]	80[a]	83[a]	3
Night respiration rate, breaths/min	84[b]	60[a]	63[a]	3
Average respiration rate, breaths/min	84[b]	66[a]	70[a]	2
Morning THI[1]	69	68	69	1
Afternoon THI[1]	78	79	80	1
Night THI[1]	76	77	79	1
Average THI[1]	74	75	76	1

[1]THI = Temperature humidity index measured during and 2 hrs prior to assessing respiration rates of cows. THI = temperature, °F - (.55 - .55 × percent relative humidity/100) × (temperature, °F - 58).
[2]A-KS = 4-row Kansas freestall barn with evaporative cooling.
[3]B-KS = 4-row Kansas freestall barn without any cooling system.
[4]C-KS = 4-row Kansas freestall barn with freestall fans and a feed-line sprinkler system.
[a,b,c]Means within the same row with unlike superscripts differ ($P<.05$).

Table 3. Comparison of Temperature, Relative Humidity, and THI[1] Outside and Inside Two Freestall Barns in Nebraska[1]

	Barns		
Item	D[2]-NE	E[3]-NE	SE
Inside barn temperature, °F	76[a]	77[b]	.2
Inside barn relative humidity, %	71[a]	81[b]	1.0
Inside barn THI[1]	72[a]	74[b]	.2
Outside temperature, °F	76	77	.2
Outside relative humidity, %	74	73	.6
Outside THI[1]	73	73	.2
Temperature difference[4], °F	0	0	.3
Relative humidity difference[4], %	-3[a]	8[b]	1.4
THI[1] difference[4]	-1[a]	1[b]	.2

[1]THI = Temperature humidity index. Data were collected from July 21 through August 17, 1999. THI = temperature, °F - (.55 - .55 × percent relative humidity/100) × (temperature, °F - 58).
[2]D-NE = 4-Row Nebraska freestall barn with freestall fans and a feed-line sprinkler system.
[3]E-NE = 4-Row Nebraska freestall barn with evaporative cooling, feed-line circulation fans and a feed-line sprinkler system.
[4]Inside barn minus outside.
[a,b]Means within the same row with unlike superscripts differ ($P<0.05$).

Table 4. Respiration Rate of Dairy Cows and Freestall Barn THI at Two Dairy Farms in Nebraska at Different Periods of the Day[1]

	Barns		
Item	D[2]-NE	E[3]-NE	SE
Morning respiration rate, breaths/min	59[a]	71[b]	7
Afternoon respiration rate, breaths/min	84	88	7
Night respiration rate, breaths/min	76	70	7
Average respiration rate, breaths/min	73	76	7
Morning THI[1]	68	70	3
Afternoon THI[1]	79	80	3
Night THI[1]	72	79	3
Average THI[1]	73	76	3

[1]THI = Temperature humidity index measured during and 2 hr prior to assessing respiration rates of cows. THI = temperature, °F - (.55 - .55 × percent relative humidity/100) × (temperature, °F - 58).
[2]D-NE = 4-Row Nebraska freestall barn with freestall fans and a feed-line sprinkler system.
[3]E-NE = 4-Row Nebraska freestall barn with evaporative cooling, feed-line circulation fans and a feed-line sprinkler system.
[a,b]Means within the same row with unlike superscripts differ ($P<0.05$).

LABOR REQUIREMENTS FOR HANDLING MANURE FROM CONCRETE BASINS

J. P. Harner III[1], T. Strahm[1], D. Key[1], and T. L. Strahm

Summary

Time requirements for loading a manure spreader and traveling to and from the field varied from 20 to 30 min per load. However, standardizing the data showed that 5 to 7 min were required per 1,000 gal (9,000 lb). The preliminary results of the time motion data indicate about 30 min per cow per year are required for handling manure from a concrete storage basin. These results were consistent among the four dairies evaluated, even though differences existed in operating procedures. These results enable dairy producers to assess labor and equipment needs for performing the various operations associated with hauling manure from a concrete storage basin.

(Key Words: Manure, Handling, Labor, Storage.)

Introduction

Time motion studies are useful in determining labor requirement to perform specific tasks in manufacturing processes. These studies have been used in the dairy industry to evaluate the labor requirements for various tasks associated with milking and milk parlor performance. Data may be used to evaluate the impact of changes, increase understanding of labor requirements, or determine detailed operational costs. The objective of this study was to determine the labor requirements for handling manure from concrete basins.

Procedures

The study was conducted at four dairies located in northeast Kansas. The dairies utilized concrete basins for storing manure prior to land application. Manure was scraped and stored in a basin and then applied using a manure spreader. The concrete basins were 3 to 6 ft deep with volumes in proportion to the storage period and herd size. Although all of the dairies utilized sand for bedding freestalls, it was not standardized. The hauling distances from the concrete basin to the field varied. Data were collected utilizing stop watches to time a specific task required during the handling of the manure. The specific tasks recorded were:

Loading time: time from when the spreader stopped at the loading area when one operator was used or when the first bucket began to dump into the spreader if two or more operators were present until the spreader moved away from the loading area.

Travel time to field: time from when the spreader moved away from the loading area until the spreading operations began.

Spreading time: time from when the spreading operation began until the spreading operation was completed.

Travel time from field: time from when the spreading operation was completed until when the next loading time began.

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The total time was an equal to the summation of the four events. Radios were used to communicate when certain events occurred. Each dairy had different operation procedures as described below.

Dairy A. Utilized a pay loader and spreader with one person operating all of the equipment.

Dairy B. Utilized a tractor front end loader and spreader with two people or one person operating each piece of equipment

Dairy C. Utilized a skid steerer and three manure spreaders with four people or one person operating each piece of equipment. Data also were collected using a 3,350-gal manure tank wagon with a single operator at this dairy.

Dairy D. Utilized a tractor front end loader and spreader with one person operating both pieces of equipment.

Data were collected for 10 to 15 round trips per dairy. A round trip represented the time required to complete the four sequenced time events. Data from each farm then were entered into a spread sheet and averaged. Manufacturer information related to spreader capacity was obtained and converted to 1,000 gal for comparison among the four dairies. The manure spreaders ranged from 1,820 to 3,300 gal in capacity.

Results and Discussion

Figures 1 through 4 illustrate the results obtained from dairies A through D, respectively. The average time for loading a spreader ranged from 3 to 7 min. Data from Dairy C (Figure 3) indicated that a manure tank could be filled in less than 4 min. A similar amount of time was required to load a spreader. The time required to go from the loading area to the field or back was about 4 min. Dairy B (Figure 2) accomplished this task in less than 2 min, but the distance to the edge of the field was less than 100 yards. Dairy A (Figure 1) had the longest hauling distance and required about 6 min per one-way trip. Spreading generally was accomplished in less than 2 min. Overall, the total time required per load of manure ranged from 13 (Figure 2) to 23 (Figure 1) min. Spreader size did not have an impact on the time requirements per 1,000 gal hauled.

The results were converted to time required per 1,000 gal, because variation exists in the size of manure spreaders. A bushel of spreader capacity was equal to 7 gal (1 bu = 0.8 cubic ft = 64 lb at 80 lb/cubic ft pcf = 7 gal at 9 lb/gal). Between 5 and 7 min were required per 1,000 gal (9,000 lb) removed from the concrete basin. Rate of removal was independent of the number of operators, differences in spreader capacity, loading equipment, and distance to the fields.

A 1,400-lb cow produces around 150 lb of manure (feces + urine) per day. Content of fresh manure averages 87% moisture. Previous work found the manure in most basins averaged less than 80% moisture. Therefore, about 36,000 lb or 4,000 gal enter a basin each year per cow. Using the time motion data collected, about 30 min of labor are required per cow each year when the manure is stored in a concrete basin. For a 100-cow dairy, this represents about 50 hrs of time per year. Time requirements for a small dairy that typically scrapes and hauls are approximately 100 hrs. This was determined based on hauling four times per week at 30 min per trip. No additional labor or time is required for hauling manure stored in a concrete basin when compared to hauling three or more times per week. Based on a cost of $75 per hr for tractor and spreader equipment, the application cost is equal to about $37 per cow if a basin is used and $75 per cow if a daily scrape and haul system is used.

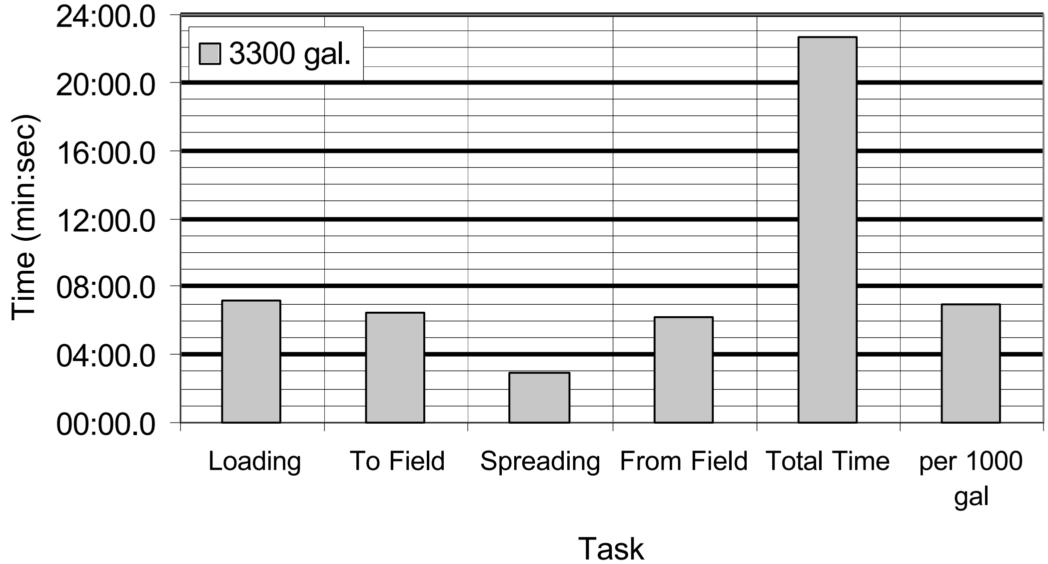

Figure 1. Average Labor Times for Manure Handling Phases Using Multiple Spreaders at Dairy A.

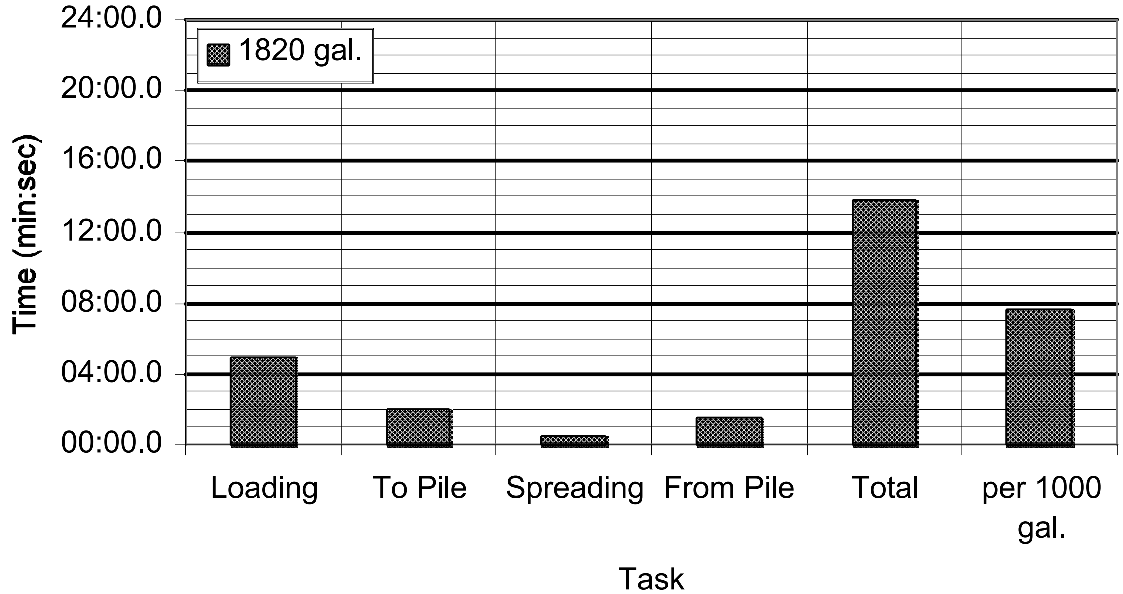

Figure 2. Average Labor Times for Manure Handling Phases at Dairy B.

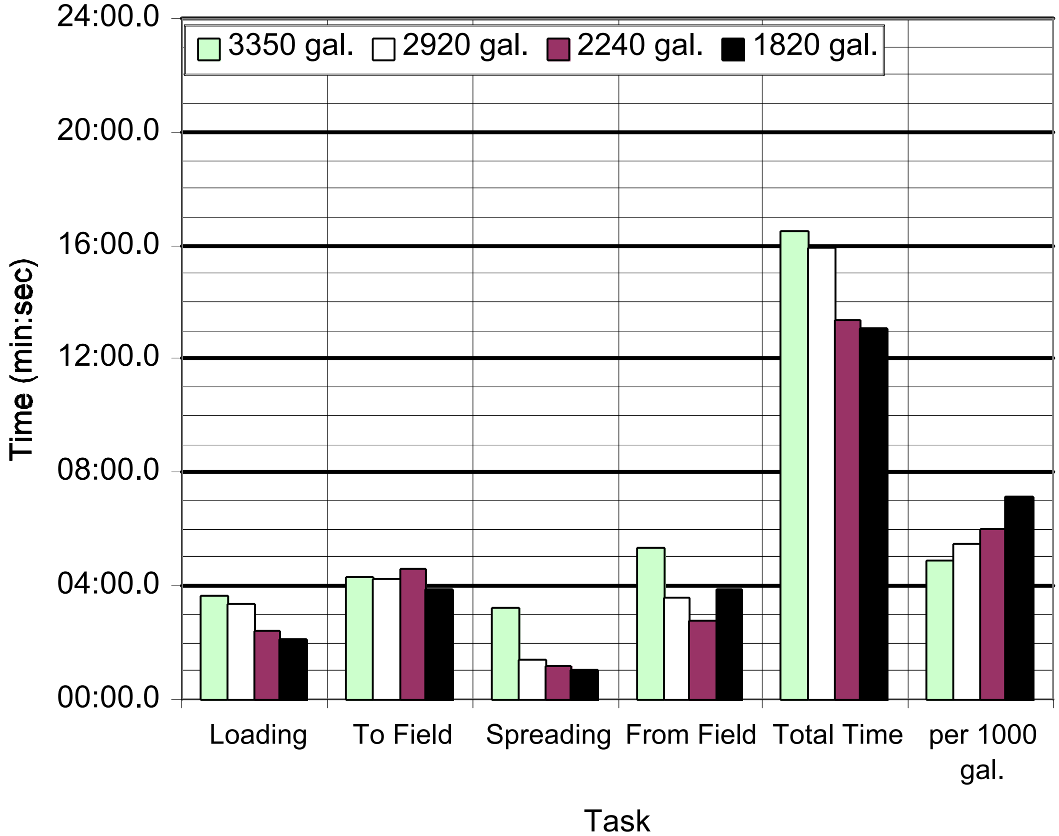

Figure 3. Average Labor Times for Manure Handling Phases Using Multiple Spreaders at Dairy C.

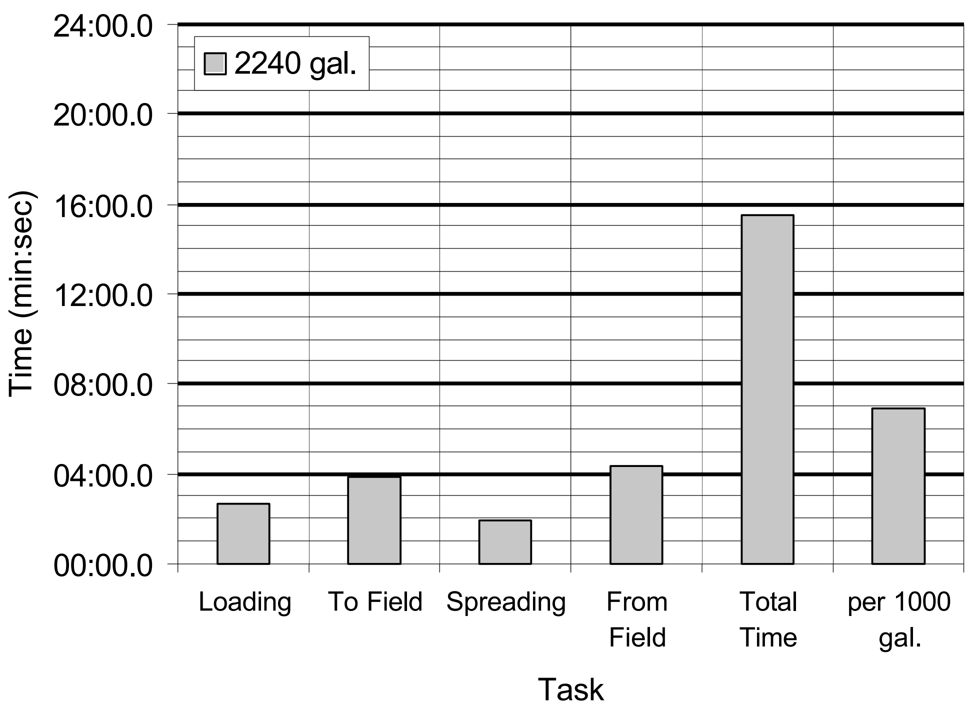

Figure 4. Average Labor Times for Manure Handling Phases at Dairy D.

NUTRIENT ANALYSIS OF SAND-LADEN DAIRY MANURE

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***D. Key*[2]*, and J. P. Murphy*[1]

Summary

Nine concrete storage basins were sampled on Kansas dairies and analyzed for nutrient content of sand-laden dairy manure. The manure average 75% moisture content during the three sampling periods. The average total nitrogen, phosphate, and potash were 9.7, 4.6, and 7.4 lb/ton, respectively. The data collected from the basin indicated that when the scraped manure from a dairy is applied at an agronomic rate of 15 tons or less per acre, accumulation of nutrients should be minimal, in particular phosphorus. The manure value was $3 to $4 per ton depending on whether commercial sources of phosphorus normally would be applied to the cropland.

(Key Words: Manure, Nutrients, Sand.)

Introduction

Environmental regulations generally focus on control and proper land application of manure nutrients. State permit procedures require submission of a nutrient management plan. This usually includes an estimate of the manure nutrients applied to the land as well as crop nutrient utilization. Consulting engineers may work with the land owners and extension educators or crop consultants within a region to obtain reasonable nutrient utilization rates for the crops. However, data on manure nutrients actually applied to the land are not as readily available.

Many dairies use total mixed rations (TMR) and sand-bedded freestalls. The difficulties in handling sand-laden manure are offset by the benefits of cow comfort and higher milk quality. However, limited information is available on the nutrient content of sand-laden manure. The purpose of this study was to characterize the nutrients in sand-laden manure scraped from dairy facilities using TMR.

Procedures

The study includes data from three sampling dates: February 5, April 8, and August 13, 1999. Samples were collected from concrete manure storage basins at nine Kansas dairies. With one exception, all the dairies used sand bedding in the stalls. Each dairy scraped the freestall housing and feeding area and the milking parlor holding pen. The concrete basins were sized to provide 160 cubic ft of storage per cow. The depth of the basin was 4 ft, and the width and length were adjusted for each dairy's site and size. Rainwater and effluent could drain from a basin through a perforated gate (4 by 12 ft) or a perforated pipe riser. All dairies fed a corn silage-based TMR. These high-producing herds ranged from 60 to 120 cows.

Liquid manure samples were retrieved using a capped polyvinyl chloride cylinder attached to a metal electrical conduit handle. A cord was connected to open the spring-closed lid while it was under the surface. Depending on the amount of manure in the

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basin, samples were taken at depths of 0.5 to 3 ft. The sampler was used to open the crust and then was pushed to the desired depth before the lid was pulled open to collect the sample. Four to six individual samples were taken from around the perimeter (3 to 4 ft from the edge) of each basin and then mixed in a bucket to make one composite sample. A plastic funnel was used to pour the sample into a 1-liter plastic bottle. The samples were refrigerated until sent for laboratory analysis. Total nutrient analysis was completed on each sample by Servi-Tech Laboratories.

Results and Discussion

Table 1 shows the average results for the samples taken from nine dairies at three dates and the overall average. The results show very little variability among the concrete basins tested, even though the storage time and volume were different. Minimal differences among the average nutrient values occurred for sampling dates. The total nitrogen, P_2O_5, and K_2O averaged 10.1, 4.6, and 7.5 lbs per ton, respectively. The nitrogen to phosphorus (P_2O_5) utilization ratio of most crops is 2:1 to 4:1. Therefore, crops with a high N/P ratio would need supplemental N sources to meet their nutrient needs, if phosphorus was a limiting nutrient. If we assume that most of the ash content is from the sand scraped into the basins, approximately 10 to 25% by weight of every load is sand. More variability among the farms occurred for the ash content than any other nutrient. This is probably a reflection of the differences in the management of the cow housing areas and amount of sand used in the freestalls.

The moisture content of the solids applied to the land ranged from 66 to 83% with an average of 76% for the February samples. Manure spread from a concrete storage basin using gravity separation of the water may have a higher moisture content than that spread by mechanical separators using screens. The dry matter content was 24%.

The economic value of the nutrients is dependent on the current phosphorus levels of the cropland. The value of the manure placed on land with high phosphorus levels is only $3 per ton, if only credit for the nitrogen and potassium is taken. Manure value increases to $4 per ton, if credit for the phosphorus is included. These values were based on nitrogen, phosphate and potash values of $0.20, 0.30, and 0.14 per lb, respectively. Manure may serve as a lime replacement to increase the soil pH of cropland that is acidic. Soil quality may be improved by addition of the sand to improve moisture movement through the soil.

Conclusions

The following are preliminary conclusions obtained from this study:

1) The total nitrogen to phosphorus (P_2O_5) ratio of manure was approximately 2:1 from dairies using corn silage-based, total mixed rations.

2) Approximately 10 to 25% of the manure applied to the land by weight was sand.

3) In the concrete solid storage basins, the moisture content of the manure averaged 75% during the winter and spring months.

4) The economic value of the nutrients in the manure was $3 to $4 per ton depending upon the current phosphorus levels in the cropland.

Table 1. Nutrient Contents of Manure from Nine Dairies

		Sampling Month			Overall
Nutrient	Units	February	April	August	Average
Organic nitrogen	lb/ton	6.88	6.89	5.70	6.49
Urea	lb/ton	3.26	2.29	2.47	2.67
Nitrate-nitrogen	lb/ton	0.01	0.01	0.01	0.01
Total nitrogen	lb/ton	10.14	9.19	7.36	8.89
Phosphorus P_2O_5	lb/ton	4.62	4.49	5.45	4.85
Potassium K_2O	lb/ton	7.54	7.25	7.54	7.44
Calcium	lb/ton	8.04	7.80	8.72	8.19
Magnesium	lb/ton	3.14	3.13	3.81	3.36
Sulfur	lb/ton	1.27	1.23	1.36	1.29
Sodium	lb/ton	1.82	1.82	1.90	1.85
Zinc	lb/ton	0.05	0.05	0.06	0.05
Iron	lb/ton	1.40	1.48	1.65	1.51
Manganese	lb/ton	0.08	0.09	0.10	0.09
Copper	lb/ton	0.01	0.02	0.02	0.01
Boron	lb/ton	0.01	0.01	0.01	0.01
Other Properties					
Moisture	%	76.0	73.8	76.3	75.4
Solids	%	24.0	26.2	23.7	24.6
Organic matter	lb/ton	195.74	198.52	197.59	197.3
Ash	lb/ton	284.93	324.74	275.70	295.1
Carbon/nitrogen ratio		11	12	14	12
Electrical conductivity	mmho/cm	10.4	6.2	33.6	16.7
pH		7.3	6.9	6.8	7.0
Total salts	lb/ton	36.10	35.10	38.41	36.54

Dairy Day 1999

RELOCATION AND EXPANSION PLANNING FOR DAIRY PRODUCERS

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Summary

Relocating or expanding a dairy facility requires a tremendous amount of time and planning. Owners or managers of dairies will go through a number of steps including: 1) developing a business plan; 2) choosing a design process; 3) developing specifications; 4) selecting location/site; 5) obtaining permits/legal; 6) obtaining bids; 7) selecting contractors; 8) buying cattle; 9) purchasing feeds; 10) financing; 11) managing construction; 12) hiring and training employees; 13) developing management protocols for the dairy; and 14) managing information flow. The dairy can be divided into these components: 1) milking parlor; 2) cow housing; 3) special needs facility (e.g., hospital, closeups); 4) replacement heifer housing; 5) manure management system; and 6) feed center. This article will focus on milking parlors, cow housing, grouping strategies, and site selection.

(Key Words: Dairy Facilities, Expansion, Cow Comfort.)

Design-Build Concept

Many owners and managers who have made the decision to expand prefer to use the design-build concept or a design team. This concept specifies that a dairy design consultant is employed to work with the dairy management specialist in developing a basic dairy design and program plan to meet the client's needs. The design team consists of a consulting engineer and supporting dairy management specialists, which could include dairy extension faculty, financial advisors, nutritionists, milking equipment manufacturers, and veterinarians. This team approach is an efficient way to integrate desired management into physical facilities.

Options for the Milking Parlor

Evaluating Parlor Performance

Milking parlor performance has been evaluated by time and motion studies to measure steady-state throughput (cows per hour). Steady-state throughput does not include time for cleaning the milking system, maintenance of equipment, effects of group changing, and milking the hospital strings. These studies also allow us to look at the effect of different management variables, including milking interval, detachers, premilking hygiene, number of operators and construction. Examples of different management techniques that affect parlor performance are listed below:

- Data collected in parallel milking parlors indicate that milking cows 3× rather than 2× daily increases throughput 8 to 10%.
- Use of detachers does not increase throughput with the same number of operators.
- Use of predip milking hygiene reduces parlor performance 15 to 20%.

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- Average number of cows milked per operator hour decreases as the number of operators increases from one to four.
- Steady-state throughput is 10 to 12% greater in new parlors than in renovated parlors.

Sizing Parallel and Herringbone Milking Parlors

Table 1 presents the design criteria for parallel and herringbone parlors.

Table 1. Design Criteria for Parallel and Herringbone Parlors

Milking Frequency	Shift Length	Turns per Hour
2×	8.0	4.0
3×	6.5	5.0
4×	5.0	6.0

Typically, milking parlors are sized so that cows can be milked once in 8 hours when milking 2× per day; once in 6.5 hours when milking 3× per day; and once in 5 hours when milking 4x per day. Using these criteria, the milking parlor will be sized to accommodate cleaning and maintenance. The facilities or cow groups are determined based on milking one group in 60 min when milking 2×, one in 40 min when milking 3×, and one in 30 min when milking 4×. Group size is adjusted slightly to be divisible by the number of stalls on one side of the milking parlor. Having as many occupied stalls as possible per cycle maximizes parlor efficiency.

Typically, it is assumed the milking parlor is turned over four and one-half times per hour during milking. The number of cows that will be milked per hour can be calculated using the following formulas:

Total number of stalls × 4.5 = cows milked per hour (CPH)

Number of milking cows = CPH × milking shift length (hours)

Sizing Rotary Parlors

Entry time (seconds/stall), number of empty stalls, number of cows that go around a second time, entry and exit stops, and the size of the parlor (number of stalls) influence the performance of rotary parlors. The entry time will determine the maximum number of cows that can be milked per hour. For example if the entry time is 10 seconds, the maximum throughput will be 360 cows per hour (3600 seconds per hour divided by 10 seconds per stall). This is referred to as theoretical throughput.

Theoretical throughput assumes that the parlor never stops, cows are milked out in one rotation, and a new cow occupies every stall at entry. In reality, there are empty stalls, cows that go around a second time, and times when the rotary table is stopped. Table 2 shows rotary parlor performance at different percentages of theoretical throughput. As the number of empty stalls, cows making a second trip around, and number of stops increase, the percentage of theoretical throughput is decreased.

Table 2. Rotary Parlor Performance

	Theoretical Throughput (cows/hr)				
Time (sec/stall)	100%	90%	80%	70%	60%
8	450	405	360	315	270
9	400	360	320	280	240
10	360	324	288	252	216
11	327	295	262	229	196
12	300	270	240	210	180
13	277	249	222	194	166
14	257	231	206	180	154
15	240	216	192	168	144
16	225	203	180	158	135

Data collected on 14 dairies (Table 3) with recently constructed new rotary parlors showed an average rotation time of 11:45 seconds and throughput averaging 79% of theoretical (100%).

The number of stalls or size of the rotary parlor affects the available unit on-time. Table 4 lists available unit on time for different sizes of rotary parlors at different rotation times. A rotary parlor must be large enough to allow approximately 90% of the cows to be milked out in one trip around the parlor.

A review of the data available today indicates that rotary parlor should be sized at an 11 to 12 sec/stall rotation and 80% of theoretical throughput. The parlor should be large enough to allow 9 min of available unit on-time.

Table 3. Performance of Rotary Milking Parlors on Commercial Dairies

Number of Stalls	Entry per Cow (sec)	Premilking Hygiene	Theory[1] (cows/hr)	Milk Freq.	Actual* (cows/hr)	Number of Operators	Cows Labor/ hr	% Actual/ Theory	Milk[2] Production
32	15:00	wipe-strip	240	2×	195	2	98	81%	57[3]
36	15:00	wipe	240	3×	187	1	187	78%	78
40	11:00	wipe-strip	320	2×	288	2	144	90%	56[4]
40	13:00	wipe-strip	276	2×	245	2	123	89%	56[4]
40	15:00	wipe	240	4×	203	1.5	135	85%	80
40	15:50	full	232	3×	188	4	47	81%	62
40	14:40	wipe-strip	250	3×	205	2	103	82%	65
48	10:00	none	360	2×	263	2	132	74%	60
48	10:00	none	360	2×	279	2	140	78%	59
48	8:80	none	409	2×	251	2	126	61%	60
48	10:25	strip	351	3×	309	3.3	94	88%	66
60	8:00	full	450	3×	336	5	67	75%	65
60	7:80	strip	462	2×	283	5	57	61%	57
72	6:60	strip	545	2×	440	4	110	81%	63
avg.	11:45		338		262		112	79%	64

[1]Steady-state throughput.
[2]Pounds of milk per cow per day.
[3]Jerseys and Guernseys.
[4]Jerseys.

Selecting Parlor Type

Currently, herringbone, parallel, and rotary parlors are the three predominant types of parlors constructed on large dairies. Earlier research indicates that parallel parlors outperformed similarly sized herringbone parlors.

Recently, there has been a renewed interest in rotary parlors. In Table 5, performance of 33 parlors is presented by type, size, and premilking hygiene. Throughput and cows/labor hour are reduced when a full premilking hygiene is used. Additional information is needed in rotary parlors with a full premilking hygiene, because we have evaluated only two.

The square footage required to house the milking parlor is influenced by parlor type. Table 6 shows the estimated square footage of the milk parlor for different sizes of parallel and rotary milking parlors. The square footage requirement for parallels range from 1890 to 5300 sq ft, whereas the area requirement for rotary parlors ranges from 3025 to

9216 sq ft. Producers need to compare the construction cost of the different parlor types they are considering.

If constructing the parlor shell costs $35/sq ft, a double-40 parallel shell would cost $184,400 and an 80-stall rotary shell $322,560. Equipment dealers estimate basic equipment inside the parlor milk line, wash line, basic detacher, and stall at $3,000/stall for herringbone and parallel parlors and $3,400 for a rotary parlor. In parallel and herringbone parlors, the operator pit can be constructed to allow additional stalls to be added as the dairy expands. Expanding rotary parlors is difficult.

In parallel and herringbone parlors, an operator can leave the parlor, and the other operators can continue to milk cows at a slower pace. In a rotary parlor, if one operator needs to leave the parlor, he or she will have to be replaced by another operator. Obviously, choosing what type and size of parlor to build is a very complex decision for a dairy operator.

Table 4. Available Unit On-Time Calculated for Rotary Parlors at Different Rotation Times[1]

		Revolution Time		Available Unit On-Time	
No. of Stalls	Entry Time sec/stall	Seconds/ Revolution	Minutes/ Revolution	Seconds/ Revolution	Minutes/ Revolution
	8	320	5:20	240	4:00
40	10	400	6:40	300	5:00
	12	480	8:00	360	6:00
	15	600	10:00	780	7:30
	8	480	8:00	400	6:40
60	10	600	10:00	500	8:20
	12	720	12:00	600	10:00
	15	900	15:00	750	12:30
	8	576	9:22	496	8:16
72	10	720	12:00	620	10:20
	12	864	14:24	744	12:24
	15	1080	18:00	930	15:30
	8	640	10:40	560	9:20
80	10	800	13:20	700	11:40
	12	960	16:00	840	14:00
	15	1500	20:00	1050	17:30

[1]Assumes 5 stalls for entry and exit, 3 stalls for premilking hygiene, 2 stalls for detaching and postdipping.

Table 5. Performance of Herringbone, Parallel, and Rotary Milking Parlors Using Different Premilking Hygiene on Commercial Dairies

Parlor Type	Total Number of Stalls	Number of Parlors Observed	Premilk. Hygiene[1]	Cows/ hr[2]	Number of Operators	Cows Labor/ hr
40 Rotary	40	1	Full[4]	188	4.0	47
Double 25 Parallel	50	2	Full[4]	231	4.0	58
60 Rotary	60	1	Full[4]	336	5.0	67
Double 30 Parallel	60	1	Full[4]	272	3.0	91
Double 32 Parallel	64	1	Full[4]	268	3.0	89
Double 35 Parallel	70	1	Full[4]	280	2.5	112
Double 40 Herringbone	80	1	Full[4]	392	7.0	56
Double 40 Parallel	80	1	Full[4]	385	4.0	96
Double 45 Parallel	90	3	Full[4]	396	5.0	79
Double 50 Parallel	100	1	Full[4]	460	5.0	92
32 Rotary	32	1	Min[3]	195	2.0	98
36 Rotary	36	1	Min[3]	187	1.0	187
40 Rotary	40	4	Min[3]	235	1.9	124
48 Rotary	48	3	Attach[1]	264	2.0	132
48 Rotary	48	1	Min[2]	309	3.3	94
Double 28 Herringbone	56	1	Min[2]	252	3.0	84
60 Rotary	60	1	Min[2]	283	5.0	57
Double 30 Parallel	60	2	Min[2]	280	3.0	93
Double 35 Parallel	70	1	Min[2]	352	3.0	117
72 Rotary	72	1	Min[2]	440	4.0	110
Double 40 Herringbone	80	1	Attach[1]	408	4.0	102
Double 40 Parallel	80	1	Min[2]	491	4.0	123
Double 50 Parallel	100	2	Min[2]	609	5.0	122

[1]Attach units. [2]Steady-state throughput. [3]Strip, attach or wipe, strip, and attach. [4]Strip, predip, wipe, attach.

Table 6. Estimated Square Footage Requirements for Rotary and Parallel Milking Parlors

Total Number of Milking Stalls	Milk Parlor Type	Platform Length or Diameter (ft)	Milk Parlor Length (ft)	Milk Parlor Width (ft)	Building Area (ft^2)	Ratio of Square Footage to Milk Stall
40	Double 20 Parallel	45	45	42	1890	47
40	40 Rotary	40	55	55	3025	76
48	Double 24 Parallel	70	70	42	2940	61
48	48 Rotary	48	63	63	3969	83
60	Double 30 Parallel	84	84	42	3528	59
60	60 Rotary	60	75	75	5625	94
80	Double 40 Parallel	106	106	50	5300	66
80	80 Rotary	81	96	96	9216	115

One vs Two Parlors

Some research indicates that two smaller parlors are more efficient than one larger parlor. One study compared two double 20 parallels versus one double 40 parallel. The net parlor return over 15 years was $908,939 greater in the two smaller parlors vs one large parlor. The initial cost of constructing two double 20 parallels was $22,227 higher than constructing one double 40. Constructing two parlors also allows producers to construct the dairy in phases.

Holding Pens

Design of holding pens is based on 15 to 17 sq ft per cow with a minimum capacity of one group of cows. If the wash pen is at a 90° angle to the cow traffic lane or the group size is greater than 200 cows, then the area per cow should be increased to 16 to 17 sq ft. When a wash pen is not used, oversizing the holding pen by 25% allows a second group to be moved into the holding pen, while the crowd gate is pulled forward and milking of the first group is being finished.

Wash Pen Design

The design and management of the wash pen is very important in U.S. dairies. With new regulations on dairy water use and additional EPA manure regulations being put in place each day, wash pen use will come under additional scrutiny.

Wash pen use is essential in open lot dairies. Many new freestall barns are being built without wash pens and will depend on proper freestall management to deliver clean cows to the milking parlor.

The necessary area per cow for proper cow cleaning depends upon several factors:

- If the wash pen is at a 90° angle to the cow traffic lane, additional area is necessary to allow the cows to fit properly into the wash pen.
- As group size increases, the area per cow increases. With group sizes up to 200 cows, a wash pen of 15 sq ft per cow is adequate. With groups above 200 cows, 16 to 17 sq ft per cow will provide adequate space.

Proper design of the sprinkler system is critical for adequate cow cleaning. With solid (concrete or metal) sidewalls, cows will face toward the parlor. This puts the udder next to the wall. A wash line should be placed 18-24 inches from the sidewall and use a pop-up sprinkler design, like a Rain-Jet. Such sprinklers are not as efficient as impact sprinklers like Rain-Birds. However, if all Rain-Birds are used, cows against the wall will not be cleaned well.

After placement of the outside row of Rain-Jets, the remaining sprinklers should be placed on a 5-ft by 6-ft grid. For example, a 40-ft wide holding pen with outside rows 2 feet from the sidewalls would have 5 rows of sprinklers spaced 6 ft apart and 5 ft top to bottom.

A three-stage timer should be used to operate the sprinklers. The timings will affect the amount of water used. This wash system is the largest user of water on the farm. Water use will vary from 18 to 30 gal per cow per wash. The first cycle is the “soak.” Its purpose is to wet the udder and loosen the dirt on the cow. One minute of water application followed by 2 minutes of stand time is adequate. The third cycle is a 3-minute wash period. If cows are still dirty, you should wait 1 minute and wash for 3 minutes again. During the stand time, cows generally move into new positions, resulting in improved wash pen efficiency.

Drip Pen Design

Drip pen area will range from 15 to 17 sq ft per cow. Size the drip pen to hold 100% of the corral or group size, thus allowing adequate time for udders to dry. The minimum size of a drip pen would be two complete turns of the milking parlor. For example, a double-20 herringbone parlor should have a minimum size to hold 80 cows (1200 sq ft). This would allow 24 to 30 min from the time in the wash pen to parlor entry.

Exit Lanes

Exit lane width depends on the number of stalls on one side of the milking parlor. In parlors with 15 stalls or fewer per side, a clear width of 3 ft is acceptable. For parlors containing more than 15 stalls per side, a clear exit lane width of 5 to 6 ft is needed.

Operator Pits

Operator pits are typically 8 ft wide between curbs. In a wedge configuration, operator pits are typically 6 ft wide at the holding pen and 10 ft wide at the breezeway. The cow platform is 38 to 40 inches above the floor of the operator pit. Provisions should be made to allow for floor mat thickness, if mats are to be used. The curb of the cow platform typically overhangs the operator pit wall 9 to 12 inches, depending on the size of the parlor. Normally, the operator pit and cow platform should have a 1% slope to the rear of the milking parlor. Operator pits typically have 2 inches of side slope from the center of the pit to the pit walls.

Constructing the Milking Parlor Shell

Several options are available when constructing the shell of the milking parlor. If no future expansion is planned, the building can be constructed with no room for expansion. This often is done in situations in which acreage is not sufficient for expansion. When long-term plans include expansion, the shell can be constructed with room to add a second parlor or add stalls to an existing parallel or herringbone parlor. If a second parlor is added, usually the two parlors will share a common equipment and milk storage facility. If additional stalls will be added to a parlor, the space should be left in the front of the parlor to reduce cow entry time and allow installation of new stalls without impeding current milking routines.

The final size of the holding pen (number of cows per group) should be sized for the total number of cows that will be milked after the expansion. The milking facility should be ventilated properly to maintain employee and cow comfort. Office, meeting room, break room, and rest room facilities should be incorporated to meet the needs of management.

Selecting Cow Housing

The predominant types of cow housing on large dairies in the U.S. are drylots and freestalls. The choice is based on climate, management style, and equity available for constructing dairy facilities. Typically, drylot facilities can be constructed where the moisture deficit (annual evaporation rate-annual precipitation rate) is greater than 20 inches annually. However, frequency and severity of winter rainfall and blizzards are becoming the key selection criteria. These facilities would provide 500 to 700 sq ft per lactating cow depending on the evaporation rate and 40 sq ft of shade per cow. Windbreaks are constructed in areas where winter weather is severe. It is important to realize that drylot housing does not allow the luxury of managing the risks that Mother Nature can present in the form of rain, snow, and severe windchill. The advantage of drylot facilities is the lower capital investment per cow as compared to freestall housing.

Freestall housing usually is selected to minimize the effect of weather changes and to improve cleanliness and cow comfort. Providing a clean dry bed is essential to minimize the incidence of mastitis in the herd. Comfort refers to providing a comfortable bed and the correct freestall dimensions. This makes it easy for the cow to move in and out of the stall and to lie comfortably in the stall. The disadvantages of freestall housing are the costs of construction and of maintaining the beds.

Selecting and Locating Freestall Barns

Several options are available when selecting freestall housing for lactating dairy cows. Some of the options include 2-row, 3-row, 4-row, or 6-row freestall barns. Access to feed is reduced by 11 inches per cow (Table 6) in 3- and 6-row barns compared to 2- and 4-row barns. The heat load per stall is greater in 3- and 6- vs 2- and 4-row barns at stocking rates of 100 to 130%. The advantage of 2- or 4-row freestall barns is access to feed, more sq ft per cow, and a lower heat load per stall. The advantage of 6-row barns is cost; however, producers should be concerned about the level of heat stress and the limited feeding area. Providing supplemental cooling in 6-row barns may be more critical because of the reduction in sq ft per stall.

Table 7. Available Feedline Space, Square Footage, and Heat Produced by Cows in Different Styles of Freestall Barns[1]

							Stocking Percentage (cows/stalls)			
Barn Style	Pen Width	Pen Length (ft)	# Stalls	Sq Ft/ Cow	Feedline Space	BTU'S/ Cow/ hr	100% BTU's/ sq ft	110% BTU's/ sq ft	120% BTU's/ sq ft	130% BTU's/ sq ft
4-Row	39	240	100	94	29	4500	48	53	58	63
6-Row	47	240	160	71	18	4500	64	70	77	83
2-Row	39	240	100	94	29	4500	48	53	58	63
3-Row	47	240	160	71	18	4500	64	70	77	83

[1]Based on a cow weighing 1500 pounds and producing 70 pounds of milk per day.

Ventilation and Orientation of Freestall Barns

Proper ventilation is essential in a freestall barn. Freestall housing should be constructed to provide good natural ventilation. Sidewalls should be 12 to 14 ft high to increase the volume of air in the housing area. The sidewalls should have the ability to open 75 to 100%. Fresh air should be introduced at the cow's level. Curtains on the sides of freestall barns allow greater flexibility in adjusting the environment around the cow. Because warm air rises, steeper-sloped roofs provide upward flow of warm air. Roof slopes for freestall housing with gable roofs should be 4/12. Gable roofs with slopes less than 4/12 may have condensation and cause higher internal temperatures in the summer. Providing openings on the end walls in addition to alley doors will improve summer ventilation. Gable buildings should have a continuous ridge opening to allow warm air to escape. The ridge opening should be 2 inches for each 10 ft of building width. Naturally ventilated buildings should have a minimum of 100 ft between structures. Freestall barns typically are oriented east to west to take advantage of sun angles and provide afternoon shade. Producers who construct barns north to south will find an overhang on the west side desirable to produce shade for stalls on that side of the barn during the afternoon. Freestall barns should be located within recommended walking distances to the milking center but not so close that natural ventilation is restricted.

Walking Distance

Facilities need to be sited to minimize the distance cows have to walk to and from the milking parlor. A forced walk in drylot housing would be from the gate of the housing area to the gate of the holding pen. Field observations in drylot facilities indicate that the maximum forced walking distance should be a 1000 ft for 2× milking, 700 ft for 3× milking, and 500 ft for 4× milking in drylot dairies. Field observation in freestall building reveals that cows begin to bunch up about halfway through the pen. It is not known if this bunching causes additional stress as compared to cows exiting drylot housing. So at this time, we estimate the forced-walk distance in freestall barns as one half of the alley length plus the distance from the top of the pen to the holding pen. Information is needed to establish the maximum forced walk in freestall barns.

Cow Traffic Lanes

The width of cow traffic lanes should be sized according to group size. When group size is less than 200 cows, 14-ft traffic lanes typically are used. Lane width is increased to 16 ft for group sizes from 200 to 300 cows and to 20 ft when group size is greater than 350 cows.

Water Availability

High-producing dairy cows can consume between 30 to 50 gal of water per day. Water should be provided to cows leaving the milking parlor. In parlors that are double 25's or smaller, one 8-ft trough is usually sufficient. In parlors larger than double 25's, two 8-ft troughs commonly are used. In freestall housing, water should be located at every crossover. There should be one waterer or 2 ft of tank perimeter for every 10 to 20 cows. In drylot housing in the southwest U.S., the following formula has been used to calculate the needed tank perimeter:

Group size × .15 × 2 = tank perimeter in feet

The water system must be able to provide 75 to 100 gal per cow per day. Peak flow rate is determined by number of waterers, assuming 100% utilization or milk parlor usage during cleaning. A minimum size well is probably 10 gal per min (gpm) per 100 cows with 20 to 30 gpm per 100 cows being preferred.

How Many Crossovers Do I Need?

Recommended distances between crossovers range from 60 to 160 ft. A good rule of thumb is to provide crossovers every 100 feet, or every 25 stalls. Crossovers are typically 10 to 12 ft wide. However, if a waterer is located in the crossover, consider increasing the width to 14 ft to allow cows to pass easily behind cows that are drinking. Producers often reduce the number of cross overs in freestall barns to reduce construction costs. However, very few producers stock feestall barns at one cow per stall. The tendency is to overstock them. Therefore, reducing the number of crossovers or the width of crossovers restricts access to feed and water, and limits the space for cows at the feed line. The bottom line is that the cows suffer when the number of crossovers is reduced.

Recommended Stall Dimensions

The dimensions used for constructing freestall area is a compromise between cow comfort and cow cleanliness (Table 8). The challenge is to construct stalls that make it easy for cows to lie down and get up naturally and comfortably, while positioning the cow to urinate and defecate in the alley. Stalls should be wide enough that cows normally do not bump or push on stall partitions in any way when rising or lying. But, stalls that are too wide may allow cows to turn around or lie diagonally. Stalls that are too long may allow lying too far forward unless brisket boards are used. All of these conditions increase the possibility of manure being deposited on the stall bed and dirty bedding. In hot climates, consideration to heat buildup in the freestall area may lead to wider (48 inches) and longer (8 ft) freestalls.

With two rows of freestalls placed head-to-head and designed for space-sharing, stall partitions usually are mounted on individual posts to allow for unrestricted open space for the forward lunge into the adjacent stall space.

It is important that building support posts are located at multiples equivalent to stall width. This will prevent building support post from obstructing the lunge space. Freestall width should determine building post spacing, not vice versa.

Table 8. Suggested Freestall Dimensions[1]

Weight, lb	Free Stall Width[2], inches	Free Stall Length[2], inches		Neck Rail Height above Stall Bed, inches	Neck Rail and Brisket Board Distance from Alley Side of Curb, inches
		Side Lunge	Forward Lunge		
800-1,200	42 to 44	78	90 to 96	37	62
1,200-1,500	44 to 48	84	96 to 102	40	66

[1]Width: "center-to-center" with 2-inch pipe partitions. Length: alley side of the curb to the front of the stall.
[2]Adapted from the Bickert and Smith (1998).

Grouping Strategies

The size and number of cow groups on a dairy are critical planning factors. Factors affecting the number and types of groups are largely associated with maximizing cow comfort, feeding strategies, reproduction, and increasing labor efficiency. Lactating cows (100%) are allotted to each of four groups; healthy (92%), fresh (4%), sick (2%), or slow milkers and lame (2%). Healthy cows should account for 92% of the total number of lactating cows and typically are divided into eight groups. Group size is determined by the size of the parlor and milking frequency.

Observations on commercial dairies indicate that a group should be milked in 60 min when milking 2× per day; 40 min when milking 3× per day; and 30 min when milking 4× per day. This will prevent the cows from being kept away from feed and water for more than 2 hrs per day. Within the eight groups of healthy lactating cows, individual cows are assigned to pens based on nutritional requirements, reproductive status, and social factors.

First, heifers respond favorably when grouped separately from older cows. Heifers have lower dry matter intakes and greater growth requirements than older cattle. In addition, mixing heifers with older cattle increases social pressure, resulting in less than optimal heifer performance. Heifers should be kept in separate groups and divided based on reproductive status. Heifers could be grouped as open-not breeding, breeding, and pregnant. This increases labor efficiency during breeding by concentrating all breeding activities to one pen. The remaining healthy lactating cows are allotted to groups by reproductive status and nutritional needs. Nutritional requirements for these groups vary, and as above, concentrating breeding activities maximizes labor efficiency. One disadvantage to the above grouping scheme is the need to move cows from pen to pen.

Movement of cattle increases labor requirements and disrupts the social order in a pen. Usually, 3 to 4 days are required to reestablish social order when cattle move to a new pen. The results are reduced feed intakes and lost milk production. Therefore, some producers have chosen to freshen cows as a group and maintain the group throughout lactation. Rather than moving the cows to correct diet or management area, this strategy brings the diet and management to the cow. The difficulty in this system is calving enough cows to fill a pen in less then 30 days.

In addition to the healthy lactating cows, some of the lactating cows will have special requirements. Separating fresh, sick, and lame or slow milking cows increases parlor and treatment labor efficiency as well as reducing stress on the cattle. Fresh cows will account for 4% of the healthy herd size assuming that the number of calvings annually is 115% of lactating cows. The fresh cows should be housed in a loose housing pen for 10 days. Provisions must be made to segregate non-salable milk. Careful attention to intake, milk production, health, and cow comfort is necessary for cattle in this pen to prosper. The sick pen should handle 2% of the healthy lactating cows. Removal of sick cattle from the healthy pens is necessary for efficient treatment, to prevent antibiotic contamination of milk, and increase cow comfort. Fresh and sick pens should be bedded with sand to maximize cow comfort. Lame and slow milking cows often are housed in the same pen and located close to the milking parlor. Removing slow moving or slow milking cows from the other pens will increase parlor efficiency 8 to 10%. Lame or slow milking cows will be about 2% of the healthy lactating cows and can be housed in freestalls.

On large dairies, nonlactating cattle should be divided into five groups defined as maternity, overconditioned dry cows, underconditioned dry cows, close-up dry cows, and close-up heifers. Nutritional needs of these groups vary greatly, and grouping of these heifers and cows according to nutritional requirements is critical to minimize subsequent metabolic problems associated with calving. Ideally, cows calve in individual maternity pens. Close attention to close up pens allows cows that are just beginning the calving process to be moved to the calving pens. Cows normally stay in the maternity pen less than 24 hours. The number of maternity pens needed is approximately equal to .33% of the total milking cows. Dry cows and springing heifers differ in nutritional requirements. Dry cows have greater intakes and are much more likely to develop milk fever than heifers. Springing heifers also may benefit from a longer transition period than normally allowed for cows. Thus, heifers and dry cows should be separated.

Dry cows more than 21 days from calving should separated into two groups, based on body condition. Cows lacking adequate body condition benefit from additional energy during the dry period, whereas feeding extra energy to adequately conditioned cows may be detrimental. Dry cows within 21 days of calving should be moved to a close up pen. The diet in this pen should have greater concentrations of protein and energy than the far off dry cow diet. In addition, the diet should be low in calcium and potassium or contain anionic salts with appropriate amounts of calcium and potassium to prevent milk fever. Milk fever is generally not a problem with heifers, but they may benefit from receiving the typical transition diet for 5 weeks rather than 3 weeks. Thus, feeding a diet fortified with protein and energy without anionic salts for 5 weeks prior to freshening would be beneficial for heifers.

These plans do not include a quarantine area. True quarantine pens should be located away from this facility. If a true quarantine period were desired, springing heifers would need to be received at another facility, at least 1 month prior to moving to this facility. In general, this is not the typical practice. Thus, the overflow pen will generally be utilized as the receiving pen for replacement heifers. Examples of preliminary sizing are presented in Table 9.

Table 9. Preliminary Sizing of Dairy Facilities with Different Parlor Sizes[1]

Item	Approx. % of Milk Herd	Double 10	Milk Parlor Size Double 20	Double 30	Double 40	Double 50
Steady state throughput[2]		90	180	270	360	450
Total lactating cows	100	600	1,200	1,800	2,400	3,000
Milking group size[3]		70	140	210	280	350
Healthy lactating cows	92	560	1,120	1,680	2,240	2,800
Sick cows[4]	2	10	20	35	45	60
Fresh	4	20	40	70	90	120
Slow milking or lame cows	2	10	20	35	45	60
Maternity	0.33	2	4	6	8	10
Dry cows and heifers	25	150	300	450	600	750
Freshened cows per year	115	690	1,380	2,070	2,760	3,450
Over-conditioned dry cows	5	30	60	90	120	150
Under-conditioned dry	5	30	60	90	120	150
Close-up dry cows	5	30	60	90	120	150
Close-up heifers	5	30	60	90	120	150
Close-up - overflow pen	5	30	60	90	120	150

[1]Design based on 3× milking, 6.5 hours of steady throughput, 1.5 hours for parlor turn time (maintenance, clean up, etc). [2]Milk parlor performance is based on steady-state throughput at 4.5 turns per hour. [3]Milk groups based on 8 groups of cows with a milking time per group of 45 minutes and rounded to accommodate the parlor. [4]Assumes the sick, fresh, and slow milking or lame cows will be milked in the same parlor during a 1.5 hour turnaround period.

Site Evaluation and Selection

Preliminary site evaluation includes land availability for the facilities, crop production, and manure disposal. Generally, land for crop production and manure application is rented or owned by a partner. Immediate and future environmental consideration suggest that 1 to 2 cows per acre of land would be required for manure application. This is based on phosphorus being the limiting nutrient, which likely becomes the standard in most areas. Currently, many use 5 to 10 cows per acre, but the potential exists for excessive nutrients, primarily phosphorus and potassium, being applied to the land unless a crop consultant is used to monitor nutrient accommodation. Other factors such as waterways, separation distances, and neighbors may limit the area where manure can be applied.

The facilities, buildings, feed center, and waste management system will require approximately 1 acre per 75 to 100 cows. Initial site evaluation must consider the availability of three-phase electricity, water accessibility, and sewer (manure storage and handling). If any one of these items appears cost prohibitive or not feasible to achieve, another site should be considered. Other factors to consider include:

- Access by milk and feed trucks
- Separation distance from other buildings for good natural ventilation
- Prevailing wind direction (affects ventilation and odor problems)
- Distance from neighbors and town, surrounding land use
- Distance from all surface water (rivers, streams, lakes, and wetlands)
- Soil type (affects waste management)
- Depth to water table and bedrock
- Drainage and slope
- Availability and quality of the water supply, and
- Availability of cropland for utilization of manure nutrients.

The layout of the complete dairy operation will be determined based on plans for:

- Freestall barns (e.g., number of groups, stall layout)
- Milking center
- Treatment and maternity facilities
- Dry cow, close-up dry cow, and fresh cow facilities
- Calf and heifer housing (if needed)
- Handling and storage of manure and milking center wastewater
- Collection and storage of runoff from outside lots, and
- Storage facilities for corn silage, haylage, dry hay, or commodity feeds

Complete plans for waste handling, storage, and land application must be developed by a consulting engineering and dairy design team.

All regulatory agencies must approve the plans before any construction begins (e.g., health department, milk inspector, designated manure regulatory agency, or local government).

Manure Management

Dairies will generate 2 to 3 lb of manure and wastewater per lb of milk produced. Most dairies use a flush system to transport the manure from the alleys, pens, or housing area to the storage area. Experiences in Kansas suggest that flushing wave velocity needs to be 7.5 to 10 ft/second with a 20 second contact time to adequately flush alleys alongside of sand-bedded freestalls. Flushing is improved by sloping the buildings 2 to 3%. Freestalls bedded with sand use an average of 50 lb of sand per cow per day. Dairies are experimenting with gravity and mechanical sand separators to reclaim the sand. Gravity systems generally require stockpiling of the reclaimed sand 6 to 12 months prior to reuse or blending with clean sand.

The manure and effluent generally are stored in a solids storage basin and liquid storage lagoon. These structures have to meet state or federal guidelines or both. The solid storage basin normally is built as economically as possible. However, this may not be the most cost-effective decision. Operations that have weekly or monthly hauling invariably will keep cropland out of production to have adequate land available for solid manure disposal. Cropping practices should be considered during the design stage. Effluent from lagoons is applied to growing crops, if possible. This requires having adequate land available to install irrigation equipment for maintaining storage volume. Stockpiling on berms or at the edge of fields to provide additional storage space results in additional handling and containment structures to control nutrients leaching from the stockpile area.

Putting the Pieces Together

This article presented some of the issues concerning planning an expansion or relocation. Its focus was on facility issues that influence cow productivity and labor efficiency. Space is not sufficient to include detailed information on the layout of the feed center, replacement heifer housing, and the manure management system. The design and layout of these two components are critical to ensure that the dairy runs smoothly. It is essential that a consulting engineer be used to design all components of a dairy.

CHANGES IN THE TEXTURAL QUALITY OF SELECTED CHEESE TYPES AS A RESULT OF FROZEN STORAGE[1]

K. A. Schmidt and T. J. Herald

Summary

The change in textural quality of cheese during frozen storage is of concern to the frozen food industry. Many food products such as frozen pizza and dinner entrees are stored at 0.5°F or below for extended periods of time. Food manufacturers have noted detrimental changes including reduced elasticity of cheese on pizza or the absence of melt in filled products. Dynamic rheological testing was used to determine the changes in Cheddar, Colby, and Mozzarella cheeses during frozen storage. Slices of cheese were tested at day 0 and after 30 days of storage at 0.5°F. Elastic attributes were measured at 40, 70, and 194°F. Results indicated that frozen storage reduced the elastic properties of all three cheeses. When cheeses were subjected to higher temperatures, the elastic properties decreased. These changes could be attributed to proteolysis, chemical composition, and component interactivity. Dynamic testing is rapid and may be a method of choice for cheese manufacturers to determine shelf life and quality.

(Key Words: Cheese, Melting Properties, Frozen Storage.)

Introduction

Frozen, prepared meals are becoming popular food choices for many people, and the demand for good-tasting, easy to prepare foods has increased each year. Frozen, prepared foods often contain cheese (e.g., pizza, Mexican-style food, pocket sandwiches), reflecting the increased demand for cheese in the U.S. and the increased practice of using cheese as an ingredient in tasty, nutritious foods.

Cheeses are consumed for flavor and texture. Cheese on pizza is expected to string and be chewy, whereas cheese used for frozen Mexican food should melt and become part of the filling. This can be a challenge to cheese and food manufacturers, because cheese is a dynamic system that continues to change in flavor and texture over time.

During the manufacture of cheese, an important processing step is the aging period. That is when enzymes react to create the unique textures and flavors associated with specific cheese varieties. For centuries, most cheeses were aged at cool to ambient temperatures, but in this century, frozen storage has become an accepted practice. The change in storage temperature greatly alters enzyme activities and rates. Therefore, flavor and texture development may not be consistent with those of a traditionally aged cheese.

Cheese texture is determined primarily by the pH and the ratio of intact casein to moisture. The texture generally changes markedly in the first 1 to 2 wks of ripening as a small fraction of á$_{s1}$-casein is hydrolyzed by residual rennin to the peptide á$_{s1-1}$casein, resulting in a general weakening of the casein network. The relatively slow change in texture thereafter is determined mainly by the rate of proteolysis, which, in turn, is controlled largely by the proportions of residual rennin and plasmin in the cheese, salt to moisture

[1]Partially funding by the Kansas Dairy Association.

ratio, and storage temperature. Final cheese texture can range from springy to plastic to noncohesive, depending on pH and calcium content.

To evaluate the texture of cheese, different approaches can be taken. However, the most common one is to apply a defined force (strain) to the cheese sample and then measure the "cheese's response" (stress). Normally, the stress can be perceived as a deformation. But depending upon the temperature and the type of force, the cheese may respond by flowing. Thus, cheese is considered to be a viscoelastic food, having properties that are both elastic (shape change referred as storage modulus in units of G) and viscous (flow movement referred as loss modulus in units of G). The proportion of these characteristics in a food often reflects the protein, fat, and water binding properties. Understanding the rheological properties of cheeses may help to control functional properties and, thus, increase the demand for cheese. Thus, this study was undertaken to determine how a frozen storage period (30 days at 0.5°F) affects the elastic properties of Cheddar, Colby, and Mozzarella cheeses.

Procedures

Sharp Cheddar, Colby, and Mozzarella cheeses (of the same national brand) were purchased from a local grocery store (Manhattan). Rectangular cheese slices 2×2×.15 inches were cut using a meat slicer. Slices (with waxed paper in between) were vacuum packaged to prevent dehydration. The cheese samples were stored at 0.5°F until the day of measurement. Samples were allowed to equilibrate at 39°F for ease of separation of the cheese slices prior to testing.

Oscillatory measurements were carried out with a Bohlin VOR rheometer to determine the storage moduli (G) of the cheese samples. The viscoelasticity of the cheese was measured as a function of frequency between 0.1 and 10 Hz at isothermal temperatures of 40 ± 0.5°F, 73 ± 1°F, and 194 ± 2.0°F that were maintained with a circulatory water bath. The rheometer was equipped with a serrated 2.36 inch-diam. bottom plate and serrated 1.18 inch-diam. top plate to reduce slippage. The gap between the parallel plates was 0.15 inches The sample was held 4 min for temperature equilibration and 3 min for cheese relaxation. Initial strain sweep experiments were conducted to determine the linear viscoelastic region for the cheeses. A plot of complex modulus vs. strain at 1 Hz showed linear behavior up to about 0.005 strain. These results are in agreement with previous published data. Thus, a 0.002 strain was selected for all measurements to avoid deforming the cheese to the extent that the gel structure was compromised. A 93.54 g-cm torque bar was used.

Two replications were done on all cheeses. Data reported are averages of these replications.

Results and Discussion

Table 1 shows the typical compositions of Cheddar, Colby, and Mozzarella cheeses. Although protein content appears to be fairly consistent in the three varieties, great differences can be seen in the fat, moisture, and salt contents. Therefore, differences in the textures of these cheeses are expected. Mozzarella cheese is a young cheese, which means that it is eaten soon after production (2 wks). Usually by 10 wks of refrigerated storage, the cheese loses its melting and shredding abilities because of rapid protein breakdown. Colby cheese is also a young cheese, but usually is aged for several weeks before consumption. However, by 4 mo after production, it usually possesses strong flavors that are uncharacteristic for Colby cheese. Cheddar cheeses are aged, and as aging time increases, flavors become more strong and textures become more crumbly.

Storage (G) moduli (1 Hz) of the cheeses at 40, 73, and 194°F are shown in Figures 1, 2 and 3 respectively. At any given frequency, the G value was greater than G (not shown), indicating a dominant elastic character of all three cheeses. Although, both G and G exhibited frequency dependency throughout the range tested, no G -G crossover was present for any of the cheeses.

These results suggest that the cheeses are "physical gels" in contrast to gels that show very little frequency dependence and are designated as covalent gels (very firm). Practically, the lack of crossover means that the gels remained in the same state throughout the frequency range tested and didn't change from a hard to a soft gel or from an elastic to a viscous gel.

Table 1. Typical Chemical Compositions (%) of Cheddar, Colby, and Mozzarella Cheeses

Cheese	Fat	Protein	Moisture	Salt
Cheddar	32	25	37	2
Colby	30	25	39	1.7
Mozzarella	18	22	53	0.7

Figures 1, 2, and 3 show that as test temperatures increased, storage moduli at 0 days decreased for all cheese varieties. This is probably a reflection of a greater proportion of the milk fat in the liquid state (melting), which would contribute to the viscous component of the cheeses. This overall trend agrees with previously reported results.

At each test temperature, the storage moduli varied among cheese varieties. This can be explained by the results in Table 1. The protein and solids contents varied in each cheese variety. In addition, the integrity of the casein network should be very different for the three cheeses. For instance, Mozzarella cheese has a high proteolytic activity, whereas sharp Cheddar (aged for > 6 mo) should exhibit signs of proteolytic behavior. However, Colby, a young cheese, should have the most intact casein network. The results at 40 and 194°F agree with these differences. At both temperatures, regardless of the amount of fat, the state of fat (proportion liquid to solid) should be fairly consistent -- relatively solid at 40, but liquid at 194°F. However, this relationship was not seen at 73°F. Thus, the data indicate that the total solids content may be the predominant contributor to the G value of these cheese varieties. For all three varieties, the milk fat should be in both liquid and solid states. Also, it should be incorporated into the casein network. But the production of these three varieties of cheese allows for different types of protein-fat interactions. Thus, the nature of these interactions may contribute to the elastic component of these cheeses. Another consideration should be the casein network itself, where the fibrous structure that is present in the Mozzarella cheese may not allow for as much fat or water binding. Therefore, the water and melted fat may contribute to the viscous phase vs being associated with the elastic component as in the Cheddar or Colby cheeses.

When the results after 30 days of frozen storage (also shown in Figures 1, 2, and 3) are considered, the interpretations become more complicated. Even though some research shows that aging results in lowering the G , freezing of dairy protein overrides that effect to result in an increase in G . Because the proteolytic system of Mozzarella cheese is very fast, and the texture generally deteriorates to an unsaleable condition within 10 weeks, we would expect the G values to decrease after frozen storage. In tests at 40°F after frozen storage, G values did decrease for Mozzarella cheese but increased for Cheddar and Colby cheeses. Thus, these results confirm that the proteolytic enzymes in Mozzarella cheese continued to degrade the $á_{s\text{-}1}$ casein during storage. However, the increased elasticity of the other two cheeses may support the theory of reorganization of the casein network resulting from the casein being dehydrated (water removed) during frozen storage. Thus, if the elasticity is a result of interactions among components, a reorganization of these interactions would be expected to lead to a different structure that would have a different elasticity character.

However, these trends were not consistent at the other two testing temperatures, 73 and 194°F. This suggests that the storage moduli are affected not only by the order of the casein network and the extent of protein degradation but also by the physical state of the fat and the binding of components with one another.

Conclusions

Frozen storage, even for a short period of time (30 days), seems to induce reorganization of the casein structure and affect not only casein-casein interactions, but probably also interactions with fat and water in Cheddar, Colby, and Mozzarella cheeses. Thus, the storage moduli of the cheeses are affected by many factors. Probably, the net result of proteolysis, chemical composition, and component interactivity defines the elastic and viscous components of the product. This research showed that the conclusions drawn about the changes in viscoelastic properties of cheeses as a result of frozen storage are highly dependent upon the testing conditions. Obviously, the physical states of the fat and water can affect these properties. This study has given evidence that cheese can be used in frozen foods; however, the viscoelastic properties of the cheese will change over time. And even though the elastic component is minimal when cheese is heated, it is still affected by the storage conditions.

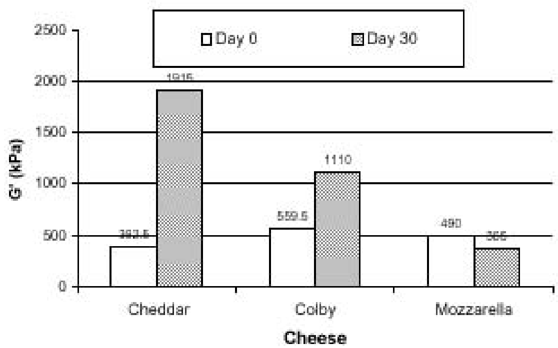

Figure 1. Storage Modulus (G′) of Various Cheeses Determined at 1 Hz and Measured at 40°F before and after Storage at −0.5°F for 30 Days.

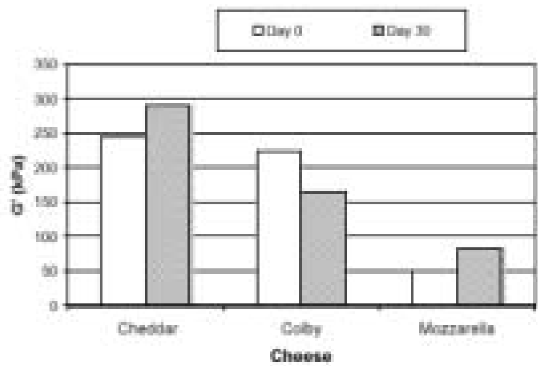

Figure 2. Storage Modulus (G′) of Various Cheeses Determined at 1 Hz and Measured at 73° F before and after Storage at −0.5° F for 30 Days.

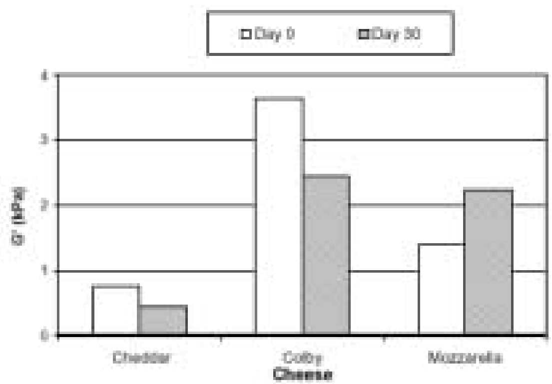

Figure 3. Storage Modulus (G′) of Various Cheeses Determined at 1 Hz and Measured at 194° F before and after Storage at −0.5° F for 30 Days.

WATER REMOVAL FROM RAW MILK AT THE POINT OF PRODUCTION

I. Cox, H. Dingeldein, and K. Schmidt

Summary

Milk processing plants are becoming fewer in number and larger in size. As a result, the distance the raw milk is transported from the point of production to the processing site increases. Because the major component in raw milk is water, the reduction of water at the production site would result in lower transportation costs as well as lower energy needs. Water can be removed from milk through a membrane filtration. This study showed that concentration of raw milk allowed for the microbes to partition into the milk solids fraction. Microbial numbers increased during refrigerated storage of this concentrated raw milk.

(Key Words: Ultrafiltration, Total Plate Counts, Coliform Counts.)

Introduction

The number of fluid milk processing plants has decreased steadily throughout the U.S. in the last 20 years. This decrease means that the distance that milk is transported from point of production (farm) to point of processing (plant) and transportation costs have increased.

Raw milk is a mixture of water, protein, lactose, fat, vitamins, and minerals. The greatest component by far is water, ranging from 83 to 87%. Almost all nonfluid dairy products (ice cream, cheese, yogurt) are concentrations of one (or more) component(s) of milk, which usually involve a water removal step during manufacturing. Reverse osmosis (RO) and/or ultrafiltration (UF) processing technologies are being used to remove water or water and some smaller sized components from milk or whey, the by-product of the cheese industry. In these processes, milk is passed over a membrane; membranes vary in pore size, so that specific-sized molecules (water, minerals, or lactose) can be removed from the milk. Thus, the milk product can be concentrated without a severe heat treatment. The fraction that passes through the membrane is called "permeate" and contains water and perhaps some lactose and minerals. The fraction that does not pass through the membrane is called "retentate" and contains the protein, fat, some lactose and minerals, and water. The selective removal of specific milk components has been exploited successfully in the cheese industry. But this technology also has applications on the farm, where partial water removal may result in decreased transportation and cooling costs and lower requirements for holding space.

Such a system is being utilized in New Mexico, where several farms use RO to remove some water before milk is sent to the cheese plant. The New Mexico Department of Agriculture and the U.S. Food and Drug Administration (FDA) placed strict processing requirements on this operation, such as maintaining milk temperature below 45°F at all times, using a maximum processing time of 8 minutes, and applying current raw milk standards for microbiological and somatic cell qualities to the retentate. At this point, FDA has given approval for the use of the RO retentate only for the cheese industry. However, the successful application of this technology easily could spread to other dairy foods industries. Thus, the objective of this study was to investigate how UF of raw milk affects microbial and somatic cell counts.

Procedures

Raw milk was obtained from the KSU Dairy Research and Teaching Center and transported to the KSU Dairy Plant. One hundred gallons were split equally. One 50-gal batch was left intact, whereas the other one was inoculated with a microbial culture to produce a raw milk product with higher microbial counts.

Fifty gallons of raw milk were ultrafiltered to 1.5× (37.5 gallons) and 2× (25 gallons) concentration within 24 hours of milking. Ultrafiltration was done on an ABCOR ultrafiltration pilot system using a spiral wound membrane (Koch Membrane System, Minneapolis, MN) operated at < 7°C at all times. Samples were collected at 1× (raw milk), 1.5× and 2× for both permeate (what went through the membrane) and retentate (concentrated raw milk). The samples were analyzed for coliform counts, total plate counts (TPC) of aerobic bacteria, and somatic cell counts as well as solids content. Bacterial counts were enumerated using appropriate Petri-Film®, and solids were determined in a forced air oven following standard methods at the KSU Dairy Plant. Somatic cell counts were quantified at the Heart of America DHIA Lab (Manhattan, KS) using Somacount 500 (Bently Instruments, Inc.). Samples were analyzed for microbial quality at three different times, immediately after processing and after 24 and 120 hrs (5 days) of refrigerated (<45°F) storage. Duplicate samples were assayed at all times, and results are reported as averages. Ultrafiltration was done on three different days in July, 1999 to achieve representative results. All results are reported as averages of the three replicates.

Results and Discussion

Table 1 shows the total solids of the permeate and retentate fractions of milk. The average total solids content of milk is 12.5%. The solids content of the permeate fraction shows that UF removes not only the water but also some of the solid material from milk, predominately lactose and minerals.

Table 1. Total Solids (%) of Retentate and Permeate Fractions of Raw Milk Ultrafiltered to Two Different Concentrations

	Concentration	
Fraction	1.5×	2.0×
Retentate	14.40 ± 0.30	19.58 ± 0.18
Permeate	5.45 ± 0.03	5.72 ± 0.19

Table 2 shows the results of the microbial partitioning after UF of raw milk. Almost all microbes partition into the retentate fraction. No differences in microbial numbers were detected between concentration samples, thus verifying that the pore size was smaller than the bacteria and would not allow the bacteria to concentrate into the permeate fraction. Thus, after one pass, theoretically, almost all of the microbes should be in the retentate fraction. This explains the fact that the numbers of microbes remain the same for the concentration factor as well as over UF time. However, during storage time, the microbial numbers increased (as expected), although temperatures were maintained below 45°F throughout the study. Because the microbial numbers in the retentate after 5 days of storage were less than 100,000 CFU/mL, this retentate would be considered legal, at least from a TPC standpoint for a single producer.

However, when the initial raw milk contained greater concentrations of bacteria, the acceptance results changed. Table 3 shows the results for milk that contained ~80,000 CFU/mL of bacteria. The same patterns emerge as shown in Table 2; the majority of the microbes partitioned into the retentate. The concentration factor had little effect on the microbial numbers, and they increased with time. Within 24 hrs, the microbial numbers of the retentate increased above the maximum for total number of aerobic bacteria allowable from a single producer. By 5 days of storage, this retentate had very high counts and would be considered unacceptable for a fluid milk processor.

Two obvious conclusions can be made from the results in Tables 2 and 3. One, UF needs to be done just before milk pickup (perhaps 4 to 6 hrs). Two, raw milk with high microbial counts may not be suitable for this technology, because the concentration process may induce higher counts than are acceptable for raw milk.

Table 2. Total Number of Aerobic Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltered Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	12,000		22,000		61,000	
1.5×	<1	18,000	4	30,000	11	64,000
2.0×	<1	17,000	6	39,000	11	62,000

Table 3. Total Number of Aerobic Bacteria (CFU/ml) in Inoculated Permeate (P) and Retentate (R) of Ultrafiltered, Inoculated Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	81,000		150,000		500,000	
1.5×	<1	90,000	4	170,000	17	560,000
2.0×	<1	97,000	4	260,000	16	570,000

Although no standards exist for coliform bacteria in raw milk, it is generally accepted that few fluid milk processors want to accept raw milk with coliform counts higher than 100 CFU/mL. High coliform counts can be responsible for unacceptable off flavors and odors and are indications of poor sanitation practices. Thus, coliform counts were tracked in this study and the results are shown in Tables 4 and 5 for the uninoculated and inoculated raw milk trials. As can be seen in these tables, the same patterns emerge as with the aerobic bacteria. The majority of coliforms will partition into the retentate and then will continue to multiply over time.

As with the bacteria, the somatic cells also partitioned into the retentate (Table 6). Because somatic cells should not increase during time nor could they be added artificially to the raw milk prior to UF, samples were checked only once. Inoculation with bacteria did not affect the partitioning of the SCC or the bacteria. Results generally remained the same. And for all samples, the retentate met the standard for SCC in raw milk.

Conclusions

This study shows the usefulness of UF just prior to milk pick-up. For a producer to use such technology on his/her operation certain guidelines should be in place, such as high quality milk (low microbial and somatic cell counts). Ultrafiltration should occur prior to pick up and be used within a short period of time at the processing facility. But as of today, this technology is not approved for on-farm use in Kansas. However, the results presented in this study show that high quality raw milk can be maintained while using this technology and result in a volume reduction. As more data are collected and critical control points established and controlled, the FDA will consider UF as an on-farm process.

Table 4. Total Number of Coliform Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltered Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	5		38		180	
1.5×	<1	6	<1	31	<1	150
2.0×	<1	6	<1	25	<1	140

Table 5. Total Number of Coliform Bacteria (CFU/ml) in Permeate (P) and Retentate (R) of Ultrafiltrated, Inoculated Raw Milk Stored for up to 5 Days

	Time, hrs					
	0		24		120	
Concentration	P	R	P	R	P	R
Raw milk	19		28		750	
1.5×	<1	21	<1	31	<1	790
2.0×	<1	13	<1	25	<1	770

Table 6. SCC in Retentate and Permeate of Inoculated and Uninoculated Raw Milk

	Retentate		Permeate	
Concentration	Uninoculated	Inoculated	Uninoculated	Inoculated
Raw milk	315	320	0	0
1.5×	447	530	0	0
2.0×	443	361	0	0

USING THE OVSYNCH PROTOCOL FOR PROMPT RE-INSEMINATION OF COWS DIAGNOSED OPEN AT PREGNANCY CHECKS

J. S. Stevenson

Summary

Using the Ovsynch protocol to prepare cows for re-insemination proved to be very effective. Its use guarantees that all cows found open at pregnancy diagnosis are re-inseminated promptly within 10 days, and the average pregnancy rate of 28.7% in 136 cows was acceptable. Pregnancy rates were not different whether or not estrus was detected in cows at the timed insemination, but they tended to be greater at second services compared to other repeat services. The Ovsynch protocol is an effective tool to use to ensure prompt re-insemination of open cows.

(Key Words: Ovsynch Protocol, Open Cows.)

Introduction

Finding cows not pregnant at pregnancy diagnosis is frustrating. But what is done at that time is critical for getting those cows inseminated as quickly as possible. The reason for diagnosing pregnancy is to identify the nonpregnant cows!

Traditionally, the recommendation for handling open cows was for the veterinary practitioner to palpate the ovaries and determine if a functional corpus luteum (CL) was present that should respond to an injection of prostaglandin $F_{2á}$ (PG). When a cow has a functional CL, PG induces luteolysis (death) of the CL, allowing the cow to come into estrus in the next 2 to 5 days. Although this method is the best practice to follow to prepare cows for prompt re-insemination, it has two disadvantages: 1) errors in palpation and 2) missing expressed heats of cows because of inadequate heat detection. The first disadvantage occurs because palpation is difficult and not always accurate. For example, the probability of finding a CL and then diagnosing it to be functional (able to respond to PG) is about 80%. In addition, the probability of not palpating a functional CL when it is present is about 30%. The second disadvantage of using PG, even when the diagnosis of a functional CL is accurate, is that not all estrus activity after PG is observed. As a result, too many cows are not promptly re-inseminated and can become “lost” in the herd, until they are either detected in heat or later “found” in the herd after analysis of records.

Using the Ovsynch protocol may be one solution to this problem. The Ovsynch protocol is accomplished by injecting gonadotropin-releasing hormone (GnRH) 7 days before PG. About 48 hrs after PG, a second injection of GnRH is given followed by insemination about 16 to 18 hrs later. The objective of this demonstration was to determine the effectiveness of using the Ovsynch protocol to re-inseminate promptly all cows palpated open at pregnancy diagnosis.

Procedures

Beginning in October 1998, when lactating cows were palpated open at our twice monthly pregnancy checks, cows were injected with 1 cc of GnRH (50 µg of Cystorelin®, Merial, Iselin, NJ). The following Monday afternoon (7 days later) between 3 and 5 p.m., each cow was injected with 25 mg of PG (Lutalyse®, Pharmacia and Upjohn, Kalamazoo, MI). On Wednesday (48 hrs after the PG injection), each cow was given a second GnRH injection and then inseminated 16 hrs later on Thursday morning. Anytime a cow was detected in heat after the initial injection of GnRH at pregnancy diagnosis, she was inseminated according to detected estrus, and the remaining protocol was discontinued. The percentage of cows conceiving was determined by either palpation of uterine contents after 38 days or by return to estrus following insemination.

Results and Discussion

The average pregnancy rate achieved by this demonstration in 136 cows was 28.7%. Of 136 cows begun on the Ovsynch protocol, 14 (11.1%) were detected in estrus before the protocol was completed and inseminated based on signs of heat. Only one of those 14 cows conceived (7.1%), whereas 38 of the remaining 122 cows that completed the Ovsynch protocol conceived (31.2%).

Of those cows detected in estrus before the completion of the Ovsynch protocol, one was in heat 4 days after pregnancy diagnosis, two on the fifth day, three on the seventh day (day of PG injection), four on the eighth day (1 day after PG injection), and four on the ninth day (day of second GnRH injection).

Of those detected in estrus (19.3%) at the time of the second GnRH injection or at the timed breeding of the protocol, pregnancy rates were 26.1% compared to 29.5% in those cows that were not observed in estrus.

Pregnancy rates were classified according to the ovarian structures palpated at the time of pregnancy diagnosis (Table 1). Pregnancy rates were similar whether or not a CL was palpated along with at least one palpable follicle. Three of four cows with at least one large, cystic follicle conceived indicating that the Ovsynch protocol may be an effective treatment for this ovarian abnormality.

The pregnancy rate for cows inseminated for the second time since calving averaged 44.8% and tended ($P<.10$) to be greater than that in all other cows that were inseminated at other repeat services (24.3%). Pregnancy rates were very similar for cows inseminated for either the third (25%), fourth (23.1%), or fifth or more times (24.3%).

These results indicate that the Ovsynch protocol is an effective tool, because it guarantees that all open cows are re-inseminated within 10 days after their pregnancy status is determined and achieve acceptable pregnancy rates.

Table 1. Pregnancy Rates Based on Palpated Ovarian Structures

Ovarian Structure	No.	% of Total	Pregnancy Rates, %
CL + follicle(s)	77	56.6	28.6
Follicle(s)	47	34.5	25.5
Cyst	4	2.9	75.0
No significant structures	3	2.2	66.7
Unknown	5	5.9	0.0

PREGNANCY RATES IN DAIRY CATTLE AFTER THREE DIFFERENT, TIMED, BREEDING PROTOCOLS[1]

J. A. Cartmill, S. Z. El-Zarkouny, G. C. Lamb, and J. S. Stevenson

Summary

Synchronizing ovulation enables dairy producers to inseminate cows by appointment rather than after detected estrus. Three different, timed artificial insemination protocols using different combinations of prostaglandin $F_{2\alpha}$ and gonadotropin-releasing hormone were used to synchronize ovulation in 702 lactating Holstein cows. Cyclicity, pregnancy rate, and embryonic survival rate from each treatment were compared. Our results indicate that all three treatments produced acceptable pregnancy rates in first lactation cows. However, for cows in their second or greater lactation, the treatment using prostaglandin $F_{2\alpha}$ 12 days before the Ovsynch protocol improved pregnancy rates more than the other two.

(Key Words: Ovsynch Protocol, Pregnancy Rates, Timed AI.)

Introduction

The objective of this experiment was to determine the merits of three protocols to synchronize ovulation prior to timed artificial insemination (TAI). A successful breeding program that allows a dairy producer to inseminate all cows by appointment after a voluntary waiting period without estrus detection potentially could decrease the number of cows remaining nonpregnant later in lactation.

The Ovsynch protocol has been adopted by dairy producers because of its acceptable conception rates. This protocol consists of two injections of gonadotropin-releasing hormone (GnRH); one given 7 days before prostaglandin $F_{2\alpha}$ (PG) and the second given 48 hrs afterwards. Cows then are inseminated 16 to 20 hrs after the second GnRH injection.

Previous research indicated that conception rates were greater in dairy cows when they began the Ovsynch protocol between days 5 and 12 of the estrous cycle (day 0 = estrus). Therefore, we formulated a treatment in which one injection of PG was given 12 days before initiating the Ovsynch protocol, so a greater percentage of cows would be between days 7 and 10 of the cycle when it began. In addition, we compared those two protocols (Ovsynch and PG + Ovsynch) to a treatment in which cows were given two injections of PG 12 days apart, followed 48 hrs later by an injection of GnRH, and TAI 16 to 20 hrs later.

Procedures

Cows on two dairy farms were grouped into 3-week breeding clusters as they calved, resulting in 17 clusters in one herd and 25 clusters in another. Cows then were assigned randomly to each of three treatments before TAI was carried out between 57 and 77 days postpartum. Inseminations were performed between July 1997 and February 1999, excluding the months of June through November 1998.

[1]Thanks to Steve Ohlde and Ohlde Dairy, Linn, KS, for their cooperation in this study and to the Kansas Dairy Association for partial funding.

Figure 1 shows the treatments: Ovsynch (OVS), Ovsynch preceded 12 days earlier by a single injection of prostaglandin $F_{2\alpha}$ (PG + OVS), and two injections of PG 12 days apart with a single injection of GnRH 48 hrs after the second PG injection (2 × PG12). All cows received TAI between 16 and 20 hrs after the second injection of GnRH. Blood samples were collected from the tail vein of each cow at the time of injection (days −22, −15, −10, −3, and −1) regardless of treatment. Concentrations of progesterone in blood serum were measured to determine whether or not the cow was cycling before the onset of treatment. Pregnancy was confirmed by transrectal ultrasonography at 28 days postinsemination and reconfirmed by palpation of the uterus at 40 to 54 days by the herd veterinary practitioner.

Cows were milked 2× daily and housed either in freestall barns bedded with sand or in a tie-stall barn. Cows were fed a total mixed ration consisting of chopped alfalfa, corn silage, whole cottonseed, and concentrate-mineral mix to meet or exceed their daily requirements for maintenance and milk production.

Results and Discussion

The proportion of cows cycling (elevated progesterone in their blood indicative of a functional corpus luteum) varied from 81 to 86% and was not different among treatments (Table 1).

Overall, pregnancy rates were greater (P<.01) in cows with previous cycling activity than in those with low progesterone concentrations on days 22, 15, and 10 before insemination, 39 vs 25% at 28 days and 29 vs 17% at 40 to 50 days.

Table 1. Percent of Cycling by 45 to 65 Days in Milk

	Treatments[1]		
Item	Ovsynch	PG + OVS	2 × PG12
No. of cows	230	234	241
% cycling	86	81	83

[1]See Figure 1.

Pregnancy rates are summarized by treatment and lactation number in Table 2. Overall, first lactation cows had greater (P<.01) pregnancy rates than older cows. A treatment by lactation interaction (P=.07) occurred for pregnancy rates. The PG + OVS treatment tended to increase pregnancy rates in the older (2+) lactating cows compared to the OVS and 2 × PG12 treatments, but not in first-lactation cows.

Regardless of treatment, cows in their first lactation had greater (P<.01) rates of embryo survival (79 vs. 66%; Table 2) than older cows. Embryonic survival was greater (P=.05) in the Ovsynch and PG + OVS treatments than in the 2 × PG12 treatment (Table 3).

In conclusion, using an injection of PG 12 d prior to the start of OVS improved pregnancy rates of cows in their second or greater lactation. This treatment provides dairy producers with an improved protocol that should improve pregnancy rates in older cows compared to the traditional Ovsynch protocol.

Table 2. Pregnancy Rates by Treatment and Lactation Number

		Treatments[1]		
Item	Lactation No.	Ovsynch	PG + OVS	2 × PG12
No. of cows	1	109	104	103
	2+	121	131	137
Pregnancy rate at 28 days, %	1	40	39	44
	2+	28	41[x]	27
Pregnancy rate at 40 to 54 days, %	1	30	34	34
	2+	18	28	17

[x]Different (*P*=.07) from Ovsynch and 2 × PG12.
[1]See Figure 1.

Table 3. Embryo Survival from Day 28 to Days 40 to 54

	Treatments[1]		
Item	Ovsynch	PG + OVS	2 × PG12
Embryo survival, %	77	95	82
	79	75	58[x]

[x]Different (*P*=.05 from Ovsynch and PG + OVS.
[1]See Figure 1.

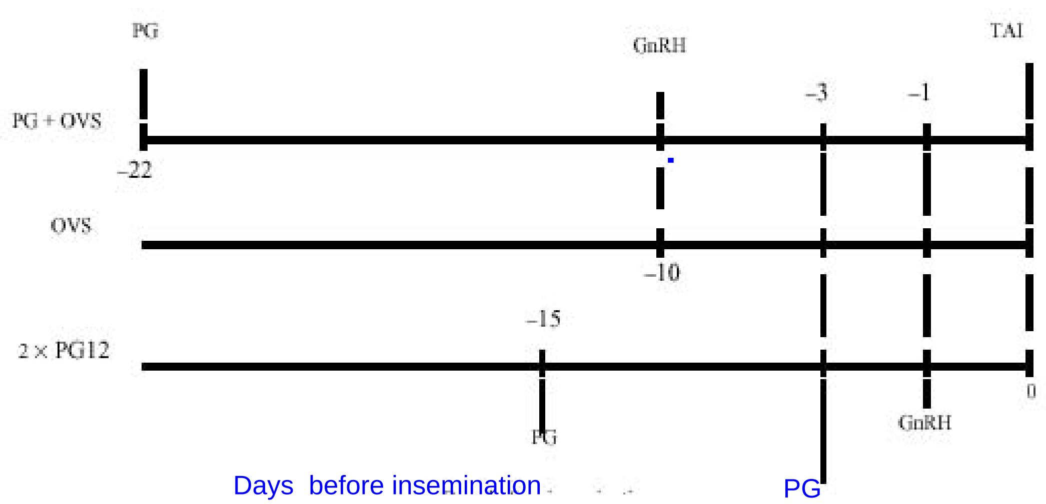

Figure 1. Treatment Protocols. GnRH = gonadotropin-releasing hormone (100 Fg of Cystorelin®, Merial, Iselin, NJ); PG = prostaglandin $F_{2\alpha}$ (25 mg of Lutalyse®, Pharmacia and Upjohn, Kalamazoo, MI); and TAI - timed artificial insemination.

SUPPLEMENTAL PROGESTERONE INCREASES PREGNANCY RATES AND EMBRYO SURVIVAL IN LACTATING DAIRY COWS[1]

S. Z. El-Zarkouny, J. A. Cartmill, and J. S. Stevenson

Summary

Administering progesterone to lactating dairy cows has sometimes proven effective in increasing pregnancy rates. In this study, cows were treated with the Ovsynch protocol in addition to supplemental progesterone given for 7 days between the first gonadotropin-releasing hormone (GnRH) injection and the prostaglandin $F_{2á}$ ($PGF_{2á}$) injection. Conception rates were greater in lactating Holstein dairy cows receiving exogenous progesterone (62.5%) than in controls treated with only the Ovsynch protocol (35.5%). In addition, progesterone supplementation increased embryo survival between 28 and 56 days of pregnancy.

(Key Words: Ovsynch Protocol, Progesterone, Lactating Cows, Pregnancy Rates.)

Introduction

Lactating dairy cows with high genetic merit and outstanding production are likely more vulnerable to fertility problems such as lower conception rate, weaker expression of estrus, and greater embryonic loss after insemination than lower producing cows.

This experiment was based on the hypothesis that cows with higher concentrations of progesterone during the luteal phase of the cycle before AI will be more likely to conceive. Using a progesterone insert for 7 days with the Ovsynch protocol provides a means to test the hypothesis that progesterone might improve synchronization of ovulation with the Ovsynch protocol and pregnancy rates in dairy cows.

Procedures

Lactating dairy cows (n = 184) from one herd (less than 50 days in milk) were used. Cows were assigned randomly to each of the two treatments (Figure 1):1) Ovsynch (OVS) protocol; 2) the OVS protocol + CIDR (OVS + CIDR). The CIDR (controlled internal drug release) is an experimental intravaginal device implanted with 1.9 g of progesterone. In the OVS protocol, cows received two injections of gonadotropin-releasing hormone (GnRH), one 7 days before an injection of prostaglandin $F_{2á}$ ($PGF_{2á}$) and the second 48 hrs after. Cows were inseminated 17 to 19 hrs after the second GnRH injection. The OVS + CIDR cows received the same OVS protocol with the CIDR inserted at the time of first GnRH injection and removed 7 days later before the ($PGF_{2á}$) injection.

Blood samples were collected prior to each hormone treatment for later determination of blood concentrations of progesterone. The size of the ovulatory follicle was determined by transrectal ultrasonography on the day of the second GnRH injection. To determine if that follicle ovulated, a second ultrasonographic examination was conducted 48 hours later. Pregnancy was diagnosed by ultrasonography of uterine contents (viable embryo) at 28 and 56 days after insemination.

[1]Thanks to Meier Dairy, Palmer, KS, for their cooperation in this study.

Cows were housed in a 4-row freestall barn with bedding sand. They were fed a total mixed ration consisting of chopped alfalfa, corn silage, whole cottonseed, and concentrate- mineral mix to meet their daily requirements for maintenance and milk production.

Results and Discussion

Lactating Holstein dairy cows in the OVS + CIDR treatment had greater (P<.01) pregnancy rates on day 28 after insemination than control cows treated with only the OVS treatment (Table 1). Early in pregnancy, luteal function becomes established to provide the appropriate conditions for survival of the embryo. In other studies with different species, progesterone had remarkable effects on the uterus by modulating its function and performance, such as secretion of milk and of some essential nutrients to sustain the embryo during early pregnancy.

Pregnancy rates at 56 days also were increased (P<.01) by the OVS + CIDR treatment (Table 1). Therefore, progesterone treatment increased (P<0.05) embryo survival between days 28 (first pregnancy check) and 56 (second pregnancy check) of pregnancy (Table 1).

Further studies are needed to validate these findings and ensure their repeatability in other herds of lactating dairy cows. Further, it is important to determine how and why this design of progesterone treatment (OVS + CIDR) improves the compromised fertility of high-producing dairy cows.

Table 1. Effects of Ovsynch and Ovsynch + CIDR in Lactating Dairy Cows

	Treatment[1]	
Item	Ovsynch	Ovsynch + CIDR
No. of cows	93	91
Pregnancy rate at 28 days, %	35.8	62.5[x]
Pregnancy rate at 56 days, %	20.5	50.0[x]
Embryo survival (28 to 56 days), %	57.2	79.8[y]

[x]Different from Ovsynch (P<0.05).
[y]Different from Ovsynch (P<0.01).
[1]See Figure 1.

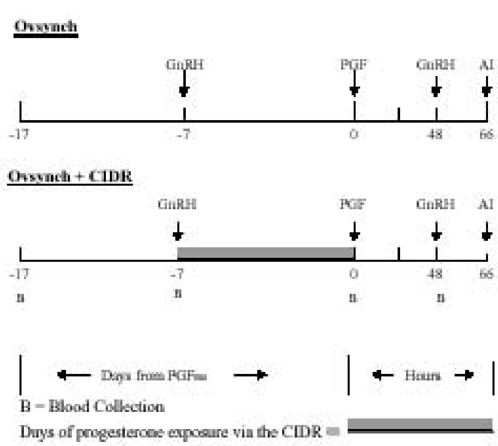

Figure 1. Treatment Protocols. GnRH = gonadotropin-releasing hormone (100 Fg of Cystonelin®, Merial, Iselin, NJ); PGF = prostaglandin F_{2a} (25 g of Lutalyse, Pharmacia and Upjohn, Kalamazoo, MI); and CIDR = controlled internal drug release (intravaginal progesterone insert, InterAg, Hamilton, NZ).

INCREASING PREGNANCY RATES AT FIRST SERVICE IN DAIRY COWS EXPOSED TO HIGH AMBIENT TEMPERATURES BEFORE AND AFTER CALVING[1]

J. A. Cartmill, T. G. Rozell, S. Z. El-Zarkouny, J. F. Smith, and J. S. Stevenson

Summary

Cows exposed to heat stress before or after calving or both are prone to reduced fertility because of reduced expression of estrus and less embryonic survival if pregnant. Cows calving on three dairy farms during the summer of 1998 were studied. First inseminations were programmed to occur between 50 and 70 days in milk using the Ovsynch protocol, which included a timed artificial insemination. Control cows were treated similarly but did not receive the second injection of gonadotropin-releasing hormone and were inseminated only after estrus was detected (Select Synch). The Ovsynch protocol increased pregnancy rates from 17.6 to 31.3%, because AI submission rates were 100% and conception rates were not different from those of control (Select Synch) cows.

(Key Words: Ovsynch Protocol, Heat Stress, Estrus.)

Introduction

Cows that are heat stressed around the time of calving, during late gestation, and during the breeding period have reduced fertility compared to those in a more comfortable, thermally neutral environment. Decreased expression of estrus and reduced embryonic survival are major contributors to the unacceptable pregnancy rates observed during summer months. Breeding programs, such as the Ovsynch protocol, that synchronize ovulation before a timed artificial insemination (TAI) eliminate the need for estrus detection, result in all cows being inseminated, and can improve pregnancy rates in lactating dairy cows. If a TAI protocol that does not require estrus detection were successful during heat stress, it could decrease the number of repeat breeders and the average interval from parturition to conception.

The Ovsynch protocol has produced acceptable conception rates in previous studies. In fact, in most studies, conception rates are equal to those achieved when cows are inseminated after detected estrus. The Ovsynch protocol consists of two injections of gonadotropin-releasing hormone (GnRH) administered 9 days apart with an injection of prostaglandin $F_{2\alpha}$ (PG) given 2 days before a second GnRH injection. Cows then are inseminated by appointment 16 to 20 hrs after the second GnRH injection.

The objective of this experiment was to determine the success of a breeding protocol during summer months that synchronized ovulation before a TAI compared to a similar protocol that depended entirely upon estrus detection. We compared the pregnancy rates of cows treated according to the Ovsynch protocol with those of cows receiving a similar treatment minus the second injection of GnRH and inseminated only after a detected estrus. If conception rates (the proportion pregnant of those inseminated) are not different between these two protocols, then pregnancy rates (the proportion pregnant of all cows treated) should be in-

[1]Thanks to Ohlde Dairy, Linn, KS and Meier Dairy, Palmer, KS, for their cooperation in this study and to the Kansas Dairy Association for partial funding.

creased after the Ovsynch protocol because all cows are inseminated.

Procedures

Cows (n = 371) from three cooperating dairies in northeast Kansas that calved between April and October 1998 were assigned randomly to each of two treatments in 3-week breeding clusters before first inseminations occurred between 50 and 70 days in milk. Figure 1 shows the treatments Ovsynch (OVS) and Select Synch (SS). Cows in the OVS treatment were all inseminated 15 to 18 hrs after the second injection of GnRH. Cows in the SS group were inseminated only after a detected estrus during the target-breeding week.

Blood was collected prior to each hormone injection regardless of whether or not the cow was injected. Concentrations of progesterone in the blood were assayed to determine luteal status of cows before insemination.

Pregnancy was confirmed using transrectal ultrasonography 27 days after insemination and reconfirmed by palpation of the uterus at 40 to 50 days by the herd veterinary practitioner. Estrus detection rate or AI submission rate (proportion of cows detected in estrus of total treated), conception rate, and pregnancy rate then were determined.

Cows were housed in freestall barns. Cows in two herds were managed with overhead fans and feed-bunk misters. Cows in the third herd were managed only with overhead sprinklers on the feed-bunk side of the barn. Cows were fed a total mixed ration consisting of chopped alfalfa, corn silage, whole cottonseed, and concentrate-mineral mix to meet or exceed their daily requirements for maintenance and milk production.

Results and Discussion

The AI submission rate (percentage of cows detected in estrus) in the SS group was less (*P*<.01) than that of cows in the OVS protocol (Table 1). Although conception rate was not different (31.3 vs. 28.7%) between protocols, the 27-day pregnancy rate (31.3 vs. 17.5%) was increased (*P*<.01) by the Ovsynch protocol.

Table 1. Effects of Select Synch vs. Ovsynch Protocols during Heat Stress

	Treatments[1]	
Item	Select Synch	Ovsynch
No. of cows	189	182
AI submission rates, %	61.5	100[x]
Conception rates, %	28.7	31.3
Pregnancy rates, %	17.6	31.3[x]

[x]Different (*P*<.01) from Select Synch.
[1]See Figure 1.

These results indicate that using a TAI protocol during times of high ambient temperature and humidity can improve pregnancy rates compared to breeding only after a detected estrus. We conclude that application of the Ovsynch protocol for synchronization of cows during heat stress increased pregnancy rate because it is independent of expression or detection of estrus.

Furthermore, when conception rates are equal, using a TAI protocol will always increase pregnancy rates, because all cows are inseminated. Therefore, the limiting factor becomes the estrus detection or AI submission rate. Regardless of weather conditions, when estrus detection rates are poor, the Ovsynch protocol will prove superior to any program that is dependent on heat detection.

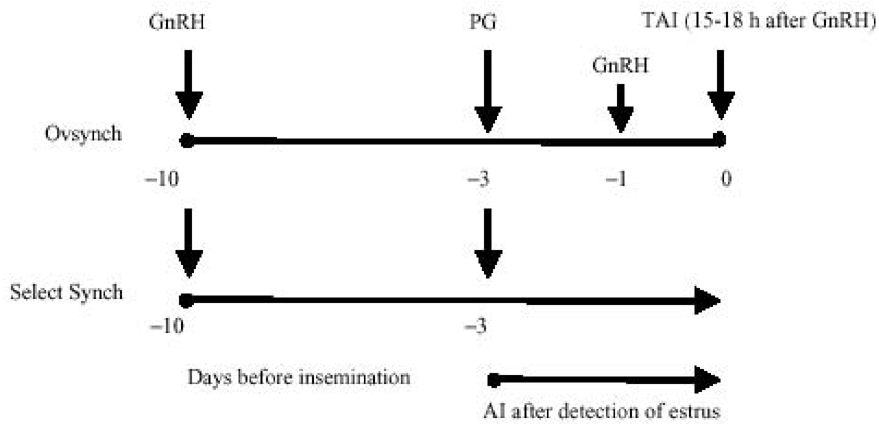

Figure 1. Treatment Protocols. GnRH = gonadotropin-releasing hormone (100 μg of Fertagyl®, Intervet, Millsboro, DE); PG = prostaglandin $F_{2\alpha}$ (25 mg of Lutalyse®, Pharmacia and Upjohn, Kalamazoo, MI); and TAI - timed artificial insemination.

INDEX OF KEY WORDS

Indexer's note: The numbers indicate the first pages of each article that uses the listed key word.

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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 "$P<.05$". 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 $2.5 \pm .1$. The 2.5 is the average; .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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