



DAIRY RESEARCH 2017



DAIRY RESEARCH 2017

Contents

III Foreword

Physiology and Management

- 1 Case Study: Improving Heat Abatement Strategies for Lactating Dairy Cows in Southwest Kansas
- 7 The Effects of an Evaporative Cooling System on Reducing Heat Load in Lactating Dairy Cows
- 13 Association Between Reproduction and Postpartum Cow Health During Summer Months in Dairies Located in the Great Plains Region
- 18 Resynchronization of Lactating Dairy Cows at Open Pregnancy Diagnosis Based on the Presence or Absence of a Corpus Luteum: A Practical Approach
- 25 Dose and Frequency of PGF_{2 α} Administration to Lactating Dairy Cows Exposed to Presynchronization and Either Five- or Seven-day Ovsynch Protocols: Ovulation, Luteolysis, and Pregnancy Rates

Nutrition and Feeding

- 32 Effects of Milk Feeding Strategies on Short- and Long-term Productivity of Holstein Cows
- 37 Productivity of a Triticale and Crimson Clover Winter Cover Crop for Dairies
- 44 Development of a Berry Processing Score for Sorghum Silage and Assessment of Processing Effects on Sorghum Silage Starch Digestibility
- 49 Effects of Dietary Supplementation of *Scutellaria baicalensis* Extract During Early Lactation on Milk Production of Dairy Cattle
- 60 Acknowledgments
- 61 Biological Variability and Chances of Error
- 62 The Livestock and Meat Industry Council Inc.

DAIRY RESEARCH 2017

Foreword

Kansas State University is pleased to present the 2017 Dairy Research Report of Progress. We continue to watch the Kansas dairy industry grow, and in 2016 our state ranked 10th for largest growth in total milk produced. During the past 5 years (2011 to 2016), total milk production in Kansas has increased by 29%; the number of cows by 18%; and annual pounds of milk per cow by 1,785. Therefore, the Kansas dairy herd is not only growing, but is becoming more productive and efficient. At the end of 2016, Kansas ranked 13th nationally in milk yield per cow at 22,801 lb, 16th in the number of dairy cows (146,000), and 16th in total milk production (3.33 billion lb). Kansas now has 290 dairy operations and averages 503 cows per herd (*Hoard's Dairyman*, March 25, 2017, pp 204–205).

Selected production traits of our Kansas State University Dairy Teaching and Research Center (DTRC) herd are shown below. The excellent functioning of our herd is largely a tribute to the dedication of our staff: Michael Scheffel (manager), Daniel Umsheid, Robert Feist, Alan Hubbard, Kris Frey, Eulises Jiron Corrales, Morgan Taylor, Cory Sunderman, and Rhonda Chartier. Special thanks are given to Cheryl Armendariz, Wenjing Fausnett, Haixia Liu, and a host of graduate and undergraduate students for their technical assistance in our laboratories and at the DTRC. We also acknowledge the support and cooperation of the Heart of America Dairy Herd Improvement Association (DHIA) for its assistance in handling research milk samples.

Kansas State University Dairy Teaching and Research Center Herd¹

Cows, total no.	282
Rolling herd milk, lb	32,831
Rolling herd fat, lb	1,160
Rolling herd protein, lb	959
Somatic cell count × 1,000	119
Calving interval, mo	12.7

¹October 24, 2017 test day (milking 2 to 3 times daily).

The sustained increases in productivity and efficiency on dairy farms in Kansas and across the United States are largely driven by improved technology and management decisions by dairy producers. It is our hope that the type of research presented in this report contributes to those improvements.

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

B.J. Bradford, Editor
2017 Dairy Research Report of Progress

Case Study: Improving Heat Abatement Strategies for Lactating Dairy Cows in Southwest Kansas

L. Mendonça and A. Scanavez

Summary

Temperature loggers attached to intravaginal devices can be used to assess severity of heat stress in dairy cows. Vaginal temperature data collected using this method can be used to evaluate effectiveness of heat abatement systems. The goal for this study was to use vaginal temperature information to evaluate the impact of implementing new heat abatement strategies in order to minimize heat stress in lactating dairy cows. Vaginal temperature of cows from 2 dairies located in southwest Kansas were assessed during summers of 2014 and 2017. Dairy A improved the heat abatement systems in 2017, while Dairy B did not. Historical information of herd fertility was evaluated from 2012 to 2017 for both herds. In 2014, cows from Dairy A had greater vaginal temperature compared with Dairy B. The assessment conducted in 2017, after implementation of new heat abatement strategies, revealed that cows from Dairy A had comparable vaginal temperature to their counterparts from Dairy B. This indicates that the new cooling system minimized the effects of heat stress. Moreover, fertility of Dairy A in the summer of 2017 was improved compared with previous years. Herd fertility during the summer was better in Dairy B than Dairy A from 2012 to 2016. In contrast, Dairy B had poorer fertility than Dairy A in 2017. These data suggest that fertility of dairy herds may be positively impacted by reducing heat stress through improved cooling systems.

Introduction

Heat stress in dairy cows impacts production, health, and reproduction. Furthermore, wellbeing of cows may be affected because their behavior is altered during periods of heat stress. Even though heat abatement strategies have been demonstrated to minimize the effects of heat stress, most strategies do not completely eliminate the negative effects of hyperthermia in dairy cattle. In addition, efficacy of heat abatement systems may vary across dairies. Core body temperature assessment can be used to evaluate effectiveness of heat abatement strategies used in dairy farms. Since the core body temperature of heat-stressed lactating cows fluctuates remarkably, it is important to assess the circadian rhythm of body temperature to fully understand how cows are regulating body temperature throughout the day.

Temperature loggers attached to a controlled internal drug release (CIDR) insert can be used to assess vaginal temperature of cows. Therefore, it is a useful tool to evaluate effectiveness of heat abatement strategies. When using this methodology, vaginal temperature should be assessed frequently (every 5 minutes) for consecutive days because of cows' time budgets. For instance, milking time during summer is a critical period for lactating dairy cows because heat abatement strategies in the holding pen and parlor may drastically impact body temperature of cows. If heat is not dissipated while cows are in the milking barn, core body temperature may increase and the negative effects of heat stress are aggravated. Because heat stress vastly impacts fertility traits of dairy cows,

herds that do not have an efficient heat abatement strategy often do not observe good reproductive efficiency during summer.

The purpose of this case study was to evaluate how implementing new heat abatement strategies in a dairy farm impact vaginal temperature of lactating dairy cows and overall herd fertility during summer months.

Experimental Procedures

Vaginal temperature assessments of multiparous lactating dairy cows were conducted in 2 dairies in August 2014 and August 2017. Assessments at the dairies were conducted concomitantly. In 2014 and 2017, 21 cows (Dairy A = 9; Dairy B = 12) and 40 cows (Dairy A = 20; Dairy B = 20) were used in the study, respectively. Calibrated temperature loggers (iButton DS1922L, Embedded Data Systems, Lawrenceburg, KY) were attached to a blank CIDR device to assess vaginal temperature. Temperature data were collected every 5 minutes for 5 and 7 consecutive days in 2014 and 2017, respectively.

Facilities – Dairy A

Cows were housed in a freestall barn and had access to a dirt exercise lot. In 2014, the freestall barn was equipped with 48-inch fans spaced 25 feet apart. In 2017, the new heat abatement system consisted of substituting fans. The barn was equipped with 72-inch fans spaced 50 feet apart. In both years, fans were mounted above the stalls, and feed-line sprinklers were activated intermittently.

In 2014, six 50-inch fans were mounted in the front part of the holding pen and sprinklers were activated intermittently. No fans were above the cows in the parlor. In 2017, five 50-inch fans and one 72-inch fan were mounted in the front part of the holding pen and sprinklers were activated intermittently. Six fans were mounted above the cows in the parlor. In addition, four fans were mounted in the side of the parlor with a high pressure fogging system. Cows were milked thrice daily at approximately 01:45, 09:45, and 18:15 h.

Facilities – Dairy B

Cows were housed in dry-lot corrals with shade. Heat abatement in the holding pen and parlor were similar for 2014 and 2017. Four 48-inch fans were mounted in the front part of the holding pen and sprinklers were activated intermittently. In the parlor, six 48-inch fans were mounted above the cows. Cows were milked twice daily at approximately 07:00 and 19:00 h.

Fertility

Reproductive efficiency from 2012 to 2017 was assessed from Dairy A and Dairy B. Number of cows that were eligible to become pregnant and cows that became pregnant were extracted in cycles of 21 days for calculation of 21-day pregnancy risk. Each cycle was assigned to the month in which at least 50% of the days of the cycle were within the month. For calculation of 21-day pregnancy risk according to season, warm and cool months were considered to be June to August and September to May, respectively. To calculate 21-day pregnancy risk per season, total number of pregnancies was divided by total number of cows eligible to become pregnant from June to August and from

September to May. Warm to cool ratio was calculated by dividing 21-d pregnancy risk in warm months by the same metric in cool months.

Number of cows inseminated per month and pregnancy outcomes of these inseminations were extracted for calculation of pregnancy per artificial insemination (P/AI). Warm to cool ratio was calculated as described for pregnancy risk.

Results and Discussion

Vaginal temperature of cows from Dairy A and Dairy B from assessments conducted in 2014 and 2017 are outlined in Figure 1 and Figure 2, respectively. In 2014, cows from Dairy A tended ($P = 0.06$) to have greater average temperature than cows from Dairy B (Table 1). Percentage of time with temperature $\geq 103.1^\circ\text{F}$ was greater for cows from Dairy A than for cows from Dairy B (42.2 vs. 26.6%). In addition, average of minimum temperatures was greater ($P < 0.01$) for cows from Dairy A than for cows from Dairy B (Table 1). These findings suggest that heat abatement strategies used in 2014 for Dairy A were not sufficient to minimize the effects of heat stress, which resulted in cows having greater peak temperature in the afternoon and a dampened decrease in temperature in the morning. In 2017, however, average temperature did not ($P = 0.95$) differ between cows from Dairy A and Dairy B (Table 2), which indicates that the new heat abatement strategies implemented in Dairy A minimized the effects of heat stress. Indeed, cows from Dairy A had reduced ($P = 0.03$) maximum temperature compared with cows from Dairy B (103.0 ± 0.10 vs. $103.3 \pm 0.10^\circ\text{F}$). Nonetheless, cows from Dairy B had lower minimum temperature than cows from Dairy A. It is possible that the additional heat abatement strategies in Dairy A were efficient in reducing the peak temperature of cows in the afternoon, but Dairy B had a better cooling system in the parlor. The decrease in temperature at milking time for cows in Dairy B indicates that cows dissipated heat in a significant manner in the milking barn. On the other hand, the same pattern is not observed in Dairy A. Although it seems the additional heat abatement system installed in the parlor in Dairy A did not play a significant role in reducing heat stress during milking time, it is likely that the 72-inch fans installed in the freestall barns had a major impact in cooling cows.

Historical fertility data were compiled per season (e.g., warm and cool months) to demonstrate fertility of the herds during periods with and without heat stress (Table 3 and 4). From 2012 to 2017, 21-d pregnancy risk was greater than 21% during the cool season for both herds. From 2012 to 2016, 21-d pregnancy risk was decreased during the warm season, indicating that fertility was compromised during periods of summer heat stress. In 2017, after implementation of the new abatement system, Dairy A had an exceptional 21-d pregnancy risk during the warm season. Improved reproduction for 2017 could be partially attributed to the improved heat abatement systems.

Caution should be taken in making direct comparisons across years, because other factors may have influenced herd reproductive efficiency. Nonetheless, decreased vaginal temperature observed in the 2017 assessment supports the idea that improving the environment of cows impacted reproductive traits. In addition, the warm to cool ratio of 21-d pregnancy risk in Dairy A was consistently less than 80% across the years, except for 2017. In Dairy B, warm to cool ratio ranged from 74.3 to 87.1% from 2012 and 2016, indicating a greater reproductive efficiency during the summer when compared

with Dairy A. In 2017, however, Dairy A had greater warm to cool ratio than Dairy B (105.1 vs. 94%). Furthermore, P/AI during the warm season in 2017 was greater for Dairy A than Dairy B (Table 3 and 4). In previous years (2012 to 2016), Dairy A consistently had decreased P/AI compared with Dairy B.

In conclusion, this case study presents evidence that using effective heat abatement strategies to decrease body core temperature of lactating dairy cows impacts herd reproductive efficiency.

Table 1. Vaginal temperature and percentage of time with vaginal temperature greater than specific cut-offs of multiparous cows from two dairies in August 2014

	Dairy A	Dairy B	<i>P</i> -value
Average of maximum temperature, °F	104.5 ± 0.23	104.1 ± 0.20	0.29
Average temperature, °F	102.9 ± 0.18	102.5 ± 0.16	0.06
Average of minimum temperature, °F	101.5 ± 0.17	100.8 ± 0.15	< 0.01
Percentage of time with temperature ≥ 101.3°F	96.1 ± 3.05	84.9 ± 2.64	0.01
Percentage of time with temperature ≥ 102.2°F	75.9 ± 6.11	56.4 ± 5.29	0.03
Percentage of time with temperature ≥ 103.1°F	42.2 ± 6.65	26.6 ± 5.76	0.09
Percentage of time with temperature ≥ 104.0°F	14.4 ± 3.83	9.8 ± 3.32	0.38

Table 2. Vaginal temperature and percentage of time with vaginal temperature greater than specific cut-offs of multiparous cows from two dairies in August 2017

	Dairy A	Dairy B	<i>P</i> -value
Average of maximum temperature, °F	103.0 ± 0.10	103.3 ± 0.10	0.03
Average temperature, °F	101.9 ± 0.09	101.9 ± 0.08	0.95
Average of minimum temperature, °F	100.8 ± 0.06	100.6 ± 0.06	0.02
Percentage of time with temperature ≥ 101.3°F	80.5 ± 2.60	70.8 ± 2.57	0.01
Percentage of time with temperature ≥ 102.2°F	27.0 ± 3.77	27.2 ± 3.72	0.97
Percentage of time with temperature ≥ 103.1°F	3.2 ± 2.00	7.4 ± 1.97	0.14
Percentage of time with temperature ≥ 104.0°F	0.07 ± 1.11	1.9 ± 1.09	0.25

Table 3. Herd fertility of Dairy A from 2012 to 2017 during cool and warm seasons

	Years					
	2012	2013	2014	2015	2016	2017
21-d pregnancy risk in the warm season, %	16.8	15.9	16.4	17.4	16.1	26.1
21-d pregnancy risk in the cool season, %	23.0	22.5	21.7	21.8	22.4	24.8
Warm to cool ratio of 21-d pregnancy risk, %	72.9	70.8	75.4	79.8	71.8	105.1
Pregnancy per AI in the warm season, %	26.9	27.4	28.0	27.9	27.4	35.7
Pregnancy per AI in the cool season, %	35.6	36.1	37.1	34.9	36.2	35.9
Warm to cool ratio of pregnancy per AI, %	75.7	75.8	75.4	80.1	75.8	99.4

In Dairy A, a modified heat abatement strategy was implemented in 2017 immediately before the beginning of summer.

Cool season = September to May.

Warm season = June to August.

Table 4. Herd fertility of Dairy B from 2012 to 2017 during cool and warm seasons

	Years					
	2012	2013	2014	2015	2016	2017
21-d pregnancy risk in the warm season, %	21.3	19.6	19.1	20.0	19.3	23.8
21-d pregnancy risk in the cool season, %	25.7	23.8	25.7	22.9	23.6	25.3
Warm to cool ratio of 21-d pregnancy risk, %	82.7	82.3	74.3	87.1	81.8	94.0
Pregnancy per AI in the warm season, %	30.7	29.1	28.9	29.3	28.6	33.5
Pregnancy per AI in the cool season, %	35.7	34.0	36.9	33.6	33.8	36.0
Warm to cool ratio of pregnancy per AI, %	85.9	85.7	78.5	87.2	84.7	93.1

Cool season = September to May.

Warm season = June to August.

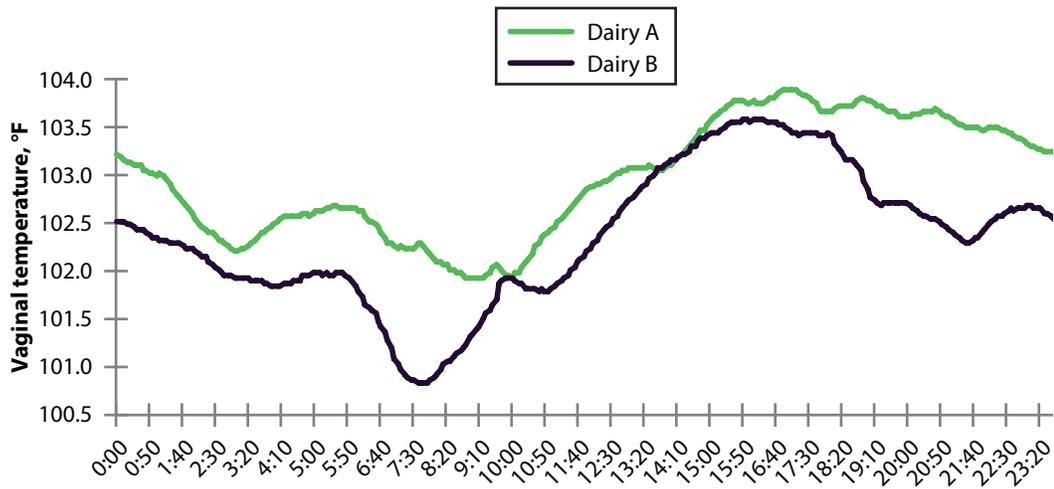


Figure 1. Vaginal temperature of multiparous cows from Dairy A and Dairy B in 2014.

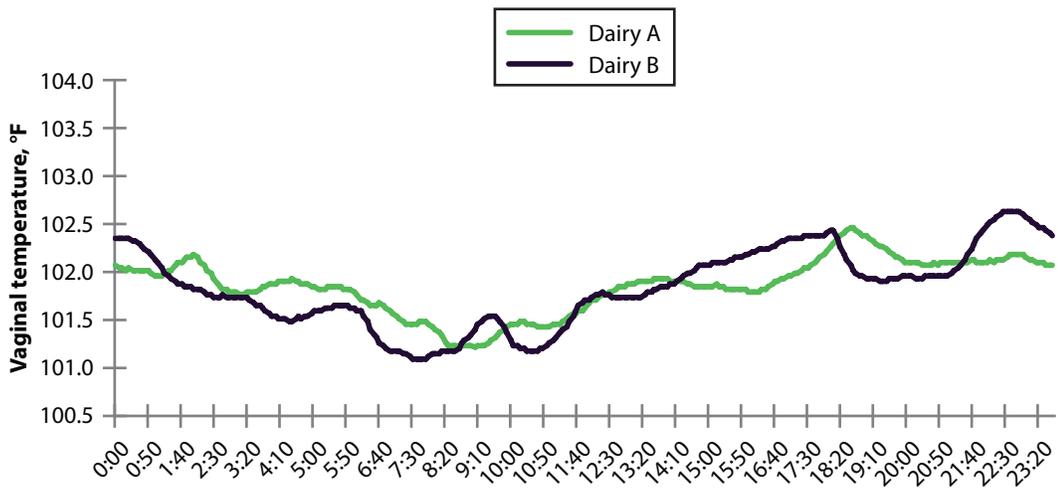


Figure 2. Vaginal temperature of multiparous cows from Dairy A and Dairy B in 2017.

The Effects of an Evaporative Cooling System on Reducing Heat Load in Lactating Dairy Cows

J.R. Johnson, M.J. Wolf, J. McBride, and M.J. Brouk

Summary

This study was conducted to evaluate the effect of 2 cooling systems on barn temperature, core body temperature (CBT), respiration rate, rear udder temperature, and lying time in lactating Holstein dairy cows. Twenty lactating Holstein dairy cows were randomly assigned to 1 of 2 treatment groups: CONV, where cows were housed in a conventional, open-sidewall freestall barn equipped with feedline soakers and fans located over the feedline and stalls; and TUNNEL, where cows were housed in a tunnel-ventilated freestall barn utilizing an evaporative cooling system. TUNNEL was effective at reducing barn temperature humidity index (THI) compared to CONV, but failed to alter CBT ($101.5 \pm 0.04^\circ\text{F}$). TUNNEL cows had reduced respiration rates (52.0 vs. 57.9 ± 2.2 breaths per minute) and skin temperatures (91.8 vs. $94.1 \pm 0.6^\circ\text{F}$) compared to CONV, while TUNNEL cows had increased lying time by 1 hour per day (11.8 vs. 10.8 ± 0.3 hours per day). Overall, the evaporative cooling system (TUNNEL) was effective in reducing barn THI leading to reduced respiration rates and rear udder temperatures and increased daily lying time. No treatment differences were detected for CBT, however, likely a result of the cooler ambient conditions under which the study took place.

Introduction

Heat stress greatly affects dairy cattle every year throughout the United States. Heat stress not only reduces milk production but also greatly decreases efficiencies for growth and reproduction, and leads to animal welfare issues such as lameness. It has been estimated that heat stress costs the U.S. dairy industry ~\$900 million annually.

Maintaining a normal CBT is critical for lactating dairy cows to sustain production and reproduction throughout the summer months. Milk production has been shown to decline when rectal temperature exceeds 102.2°F for more than 16 hours per day. In addition, reproductive efficiency and fertility have been shown to decrease when CBT exceeds 102.2°F . Meanwhile, heat-stressed dairy cows increase daily standing time to increase dissipation of body heat. Ideally, high-producing dairy cows should be lying down for a minimum of 12 hours per day and it has been proposed that each additional hour of lying time results in an increase of 2.0 to 3.5 lb of milk per day. In addition, when cows do not have adequate lying times, animal welfare issues and lameness may be a concern. Cooling systems that are able to reduce CBT and increase daily lying times in summer are necessary and could greatly increase profitability of the dairy herd.

Evaporative cooling systems equipped with a fogging system have been used to decrease air temperature around the cow and increase heat exchange between the cow and the environment. The fog cools the air as it moves through the facility, aided by the movement of air provided from strategically placed fans throughout the barn. Fan placement

and spacing is of utmost importance in order to achieve adequate effective cooling velocity over the cows. The objective for this study was to evaluate the use of high velocity fans equipped with a fogging system and measure effects on temperature humidity index (THI), respiration rate, rear udder surface temperature, CBT, and lying time in lactating Holstein dairy cows.

Experimental Procedures

This study was conducted in August 2016 at a commercial dairy in Nebraska that contained a tunnel-ventilated freestall barn and an open-sidewall, conventional freestall barn. The tunnel-ventilated barn contained ECV72 fans (72-inch diameter) provided by VES Environmental Solutions (Chippewa Falls, WI) equipped with a fogging system as the main source of cooling. Fans were located over the freestalls with fans spaced 60 feet apart. The fog system cycled on and off throughout the late morning and afternoon hours, determined by the temperature and relative humidity within the facility. The conventional freestall barn had 40-inch basket fans located over the stalls, 36-inch basket fans located over the feedbunk, and a feedline soaker system that turned on and off intermittently, determined by ambient temperature. Spacing between fans located over the feedbunk and freestalls was 30 feet. Prior to the start of the study, it was assured that stocking density and freestall dimensions were similar between barns. Both barns used sand bedding.

Twenty lactating Holstein dairy cows were randomly assigned to 1 of 2 treatment groups. Group 1 was made up of 10 cows that averaged 166 ± 34 days in milk and 40 ± 3 days carried calf. Group 2 consisted of 10 cows averaging 155 ± 9 days in milk and 40 ± 3 days carried calf. This study utilized a switchback design where both groups of cows were moved between barns every 24 h for 6 consecutive days, therefore exposing both groups of cows to each barn environment for a total of 3 days. TUNNEL consists of the time period when these 20 cows were located in the tunnel-ventilated freestall barn while CONV refers to cows located in the conventional freestall barn.

Throughout the study, ambient temperature and relative humidity were measured with 2 weather stations located throughout the farm. Within each barn, 3 weather stations were placed throughout the pen to track pen temperature and relative humidity. Each cow also received an intravaginal stainless-steel temperature logger attached to a blank controlled internal drug-releasing device that recorded vaginal temperature, a measure of CBT. In addition, each cow was fitted with an electronic data logger attached to the right hind leg, allowing daily lying time to be measured.

Individual cow measurements of respiration rate and rear udder temperature were taken daily at 1000 h and 1600 h. Respiration rate (breaths per minute) was measured by counting the number of flank movements for 30 seconds and then multiplying by 2. Body surface temperature was taken using an infrared thermography gun.

Results and Discussion

Average daily ambient temperature during the study was $72.1 \pm 3.4^\circ\text{F}$ and average relative humidity was $78.1 \pm 14.2\%$, resulting in an average THI of 70.1 ± 4.6 during the study. Ambient temperature and THI during the study period were less than anticipated. Barn THI was reduced for TUNNEL compared to CONV ($P = 0.04$) with the

primary difference being detected during the afternoon hours (Figure 1). The differences observed between barns were expected and indicate more effective cooling for TUNNEL due to the fogging system reducing air temperature within the barn.

Core Body Temperature

Core body temperature did not differ ($P = 0.79$) between treatment groups, with an average of $101.5 \pm 0.04^\circ\text{F}$ for CONV and TUNNEL (Figure 2). While there were numerical differences between treatment groups for categorical CBT (Table 1), CONV, and TUNNEL cows spent similar amounts of time within each CBT category (< 101.5 , ≥ 101.5 , and $\geq 102.2^\circ\text{F}$) resulting in a lack of treatment effect ($P > 0.05$).

Respiration Rate and Skin Temperature

Respiration rates were reduced in TUNNEL cows compared to the CONV (Table 2). CONV had an average daily respiration rate of 57.9 ± 2.2 breaths per minute (BPM), while TUNNEL had an average respiration rate of 52.0 ± 2.2 BPM ($P < 0.01$). When broken into the morning (0900 h) and afternoon (1600 h) time periods, respiration rates were reduced for TUNNEL cows in the morning (48.6 vs. 52.9 ± 2.0 BPM; $P = 0.03$) and afternoon (55.4 vs. 63.0 ± 2.6 BPM; $P < 0.01$) periods (Table 4).

Rear udder skin temperature averaged 94.1 and $91.8 \pm 0.6^\circ\text{F}$ for CONV and TUNNEL, respectively ($P < 0.01$; Table 2). When broken into the morning (0900 h) and afternoon (1600 h) periods, udder temperature was reduced for TUNNEL cows both in the morning (90.5 vs. $93.4 \pm 0.5^\circ\text{F}$; $P < 0.01$) and afternoon (93.2 vs. $94.8 \pm 0.7^\circ\text{F}$; $P < 0.01$) periods.

Lying Time

Cows on the CONV treatment had reduced lying time by 1 hour per day compared to TUNNEL (10.8 vs. 11.8 ± 0.3 hours/day; Table 2). When data were divided into 3 different time periods between milkings (Table 4), TUNNEL cows spent a greater ($P < 0.01$) percentage of time within each period lying down. Cows on the CONV treatment averaged 11.8 ± 0.6 lying bouts per day, which was greater than TUNNEL cows (10.8 ± 0.6 bouts/day, $P = 0.01$; Table 2). Lying bout duration was greater ($P < 0.01$) for TUNNEL compared to CONV and averaged 69.3 and 57.5 ± 3.3 minutes per bout (Table 2). During the 1200 to 1800 hour time period, there was a significant treatment effect ($P < 0.05$) where TUNNEL cows had greater lying bout duration (90.1 vs. 61.8 ± 7.2 minutes/bout; Table 4). This indicates that the evaporative cooling system was effective at keeping cows cool during the hottest part of the day, allowing cows to continue lying for a longer duration and therefore resulting in increased total daily lying times.

Conclusions

Results of the current study show that the evaporative cooling system used in the tunnel-ventilated freestall barn was effective at reducing barn THI. This resulted in reduced respiration rates and rear udder temperatures for TUNNEL cows, while CBT did not differ between treatments. Interestingly, lying bout duration was maximized during the afternoon period (1200 to 1800 h) for TUNNEL cows, indicating effective cooling by the evaporative cooling system utilized. This led to increased daily lying time by 1 h/d for TUNNEL cows. Had this study been conducted under warmer ambient temperatures, greater differences between treatment groups for CBT would have been expected.

Table 1. Effect of cooling treatment on time (hours/day) spent within each categorical core body temperature (CBT) for each treatment throughout the study

CBT, ² °F	Treatment ¹		Standard error	P-value
	CONV	TUNNEL		
< 101.5	13.4	14.2	1.08	0.20
≥ 101.5	7.9	7.3	0.59	0.16
≥ 102.2	2.7	2.5	0.59	0.69

¹CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.

²CBT was broken into 3 categories: hours/day with CBT < 101.5°F; h/d with CBT ≥ 101.5°F but < 102.2°F; and h/d with CBT ≥ 102.2°F.

Table 2. Effect of cooling treatment on respiration rate, udder temperature, and lying time data for each treatment throughout the study

Item	Treatment ¹		Standard error	P-value
	CONV	TUNNEL		
Respiration rate, breaths/min	57.9	52.0	2.2	< 0.01
Udder temperature, °F	94.1	91.8	0.6	< 0.01
Lying time, hours/day	10.8	11.8	0.3	< 0.01
Lying bouts, number/day	11.8	10.8	0.6	0.01
Lying bout duration, min	57.5	69.3	3.3	< 0.01

¹CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.

Table 3. Effect of cooling treatment on respiration rate and udder skin temperature during the morning and afternoon observation periods for each treatment throughout the study

Item	Treatment (Trt) ¹		Standard error	P-value		
	CONV	TUNNEL		Trt	Time	Trt × Time
Respiration rate, BPM ²						
0900 h	52.9	48.6	2.0	0.03	< 0.01	0.32
1600 h	63.0	55.4	2.6	< 0.01	< 0.01	0.32
Udder temperature, °F						
0900 h	93.4	90.5	0.5	< 0.01	< 0.01	0.10
1600 h	94.8	93.2	0.7	< 0.01	< 0.01	0.10

¹CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.

²Breaths per minute.

Table 4. Effect of cooling treatment on the percent of time spent lying down within 3 time periods throughout the day

Item	Treatment (Trt) ¹		Standard error	P-value		
	CONV	TUNNEL		Trt	Time	Trt × Time
Lying time, %						
0400-1000 h	51.6 ^a	58.5 ^b	0.03	< 0.01	< 0.01	0.36
1200-1800 h	42.7 ^a	54.4 ^b	0.03			
2000-0200 h	49.2 ^a	57.7 ^b	0.03			
Lying bouts, n/time period						
0400-1000 h	2.9	3.1	0.21	0.15	0.06	0.24
1200-1800 h	2.7	2.6	0.21			
2000-0200 h	2.8	3.1	0.21			
Lying bout duration, min						
0400-1000 h	76.9	80.4	7.22	0.01	0.88	0.02
1200-1800 h	61.8 ^a	90.1 ^b	7.22			
2000-0200 h	76.0	77.7	7.22			

¹CONV refers to cows housed in the open-sidewall conventional freestall barn, while TUNNEL refers to cows housed in the tunnel-ventilated freestall barn.

^{a,b}Means within a row with differing superscripts differ ($P \leq 0.05$).

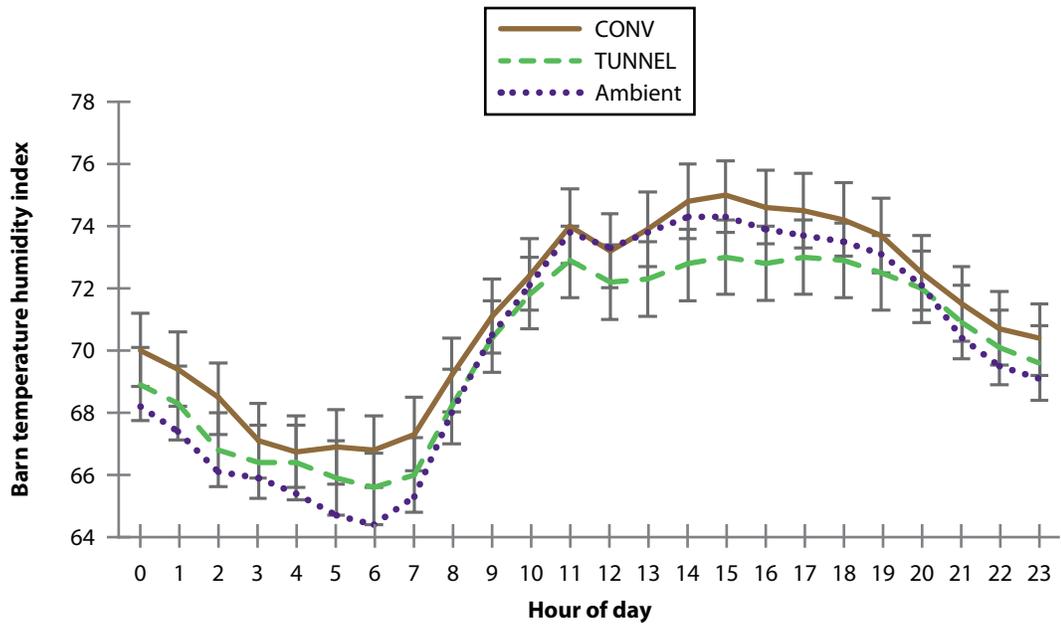


Figure 1. Effect of cooling treatment (CONV vs. TUNNEL) on barn temperature humidity index (THI) by hour of day. Ambient THI data are also shown for comparison. Treatment, $P = 0.04$; treatment \times hour, $P = 0.99$.

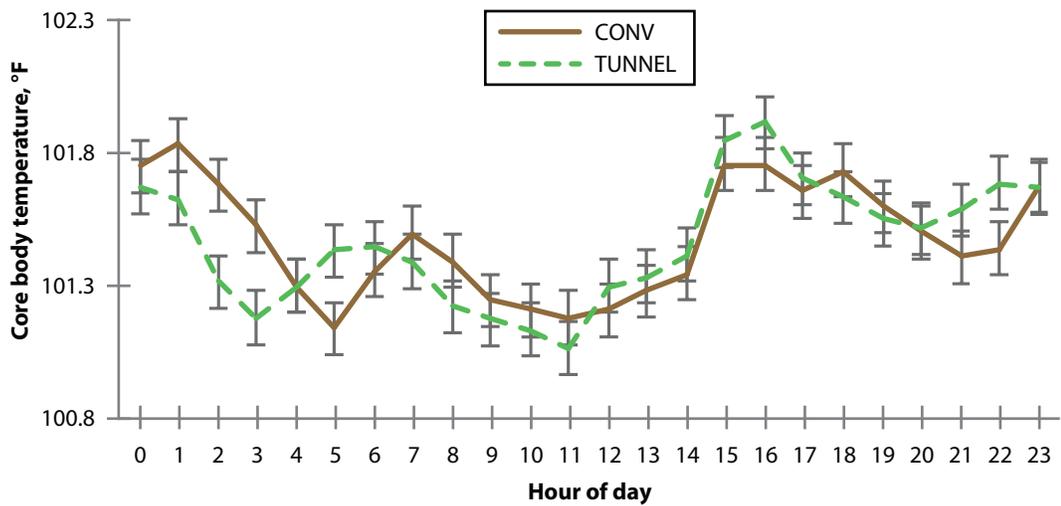


Figure 2. Effect of cooling treatment (CONV vs. TUNNEL) on core body temperature by hour of day. Treatment, $P = 0.79$; treatment \times hour, $P < 0.01$.

Association Between Reproduction and Postpartum Cow Health During Summer Months in Dairies Located in the Great Plains Region

L. Mendonça and A. Scanavez

Summary

Postpartum cow health has an impact on fertility of dairy cows, and impaired fertility in dairy herds ultimately influences profitability of dairy farms. During summer months, postpartum cow health and reproductive performance are affected in dairies located in the Great Plains region. The goal for this study was to evaluate farm-level associations between reproductive efficiency and postpartum cow health in dairy herds located in the Great Plains region. Data from June to August of 2010 to 2016 from 18 herds located in Colorado, Kansas, Oklahoma, Nebraska, and Texas were extracted. Overall pregnancy per AI was used as the measure of reproductive efficiency, and percentage of stillbirth cases, mastitis within 21 d after calving, and cows sold and cows dead within 60 d after calving were used to evaluate postpartum cow health and performance. Using the intercept and slopes from a logistic regression model, a transition cow index was created. Poor herd fertility, pregnancy per AI < 30%, was associated with percentage of stillbirth events and postpartum mastitis cases. In 93% of the instances that herds had pregnancy per AI < 30%, transition cow index was less than 0. This study demonstrates that fertility is associated with transition cow performance at the herd level during summer months in dairies located in the Great Plains region.

Introduction

The Great Plains region of the United States encompasses the following states: Colorado, Kansas, Oklahoma, Montana, Nebraska, New Mexico, South Dakota, North Dakota, Texas, and Wyoming. According to the U.S. Department of Agriculture's Economic Research Service, the number of dairy cows in this region was 1,335 million in 2016, which corresponded to 14.3% of the U.S. dairy herd. The majority of dairy farms located in this region are in the southern portion of the Great Plains and in semi-arid climates, where elevated temperatures are observed during summer months. In addition to heat stress, presence of flies and rain events may be additional stressors for dairy cows because rainfall in this area is mostly concentrated during summer.

It is well documented that reproductive efficiency and postpartum performance of dairy cows are affected under conditions of heat stress. Nonetheless, reports evaluating the association between reproductive performance and postpartum health at the farm level during summer are lacking. The objective of this study was to evaluate herd-level associations between reproduction and postpartum cow health during periods of exposure to environmental stress in dairies located in the Great Plains region.

Experimental Procedures

Records of reproductive efficiency and cow health from multiparous cows (lactation > 1) from 18 herds were used in this study. Most of the herds are enrolled in the Dairy Records Intelligence Network (DRINK) program. Data from 2010 to 2016 for the months of June, July, and August were extracted from the herds' on-farm management software. Herds were located in Colorado, Kansas, Oklahoma, Nebraska, and Texas.

Pregnancy per Artificial Insemination

Number of cows inseminated and pregnant for each herd were extracted from 2010 to 2016. For each year, herd pregnancy per AI (P/AI) was calculated by dividing the number of pregnant cows by the number of cows inseminated from June to August.

Transition Cow Health

Number of calvings, stillbirth events, first cases of mastitis within 21 d after calving, cows sold within 60 d after calving, and cows dead within 60 d after calving were extracted to calculate the percentage of stillbirth, postpartum mastitis, cows sold, and cows dead in early lactation for each herd each year. Percentages of stillbirth, mastitis, cows sold, and cows dead were calculated by dividing the number of cases by the number of cows that calved from June to August.

Model to Evaluate the Association Between Reproduction and Transition Cow Health

Data from 15 herds from 2010 to 2015 (70% of the dataset) were used to create a model to evaluate the association between P/AI and transition cow health. Pregnancy per AI $\geq 30\%$ was used as a proxy for reproductive efficiency. Pregnancy per AI ($\geq 30\%$ vs. $< 30\%$) for each herd each year was analyzed by logistic regression using the GLIMMIX procedure of SAS (version 9.4, SAS Inst., Cary, NC). The model included the following variables: percentage of stillbirth, mastitis, cows sold, and cows dead. Year was included as a random variable in the model. The intercept and slopes obtained from the logistic regression model were used to create a transition cow index. Using the entire dataset (18 herds from 2010 to 2016), transition cow indexes were calculated for each year to plot P/AI and indexes across herds and years.

Results and Discussion

Average P/AI of multiparous cows during summer months from herds located in the Great Plains region was 25% (Figure 1). Herd 1 had the greatest average P/AI (35%) from 2010 to 2016, and herd 18 had the least average P/AI (18%). For some herds, P/AI was consistent across years. For example, from 2010 to 2016, herd codes 8 to 18 did not achieve P/AI $\geq 30\%$ in any of the summers.

Percentage of stillbirth and postpartum mastitis across herds were 4.4 and 7.0%, respectively. Percentage of cows sold and dead within 60 d after calving were 6.3 and 4.2%, respectively. Postpartum mastitis and percentage of cows sold were not ($P \geq 0.12$) associated with P/AI $\geq 30\%$. Proportion of cows having a stillbirth event or dead within 60 d after calving ($P \leq 0.03$) were negatively associated with P/AI $\geq 30\%$. Transition cow index for each herd from 2010 to 2016 is displayed in Figure 2. Similar to P/AI, a pat-

tern for transition cow index was observed for some herds. Herds with greater P/AI had greater transition cow indexes. This association between reproduction and transition cow health may be related to heat stress conditions that cows are exposed to, although other environmental stressors are likely involved with the poor performance observed for some herds. Investments in dry- and lactating-cow facilities may improve herd performance during the summer, and in turn, improving P/AI and transition cow health during the summer is expected to have significant impact in profitability of dairy farms.

The association between transition cow index and P/AI is demonstrated in Figure 3. For 85% of the instances that herds achieved $P/AI \geq 30\%$, transition cow index was ≥ 0 (Table 1). Furthermore, 93% of the instances that herds had a transition cow index below 0, P/AI was $< 30\%$. It is important to mention that transition cow index < 0 was chosen as an arbitrary cut-off. Nonetheless, in occasions that transition cow performance was subpar, reproductive efficiency was likely to be suboptimal. Even though reproductive efficiency must not be only determined by P/AI, overall P/AI during the summer should be $> 30\%$ to achieve acceptable reproductive performance. Although this dataset does not evaluate the direct impact of postpartum cow health on reproductive performance, it demonstrates that transition cow performance and P/AI are associated at the herd level. Furthermore, data from primiparous cows were not used in this study. Effects of heat stress on fertility and postpartum cow health may be more severe for older than first-lactation cows (primiparous vs. multiparous). Therefore, in this study, we evaluated herd-level associations focusing on cows that are most susceptible to be affected by stress during summer months.

In conclusion, herds that do not achieve acceptable reproductive efficiency from June to August probably do not observe adequate transition cow performance in the same period. It is likely that the negative impact of environmental stressors during summer may be ubiquitous to several areas in the dairy farm (e.g., dry-cow facility and milking-cow facility).

Table 1. Frequency of distribution [% (n)] according to pregnancy per AI (P/AI) and transition cow index from June to August of 2010 to 2016 from dairy herds

Transition cow index	P/AI $\geq 30\%$	P/AI $< 30\%$	Total
Greater than or equal to 0	20% (23)	32% (37)	52% (60)
Less than 0	3% (4)	45% (52)	48% (56)
Total	23% (27)	77% (89)	100% (116)

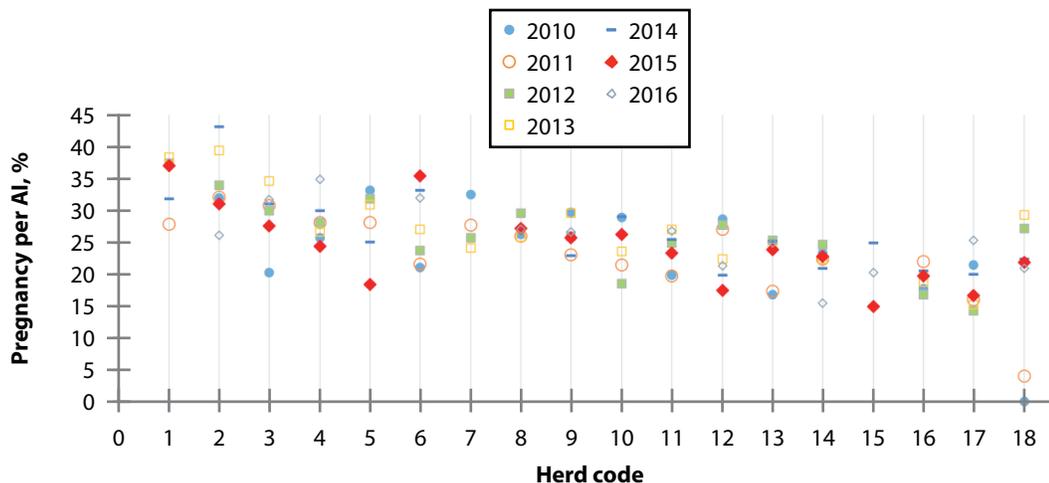


Figure 1. Pregnancy per AI of multiparous cows during summer months from herds located in the Great Plains region from 2010 to 2016. Herd code is ordered on the horizontal axis according to the average P/AI across the seven years.

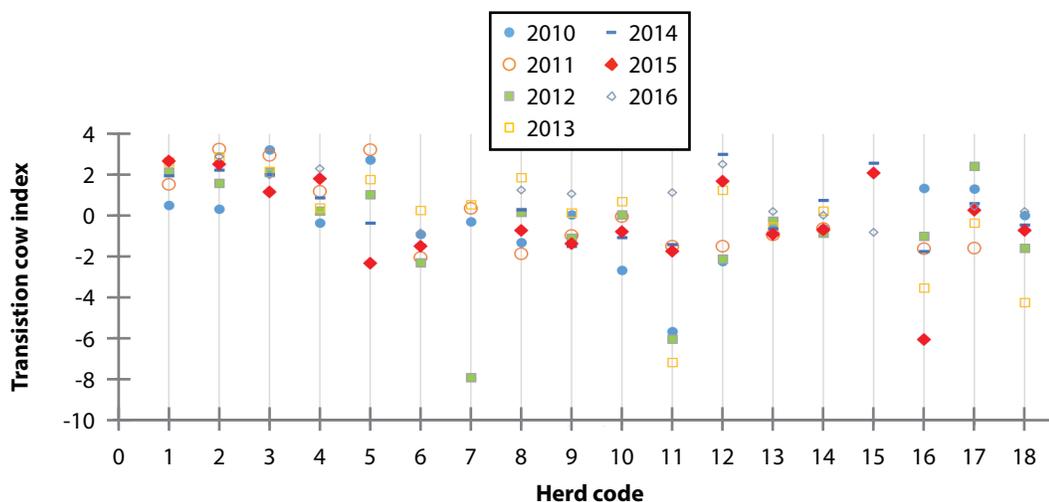


Figure 2. Transition cow index during summer months from herds located in the Great Plains region from 2010 to 2016. Intercept and slopes were obtained from the logistic regression model. Transition cow index = $5.7346 - 0.545 \times \text{percentage of stillbirth} - 0.7437 \times \text{percentage of cows dead within 60 d after calving}$.

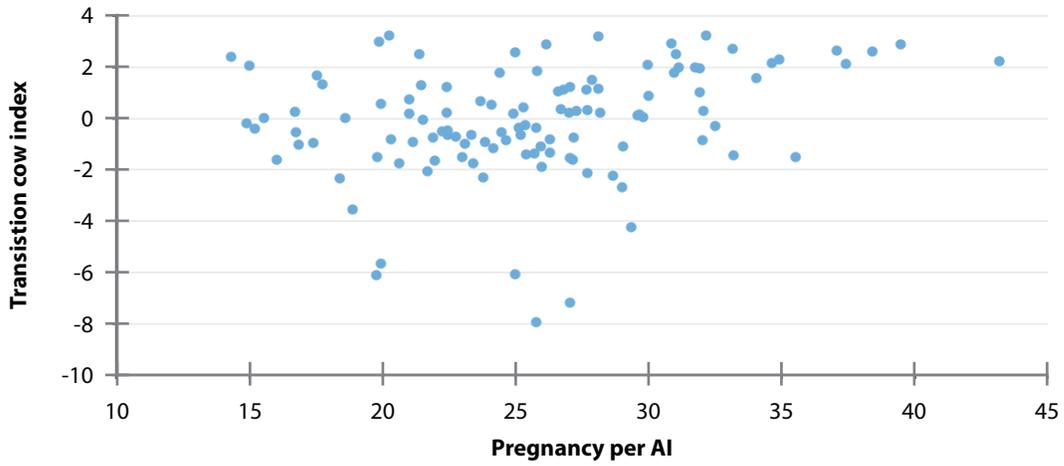


Figure 3. Transition cow index and pregnancy per AI during summer months from 18 herds from June to August of 2010 to 2016. Intercept and slopes were obtained from the logistic regression model.

Resynchronization of Lactating Dairy Cows at Open Pregnancy Diagnosis Based on the Presence or Absence of a Corpus Luteum: A Practical Approach

J.A. Sauls and J.S. Stevenson

Summary

Lactating Holstein cows in three herds were enrolled in a study at the time of nonpregnancy diagnosis. Cows were assigned to a resynchronization program based on ovarian structures determined by transrectal ultrasonography. Three resynchronization treatments were employed starting on the day of open diagnosis to test: (1) accuracy of ultrasound technician's ability to identify a functional corpus luteum (CL); (2) whether an initial GnRH injection is required to start resynchronization when a CL is present at nonpregnant diagnosis (Short Synch: PGF_{2α} — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 hours — timed artificial insemination [AI]); and (3) whether applying progesterone to cows without a CL as part of a traditional Ovsynch program (CIDR + Ovsynch: GnRH + CIDR insert — 7 days — PGF_{2α} + CIDR removal — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 hours — timed AI) would be equivalent to a standard Ovsynch program (same as CIDR-Ovsynch treatment but no CIDR was applied). Treatments produced similar proportions of pregnancies per AI, with a tendency for increased fertility when the first injection of GnRH was administered as part of a standard Ovsynch. The technician's ability to detect a functional CL was more accurate when the CL visualized was actually functional (progesterone ≥ 1 ng/mL) than when it was not functional (progesterone < 1 ng/mL). Although pregnancy outcomes tended to improve when cows were treated with Ovsynch compared with Short Synch, when a functional CL was accurately detected, pregnancy outcomes did not differ. Technician accuracy for detecting a functional CL is important for improving pregnancy outcomes when applying the Short Synch treatment.

Introduction

Approximately 65 to 70% of lactating dairy cows fail to conceive after AI. Implementing an efficient strategy to identify and inseminate non-pregnant cows is crucial to achieving acceptable reproductive performance in dairy herds. Re-insemination strategies minimize interbreeding intervals and maximize pregnancy per AI (P/AI). In well-managed dairy farms, where cows are housed partly in pasture or dry lots, more than 60% of cows are inseminated after detection of estrus. In the absence of detected estrus, cows often are enrolled in a resynchronization ovulation control program resulting in a timed AI. Initiating Ovsynch (GnRH — 7 days — PGF_{2α} — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 to 20 hours — timed AI) to resynchronize ovulation in open cows is a widely adopted program in U.S. dairy herds. The resynchronization can be initiated 7 days before or at nonpregnancy diagnosis. When pregnancy diagnosis occurs weekly once cows are 30 to 36 days since the last AI, the interbreeding interval can

range from 40 to 46 days for cows started on the program at a nonpregnancy diagnosis or even shorter (33 to 40 days) when the program is initiated 7 days before pregnancy diagnosis.

The first GnRH injection in an Ovsynch protocol is intended to induce ovulation and initiate a new follicular wave that will give rise to an ovulatory follicle, and the formation of a new CL after ovulation and AI. A disadvantage to this type of approach is the suppression of estrus expression that occurs after GnRH treatment partly because GnRH induces an ovulatory LH surge from the pituitary gland and suppresses estradiol production from the dominant follicle, thus precluding estrus expression. Previous research shows fewer cows were detected in estrus when GnRH was administered 17 to 32 days after AI. Cows bearing a CL at the initiation of Ovsynch may not require the first injection of GnRH because the CL would be responsive to PGF_{2α} to initiate estrus, thus eliminating the need for GnRH to start a 7-day program, and reduce the interbreeding interval by 7 days compared with initiating a full Ovsynch program.

Previous reports have evaluated ovarian structures and subsequent fertility of resynchronized cows after timed AI. One limitation to the success of the Ovsynch resynchronization program is the absence of a functional CL at the time of the PGF_{2α} injection. A CL is considered to be functional when concentrations of progesterone are ≥ 1 ng/mL. Cows starting Ovsynch without a functional CL conceive at rates approximately 50% less than cows with a functional CL. Improving fertility of cows with poor responses to a resynchronization program is important because cows diagnosed not pregnant incur the same expenses of completing the program as cows that become pregnant but have significantly longer delays to pregnancy establishment, thus reducing overall herd profitability. Because fertility is decreased when an Ovsynch protocol is initiated in cows without a functional CL, providing supplemental progesterone during Ovsynch may be a suitable alternative for cows starting the program without a CL.

Management strategies aimed at reducing interbreeding intervals usually involve early pregnancy diagnosis using transrectal ultrasonography between 30 and 36 days after insemination. This method of pregnancy testing allows the determination of ovarian structures of nonpregnant cows with minimal time and effort. Choosing resynchronization programs tailored to the ovarian status of cows could increase P/AI.

Therefore, we proposed to address three questions: (1) necessity of the initial injection of GnRH in an Ovsynch protocol to resynchronize ovulation in cows bearing a CL at non-pregnancy diagnosis; (2) necessity of applying supplemental progesterone to a standard Ovsynch protocol in the absence of a CL; and (3) accuracy of detecting a functional CL by one transrectal ultrasound examination.

Experimental Procedures

We enrolled 1,626 lactating dairy cows (mostly Holstein with a few crossbreeds) from three herds for 12 months (June 2016 through May 2017) at time of nonpregnancy diagnosis (NPD) in three resynchronization treatments based on the presence or absence of a CL (Figure 1). Pregnancy diagnosis occurred in all herds by employing transrectal ultrasonography to determine NPD and ovarian structures 30 to 36 days after previous

insemination. Technicians performing pregnancy diagnosis were trained to detect pregnancies and ovarian structures. When a CL was present at NPD, cows were assigned randomly to two resynchronization treatments: (1) Short Synch (PGF_{2α} — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 hours — timed AI); or (2) Ovsynch (GnRH — 7 days — PGF_{2α} — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 hours — timed AI). In the absence of a CL at NPD, cows were enrolled in Ovsynch + CIDR (GnRH + CIDR insert — 7 days — PGF_{2α} + CIDR removal — 24 hours — PGF_{2α} — 32 hours — GnRH — 16 hours — timed AI).

Blood samples were collected at NPD for later determination of progesterone concentrations, which were used to determine accuracy of the CL diagnosis by individual technicians. An active functional CL was defined to have progesterone ≥ 1 ng/mL and was the gold standard to determine if the CL diagnosis was accurate.

Pregnancy diagnoses to assess treatment performance were made at 30 to 36 days and again at 60 to 66 days to reconfirm the pregnancy with subsequent pregnancy loss calculated from any losses that occurred between pregnancy diagnoses. Pregnancy per AI (pregnancy rates) was calculated by determining the proportion of cows diagnosed pregnant in each treatment divided by the number of cows receiving AI. Any cows not completing the treatment or culled before pregnancy diagnosis were deleted from the results.

Results and Discussion

Technician Accuracy

Using concentrations of progesterone as the gold standard, accuracy of technicians detecting a functional CL and accurately placing cows in either of the two CL resynchronization treatments ranged from 76 to 94.4% (Figure 2). Technician accuracy of detecting cows without a functional CL and utilizing a synchronization protocol with supplemental progesterone ranged from 43.3 to 89.1% (Figure 2).

Pregnancy Outcomes

Pregnancy risk for all herds at 30 to 36 and 60 to 66 days after insemination tended ($P = 0.06$) to be greater for cows enrolled in the Ovsynch treatment compared with Short Synch (Figure 3). No differences, however, occurred between Ovsynch and Ovsynch + CIDR treatments. Pregnancy loss ranged from 5.8 to 9.2% and did not differ among treatments.

Pregnancy per AI for herds B and C did not differ at either time of pregnancy diagnosis when Ovsynch was compared with Short Synch (Figure 4). In contrast, herd A achieved more ($P < 0.05$) pregnancy per AI at 30 to 36 days (Figure 4) and 60 to 66 days (Figure 5) for cows treated with Ovsynch compared with Short Synch. Pregnancy loss ranged from 0.4 to 13% and did not differ among treatments.

Comparisons of treatments were made when observations were sorted into two categories based on concentrations of progesterone at the time of NPD. Cows with progesterone ≥ 1 ng/mL at NPD were those correctly assessed as having a functional CL, whereas the remaining cows with concentrations < 1 ng/mL were those with a nonfunctional

CL (either regressing or newly formed). Pregnancy per AI for cows with concentrations of progesterone ≥ 1 ng/mL ranged from 26.7 to 31.5%. Cows with progesterone < 1 ng/mL achieved P/AI between 20.2 and 28% (Figure 6). Pregnancy per AI of cows treated with Ovsynch or Short Synch, regardless of CL functional status, did not differ from those supplemented with progesterone or from each other (Figure 6).

Results from these experiments demonstrate that when cows have a functional CL at NPD, applying the Short Synch treatment by eliminating the initial injection of GnRH in Ovsynch produced comparable fertility to the standard Ovsynch protocol. Accuracy of detecting a functional CL with transrectal ultrasound is largely technician-dependent, and is more accurate when declaring a CL is present and functional than when declaring a CL is absent and nonfunctional.

Three conclusions can be made based on the results of the present study. Regardless of treatment applied in this study, when cows had a CL to start the treatment, P/AI was superior to cows without a CL. Based on the correct retrospective diagnosis of a functional CL by progesterone, improving the technician's ability to detect accurately a functional CL should enhance pregnancy per AI when using the Short Synch treatment. Thus, with more accurate diagnosis of a functional CL and employing the Short Synch treatment, cows became pregnant 7 days earlier at the same level of fertility as cows treated with the traditional Ovsynch protocol. Furthermore, applying supplemental progesterone via the CIDR insert did not improve pregnancy outcomes in cows, regardless of their CL status.

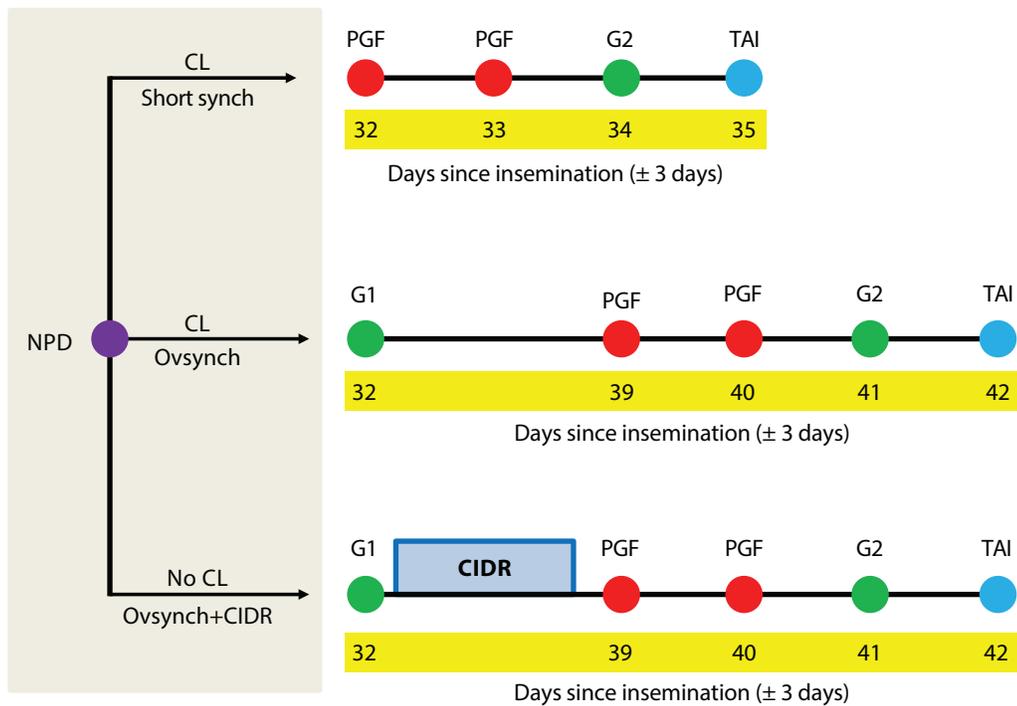


Figure 1. Design of experimental procedures and resynchronization treatments. NPD: nonpregnancy diagnosis; CL: corpus luteum; CIDR: controlled internal drug release; PGF: PGF_{2α}; G1/G2: GnRH; TAI: timed artificial insemination.

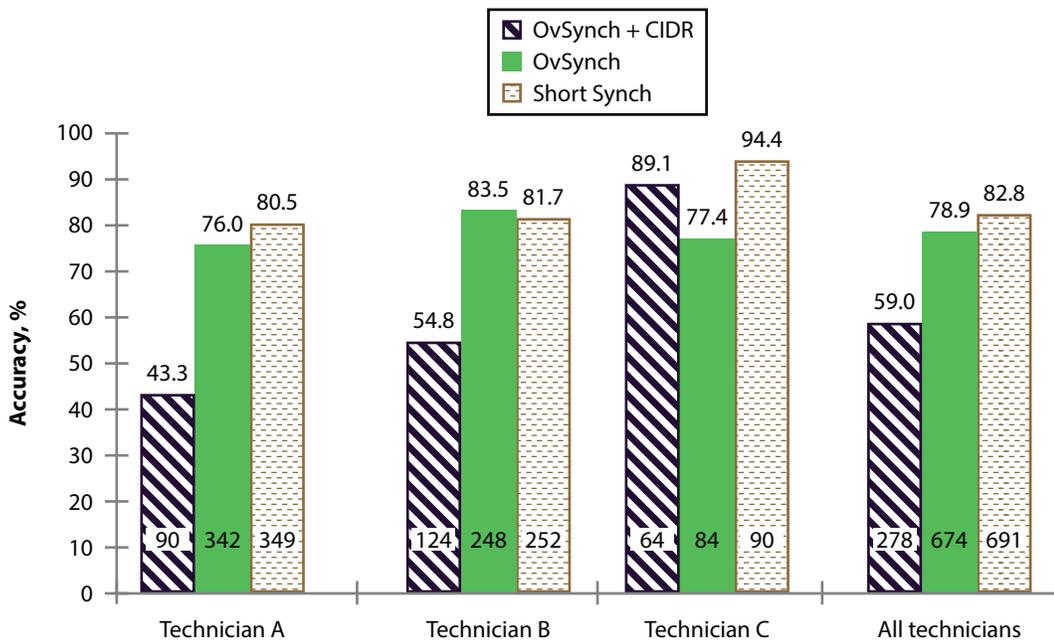


Figure 2. Accuracy of technicians' ability to identify a functional or nonfunctional corpus luteum (CL) and placement into appropriate resynchronization treatments. A functional CL was defined as the visual presence of a CL when concentrations of progesterone ≥ 1 ng/mL.

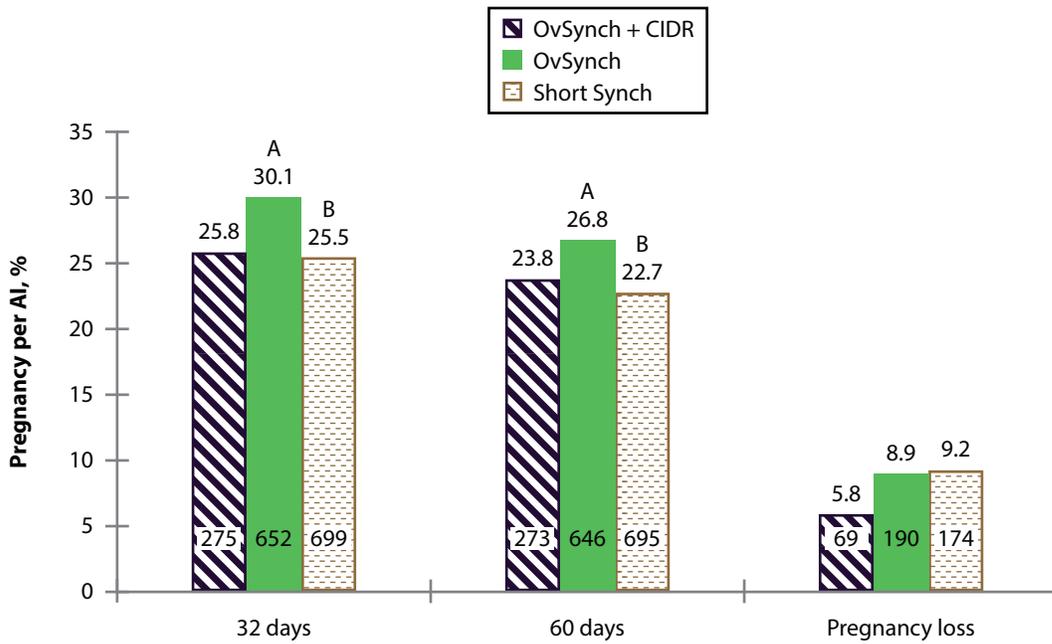


Figure 3. Pregnancy per AI at 30 to 36 days and 60 to 66 days after insemination in all three herds by resynchronization treatment. Pregnancy losses illustrated occurred between 30 to 36 days and 60 to 66 days after insemination for all herds. Uppercase letters indicate a tendency ($P = 0.06$) for P/AI to differ between cows treated with OvSynch and Short Synch.

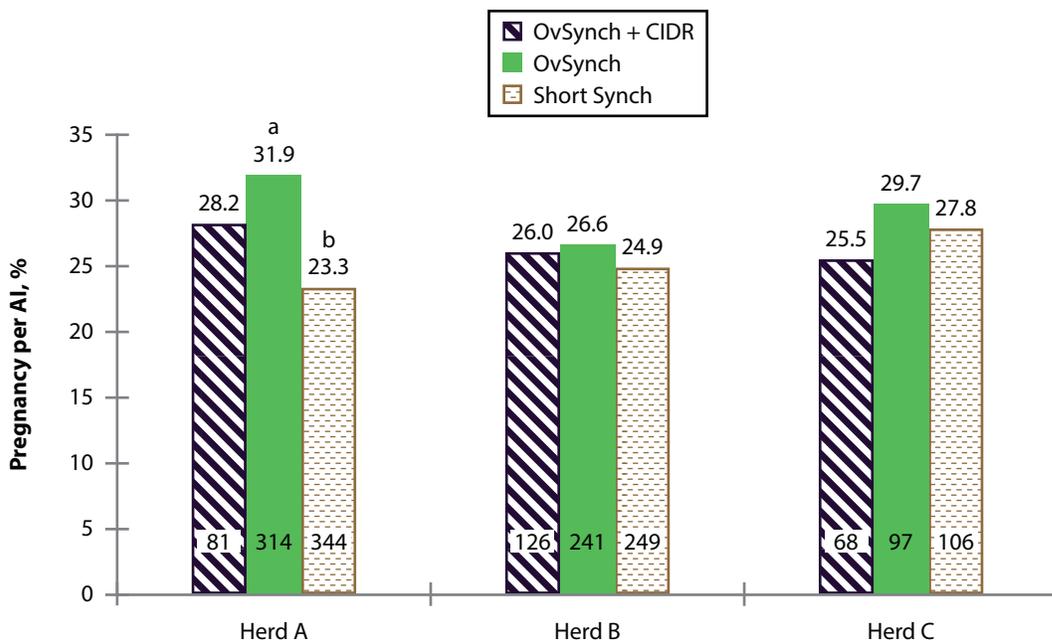


Figure 4. Pregnancy per AI at 30 to 36 days after insemination by herd. Lowercase letters indicate treatment differences ($P < 0.05$) in herd A.

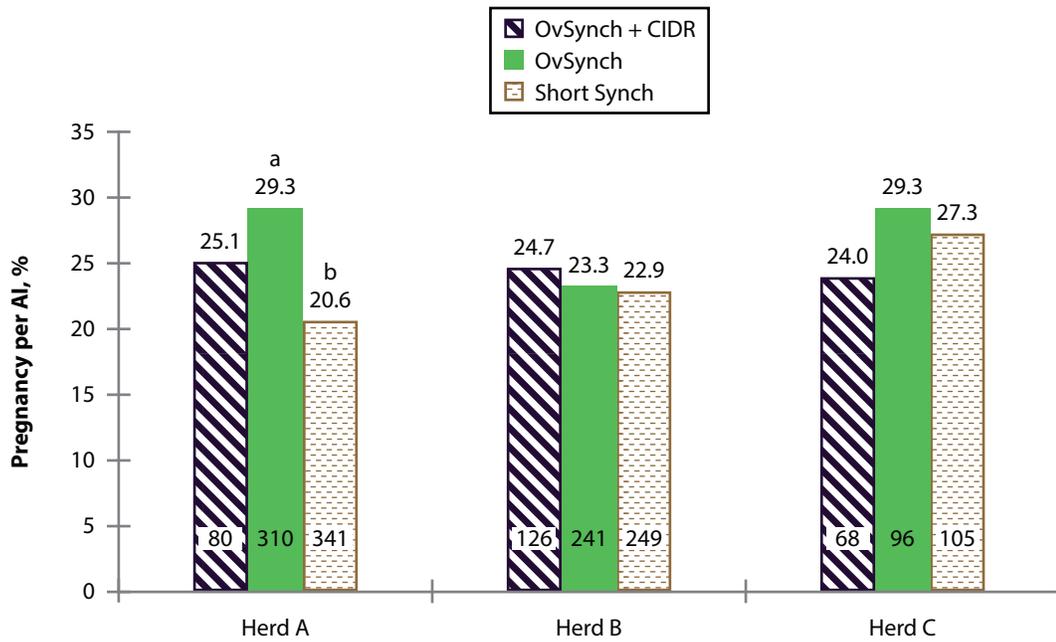


Figure 5. Pregnancy per AI at 60 to 66 days after insemination by herd. Lowercase letters indicate treatment differences ($P < 0.05$) in herd A.

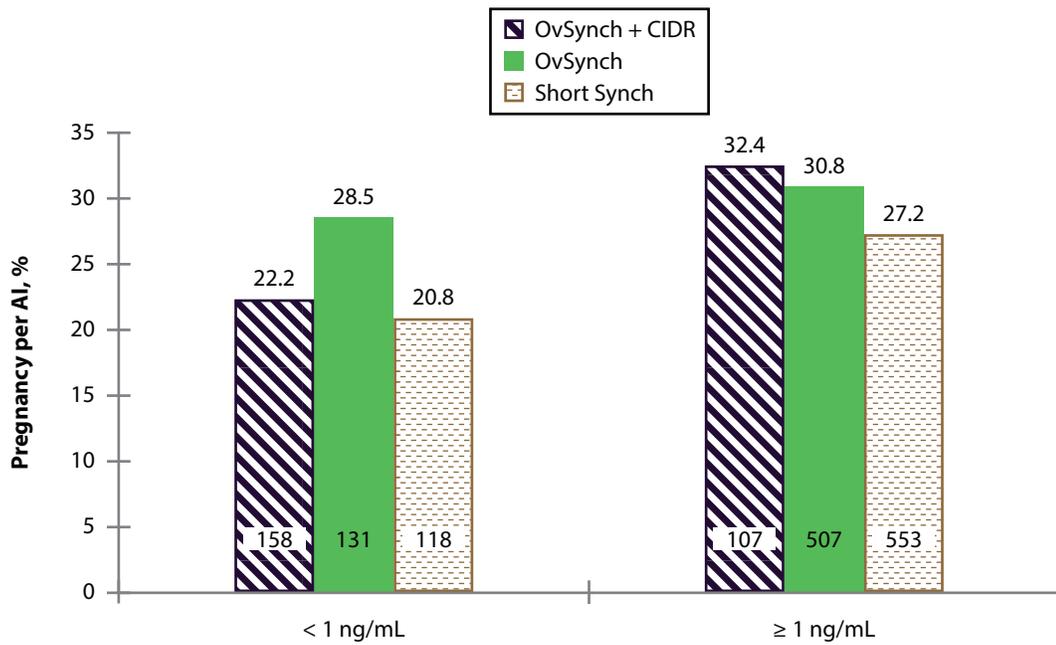


Figure 6. Pregnancy per AI based on the concentrations of progesterone at the nonpregnancy diagnosis and resynchronization treatment used.

Dose and Frequency of PGF_{2 α} Administration to Lactating Dairy Cows Exposed to Presynchronization and Either Five- or Seven-day Ovsynch Protocols: Ovulation, Luteolysis, and Pregnancy Rates

J.S. Stevenson and J.A. Sauls

Summary

Lactating Holstein cows in one herd were milked three times daily and enrolled in a $2 \times 2 \times 2$ factorial design with eight treatments before first postpartum artificial insemination (AI). These treatments were employed to test ovulatory, progesterone, and luteolytic outcomes to three main effects: (1) two GnRH-PGF_{2 α} presynchronization programs (PG-3-G vs. Double Ovsynch); (2) 5- vs. 7-day Ovsynch-duration programs; and (3) two doses (25 mg on consecutive days) or one dose (50 mg) of PGF_{2 α} administered before timed AI. Results from this experiment demonstrate no differences in the presynchronization treatments of PG-3-G vs. Double Ovsynch; both are effective in initiating estrous cycles during warm-hot vs. cool-cold seasons. Although ovulatory responses were similar after the first GnRH administration, Double Ovsynch cows tended to have greater ovulation responses after the second GnRH administration. The single large, one-time administered 50-mg dose was effective in causing luteolysis in the 7-day program but slightly less effective in the 5-day program. Thus, when using the shorter 5-day program, the two 25-mg PGF_{2 α} doses administered 24 hours apart are recommended. Insufficient numbers of cows were treated to make conclusions about pregnancy outcomes in this one-herd study. Pregnancy rates, however, were reduced in 5-day Ovsynch program when the single large 50-mg dose of PGF_{2 α} was employed.

Introduction

Potential limitations to a successful timed artificial insemination (AI) program for cows submitted for first service include cows that are not cycling (anovulatory), synchronization of the ovulatory follicle that should ovulate just after the timed AI, and regression of the corpus luteum or corpora lutea (if more than one exists when PGF_{2 α} is administered).

Two Ovsynch programs are used in the industry: 1) 5-day program: GnRH (G-1) — 5 days — PGF_{2 α} — 24 hours — PGF_{2 α} — 48 hours — GnRH (G-2) + timed AI; or 2) 7-day program: GnRH (G-1) — 7 days — PGF_{2 α} — 56 hours — GnRH (G-2) — 16 hours — timed AI.

Presynchronization programs before first postpartum AI used in the industry include combinations of PGF_{2 α} and GnRH (i.e., GnRH-PGF_{2 α} presynchronization options). These programs include: PG-3-G (PGF_{2 α} — 3 days — GnRH — 7 days — Ovsynch); G-6-G (PGF_{2 α} — 2 days — GnRH — 6 days — Ovsynch); or Double Ovsynch (GnRH — 7 days — PGF_{2 α} — 3 days — GnRH — 7 days — Ovsynch). These

GnRH-PGF_{2α} presynchronization programs are alternatives to the traditional PGF_{2α} - presynchronization programs (2 injections of PGF_{2α} 14 days apart — 10, 11, 12, or 14 days — Ovsynch) because they often further improve pregnancy rates.

The advantages of these GnRH-PGF_{2α} presynchronization programs include inducing ovulation in anovulatory cows, decreasing the percentage of cows with lower circulating progesterone concentrations (< 0.50 ng/mL) at G-1, increasing the percentage of cows with medium progesterone concentrations (0.50 < progesterone ≤ 3.0 ng/mL) at G-1, and increasing the proportion of cows with a corpus luteum (CL) at G-1. In addition, these GnRH-PGF_{2α} presynchronization programs increase the percentage of cows with high progesterone (> 3.0 ng/mL) at the PGF_{2α} treatment that immediately precedes timed AI and tend to increase average circulating progesterone at PGF_{2α}.

Early studies in beef and dairy cows indicated that an improvement in pregnancy outcome seemed to occur when a shorter 5-day Ovsynch program was compared with a 7-day program. The problem with these published studies was the confounding of program duration (5 vs. 7 days) and use of one vs. two doses of PGF_{2α} (6 to 24 h apart) to induce luteolysis. In none of the experiments were the two doses of PGF_{2α} tested in both the 5- and 7-day programs. Therefore, a test of the two doses of PGF_{2α} must occur in both programs to interpret the data correctly. If the 5-day program is not superior in pregnancy outcome, then the difference may simply be the result of improved complete luteolysis in cows treated with two doses of PGF_{2α}, regardless of program duration.

Applying a second standard dose or a single larger dose of PGF_{2α} seems to maximize complete luteolysis before timed AI. Corpora lutea less than 10 days old are resistant to complete regression after a single standard dose of PGF_{2α}. Administering PGF_{2α} as a single large dose on day 7 or as two standard doses on days 5 and 6 after G-1 (5-day Ovsynch) usually results in 70 to 84% of cows with progesterone < 0.3 ng/mL on the day of the timed AI. Progesterone concentrations at or near baseline at the final GnRH treatment influence the characteristics of GnRH-induced LH release and subsequent pregnancy risk. Increased dose or frequency of PGF_{2α} at the end of Ovsynch program has enhanced luteolysis, reduced progesterone concentrations at timed AI, and in some cases slightly increased pregnancy risk compared with a standard single dose. Recent studies demonstrated increased complete luteolysis when 7-day Ovsynch programs included a second standard dose of PGF_{2α} compared with a single standard dose.

Therefore, we proposed to address three questions. (1) Does the additional preGnRH (PreG; Figure 1) injection of Double Ovsynch improve synchronization characteristics compared with the PG-3-G presynch program? (2) Will one large dose (50 mg) of PGF_{2α} produce complete luteolysis similar to two standard 25-mg doses given 24 h apart? (3) Is the 5-day Ovsynch program superior to the 7-day program when similar dose and frequency of PGF_{2α} injections are administered in both programs?

Experimental Procedures

We enrolled 407 lactating dairy cows in a 2 × 2 × 2 factorial design consisting of 8 treatments for 20 months (September 2015 through April 2017). This approach was employed to test ovulatory, progesterone, and luteolytic outcomes to three main effects (Figure 1): (1) two GnRH-PGF_{2α} presynchronization programs (PG-3-G vs. Double

Ovsynch); (2) 5- vs. 7-day Ovsynch-duration programs; and (3) two doses (25 mg on consecutive days) or one dose (50 mg) of PGF_{2 α} administered before timed AI (Figure 1). Double Ovsynch includes the additional PreGnRH injection (PreG; highlighted box in Figure 1) that is not part of the PG-3-G presynch program.

Blood samples were collected before G-1, before PGF_{2 α} , and at 24, 48, and 72 h after PGF_{2 α} (first or only PGF_{2 α} injection) to determine concentration ranges of progesterone and assess complete luteolysis (progesterone < 0.5 ng/mL at 48 to 72 h after the first or only dose of PGF_{2 α}). Transrectal ovarian scans by ultrasonography were used to assess ovulation after G-1 and G-2. Although pregnancy risk was assessed, this experiment was not designed to test pregnancy risk but focused on: (1) ovulation responses to G-1 and G-2; and (2) proportion of cows with complete luteolysis, as illustrated in Figure 1.

Results and Discussion

Ovarian Cyclicity

On the basis of progesterone concentrations, the proportion of cows that had initiated estrous cycles at the start of the Ovsynch program did not differ between PG-3-G and Double Ovsynch (Table 1). More cows tended ($P = 0.09$) to return to having estrous cycles before the onset of ovulation synchronization programs during the cool-cold season compared with the warm-hot season (88.4 vs. 81.9%).

Ovulation Response to GnRH-1

Neither single nor multiple ovulation responses to G-1 differed between PG-3-G and Double Ovsynch treatments (Table 1). Season had differing effects on multiple ovulation in cows treated with PG-3-G and Double Ovsynch. During the warm-hot season, multiple ovulation occurred more frequently in PG-3-G than Double Ovsynch cows (17.4 vs. 6.4%), whereas during the cool-cold season, the reverse was detected (8.6 vs. 13.6%, respectively).

Luteolysis

Decreasing concentrations of progesterone (luteolysis or regression of the corpus luteum or corpora lutea) after the PGF_{2 α} treatments just preceding timed AI are summarized in Table 2. At 24 hours after the first or only PGF_{2 α} dose, the proportion of cows with progesterone concentration < 1 ng/mL was greater ($P < 0.05$) in Double Ovsynch than PG-3-G treatments; greater ($P < 0.05$) in 7- vs. 5-day Ovsynch cows, and greater in cows treated with the 1 \times 50 mg than 2 \times 25 mg PGF_{2 α} dose (no interactions). At 48 and 72 hours, more ($P < 0.01$) cows had progesterone < 1 ng/mL in the 7- vs. 5-day Ovsynch cows. At 72 hours, more ($P < 0.01$) cows had progesterone < 0.5 ng/mL in the 7- vs. 5-day Ovsynch cows and more ($P < 0.01$) cows receiving the 2 \times 25 mg dose than the 1 \times 50 mg dose. An interaction, however, was detected at 48 and 72 hours between the Ovsynch duration and the PGF_{2 α} dose-frequency (Figure 2). Although mean progesterone was < 0.05 ng/mL at both time points, the single 1 \times 50 mg was slightly less effective than the 2 \times 25 mg dose in reducing concentrations of progesterone in the 5- vs. 7-day Ovsynch-treated cows. Thus, the single large dose was equally effective as the 2 \times 25-mg dose in the 7-day Ovsynch program, but less so when applied to cows in the shorter 5-day program.

Ovulation Response to GnRH-2

Single ovulation after G-2 differed slightly between presynch treatments (Table 3). Cows presynched with Double Ovsynch tended ($P = 0.085$) to have greater ovulatory responses than PG-3-G cows. Duration of Ovsynch (5 vs. 7 days) had no effect on ovulation response to G-2. Single ovulatory response to G-2 tended ($P = 0.073$) to be greater during the cooler-cold season than during the warmer-hot season (94.2 vs. 88.3%, respectively).

In contrast, multiple ovulation tended ($P = 0.108$) to be greater in PG-3-G than Double Ovsynch cows and greater ($P = 0.004$) in 5- vs. 7-day cows. An interaction ($P = 0.011$), however, was detected between presynchronization treatments and Ovsynch duration (Table 3). Multiple ovulation was greater in PG-3-G cows in the 5-day compared with the 7-day program, whereas no differences in multiple ovulation occurred between program durations in Double Ovsynch cows. Season had no effect on the frequency of multiple ovulation.

Pregnancy Outcomes

No overall differences were detected in pregnancy rate between PG-3-G and Double Ovsynch treatments (Table 3) or between the 5- vs. 7-day program, although numerically pregnancy rates were greater for PG-3-G and 7-day program cows. Because of the differences in the effectiveness of luteolysis (decreasing progesterone after $\text{PGF}_{2\alpha}$ during the timed AI week), an interaction between Ovsynch duration and $\text{PGF}_{2\alpha}$ dose-frequency was detected (Table 3). Cows receiving the 1×50 mg dose in the 7-day program had greater ($P < 0.05$) pregnancy rates than cows receiving the 1×50 mg dose in the 5-day program.

Results from this experiment demonstrate no significant differences in the presynchronization responses to PG-3-G vs. Double Ovsynch treatments. Both are effective in initiating estrous cycles during all seasons. Although ovulatory responses were similar after G-1, Double Ovsynch cows tended to have greater ovulation responses after G-2. The single large, one-time administered 50-mg dose was effective in causing luteolysis in the 7-day but less so in the 5-day cows. Thus, when using the shorter 5-day program, the two 25-mg doses administered 24 hours apart are recommended. Insufficient numbers of cows were treated to make conclusions about pregnancy outcomes in this one-herd study. Pregnancy rates, however, were reduced in 5-day compared with the 7-day Ovsynch program when the single large 50-mg dose of $\text{PGF}_{2\alpha}$ was employed. As expected, pregnancy rate was greater ($P = 0.056$) during the cooler-cold months compared with warmer-hot season (40.2 vs. 30.0%).

Table 1. Ovarian cyclicity assessed at 7 days after two presynchronization treatments and ovulatory responses response to GnRH-1 (G-1)

Item	Presynchronization ¹		
	DO	PG-3-G	<i>P</i> -value
Cyclicity before G-1, %	88.8	90.5	0.566
Single ovulation to G-1, %	68.4	63.2	0.267
Multiple ovulation to G-1, %	7.8	8.4	0.845

¹Double Ovsynch (DO) = GnRH — 7 days — PGF_{2α} — 3 days — GnRH; PG-3-G = PGF_{2α} — 3 days — GnRH.

Table 2. Percentage of cows with progesterone concentrations < 1 ng/mL at 24, 48, and 72 hours after the first or only dose of PGF_{2α} or < 0.5 ng/mL at 72 hours

Hours after the first or only PGF _{2α} treatment	Presynchronization		Ovsynch, days		PGF _{2α} dose, ⁴ mg	
	DO ¹ (n = 164)	PG-3-G ² (n = 163)	Five ³ (n = 163)	Seven ³ (n = 164)	2 × 25 (n = 164)	1 × 50 (n = 163)
24 (< 1 ng/mL)	57.3 ^a	36.0 ^b	46.0 ^a	57.3 ^b	40.5 ^c	62.8 ^d
48 ⁵ (< 1 ng/mL)	88.4 ^a	90.2 ^a	84.0 ^c	95.5 ^d	92.0 ^a	86.6 ^a
72 ⁵ (< 1 ng/mL)	95.7 ^a	94.5 ^a	90.8 ^c	99.4 ^d	98.2 ^a	92.7 ^b
72 ⁵ (< 0.5 ng/mL)	95.9 ^a	94.1 ^a	90.6 ^c	99.4 ^d	98.2 ^a	92.0 ^b

^{a,b}Means differ (*P* < 0.05) within main effect category.

^{c,d}Means differ (*P* < 0.01) within main effect category.

¹Double Ovsynch (DO) = (DO) = GnRH — 7 days — PGF_{2α} — 3 days — GnRH;

²PG-3-G = PGF_{2α} — 3 days — GnRH.

³Five = GnRH — 5 days — PGF_{2α}; Seven = GnRH — 7 days — PGF_{2α}; both were initiated 7 d after the end of the presynchronization treatments.

⁴Two, 25-mg doses 24 h apart or one, 50-mg dose.

⁵Interaction (*P* < 0.05) between Ovsynch duration and PGF_{2α} dose.

Table 3. Ovulatory responses to GnRH-2 (G-2) in response to the presynchronization (Pre; PG-3-G or Double Ovsynch) and 5- or 7-day Ovsynch (Ovs) programs

Item	DO ¹		PG-3-G ²		<i>P</i> -value		
	Five ³	Seven ³	Five ³	Seven ³	Pre	Ovs	Pre × Ovs
Single ovulation, %	96.0	95.4	90.6	93.0	0.085	0.822	0.569
Multiple ovulation, %	16.0	14.7	32.4	11.0	0.108	0.004	0.011

¹Double Ovsynch (DO) = (DO) = GnRH — 7 days — PGF_{2α} — 3 days — GnRH.

²PG-3-G = PGF_{2α} — 3 days — GnRH.

³Five = GnRH — 5 days — PGF_{2α}; Seven = GnRH — 7 days — PGF_{2α}; both were initiated 7 d after the end of the presynchronization treatments.

Table 4. Pregnancy rate for lactating cows treated with two presynchronization treatments (Double Ovsynch [DO] vs. PG-3-G), two Ovsynch durations (5- vs. 7-days), and two PGF_{2α} (2 × 25-mg vs. 1 × 50-mg doses)

Presynch ¹	5 day ²		7 day ²		DO vs. PG-3-G
	2 × 25 mg ³	1 × 50 mg ³	2 × 25 mg ³	1 × 50 mg ³	
DO	34.5 (55)	35.1 (57)	27.8 (54)	36.8 (57)	33.6 (223)
PG-3-G	40.3 (57)	24.1 (54)	40.7 (59)	49.1 (57)	38.8 (227)
Total ⁴	37.5 ^{ab} (112)	29.7 ^a (111)	34.5 ^{ab} (113)	43.0 ^b (114)	
5- vs. 7-day	33.6 (223)		38.8 (227)		

^{a,b} Mean percentages with different superscript letters differ ($P < 0.05$).

¹DO = GnRH — 7 days — PGF_{2α} — 3 days — GnRH; PG-3-G = PGF_{2α} — 3 days — GnRH;

PG-3-G = PGF_{2α} — 3 days — GnRH.

²Five = GnRH — 5 days — PGF_{2α}; Seven = GnRH — 7 days — PGF_{2α}; both were initiated 7 d after the end of the presynchronization treatments.

³Treatment with PGF_{2α} (2 × 25-mg vs. 1 × 50-mg doses).

⁴Interaction of Ovsynch duration vs. PGF_{2α} dose ($P = 0.043$).

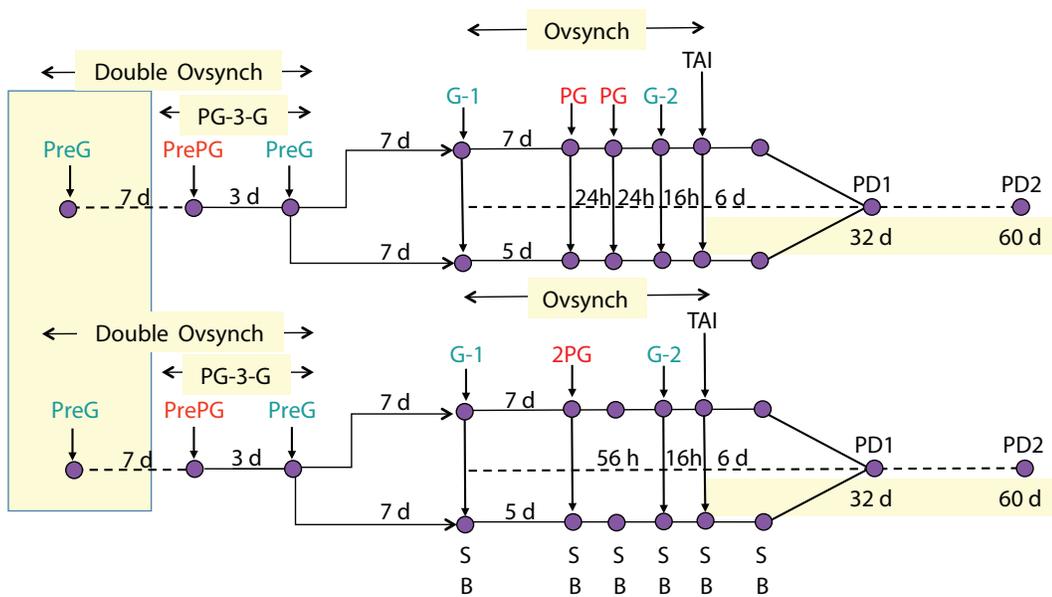


Figure 1. Illustration of the 2 × 2 × 2 factorial design of 8 treatments. Main effects included presynchronization (Double Ovsynch vs. PG-3-G), Ovsynch duration (5 vs. 7 d), and PGF_{2α} dose-frequency (2 × 25 vs. 1 × 50-mg doses) and schedule for blood collection and transrectal ultrasonograms. B = blood sample, S = transrectal ultrasonogram of ovaries; PrePG or PG = 25 mg PGF_{2α}, 2PG = 50 mg PGF_{2α}, PreG, G-1 or G-2 = 100 μg gonadotropin-releasing hormone (GnRH), PD = pregnancy diagnosis.

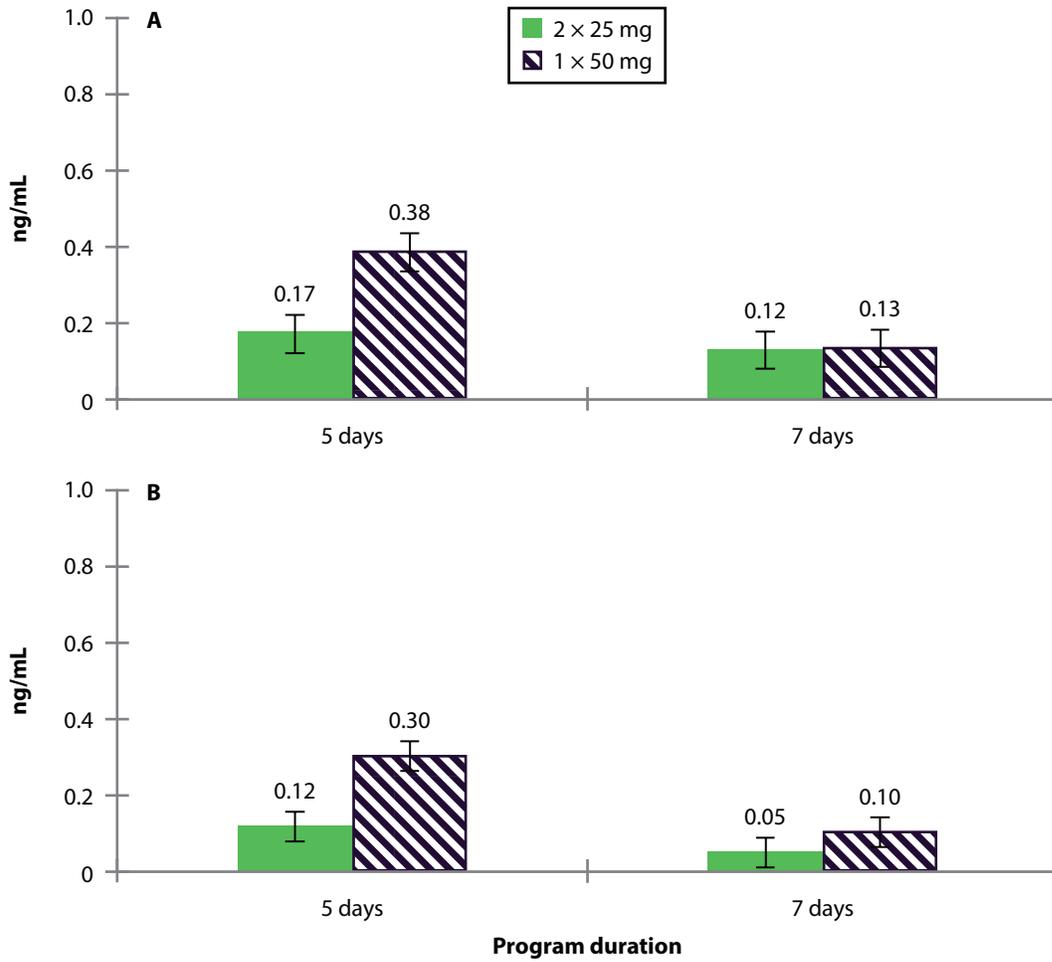


Figure 2. Progesterone concentrations at 48 (A) and 72 (B) hours after the first or only injection of PGF_{2α} showing the lesser effectiveness of the 1 × 50 mg dose to reduce progesterone concentrations in the 5-day but not the 7-day Ovsynch program.

Effects of Milk Feeding Strategies on Short- and Long-term Productivity of Holstein Cows

M. Garcia, S.R. Montgomery, L.E. Hulbert, and B.J. Bradford

Summary

The objectives of this study were to determine the impacts of feeding preweaning heifers with a high protein milk replacer (MR) or a raw or pasteurized non-saleable milk (NSM) on preweaning and first lactation performance. Holstein heifers ($n = 154$) were blocked by birth date and weight (BW) and within block randomly assigned to 1 of 3 treatments: 1) MR (4% protein and 2.6% fat, liquid basis); 2) pasteurized NSM (PNSM, 3.6% protein and 4.1% fat, liquid basis); or 3) raw NSM (RNSM, 3.6% protein and 4.1% fat, liquid basis). Heifers in RNSM were fed raw colostrum whereas heifers in MR and PNSM were fed pasteurized colostrum. Heifers were fed milk treatments 3 times per day. Low BW heifers (< 80 lb) were fed 3 pints/feeding until the target BW was achieved (then 4 pints/feeding), whereas high BW heifers (≥ 80 lb) were fed 4 pints/feeding since birth. After weaning (≥ 42 d of age and consuming at least 2 lb grain mix for 3 consecutive days), all heifers were uniformly managed. Heifers fed MR instead of NSM ate less grain (0.76 vs. 0.95 lb/d, $P = 0.01$). Low BW heifers fed RNSM had lesser average daily gain than high BW heifers fed RNSM ($P = 0.01$) but daily gain did not differ among heifers fed PNSM, perhaps because low BW heifers consumed more grain than high BW heifers on this treatment ($P = 0.01$). The 305-day mature equivalent (ME) milk yield was lower for low BW heifers compared with high BW heifers, but only when fed RNSM (28,785 vs. 32,542 lb ME milk, $P = 0.04$). Similarly, ME fat yield was reduced when RNSM was fed to low-BW heifers (1,094 vs. 1,244 lb ME fat, $P = 0.05$). The type and quantity of milk fed did not impact reproductive efficiency ($P > 0.10$). Feeding RNSM may impair the first lactation performance of low BW heifers, whereas it did not appear to affect high BW heifers.

Introduction

According to the U.S. Department of Agriculture, small- and medium-sized dairies rely heavily on milk for calf feeding. Among the dairies feeding milk, more than 50% feed unpasteurized saleable or NSM, whereas only 5% of the small but 43.8% of the large dairies feed pasteurized milk.

Smaller-scale pasteurization systems are now available and are becoming more widely used by medium and small dairies. Research conducted in the last decades has proven the efficacy of on-farm pasteurization for reducing microbial load in colostrum and milk. Furthermore, the benefits of enhanced preweaning growth on milk yield in the subsequent lactation has been concluded in two recent meta-analyses. One of those studies also concluded that preweaning management was the major factor contributing to the variation in milk production at first lactation.

Studies have reported that “accelerated” (28% CP and 20% fat) compared with a “traditional” (20% fat, 20% protein) milk replacer (MR) feeding programs increase pre-

weaning growth rates. However, when an accelerated MR feeding program is compared with milk feeding, even at comparable concentration of nutrients, calves fed milk often outperform those fed MR. The current study hypothesizes that feeding a PNSM relative to feeding RNSM or a high-protein MR would not only benefit the health and growth of heifers during the preweaning period but would extend into first lactation performance.

Experimental Procedures

Holstein heifers ($n = 154$) born at the Kansas State University Dairy Teaching and Research Center, Manhattan, KS, with BW > 60 lb and calving ease score < 3 were enrolled in the study. Heifers were blocked by birth date and BW ($<$ or ≥ 80 lb) and were randomly assigned within block to 1 of 3 treatments: (1) MR, (2) PNSM, or (3) RNSM. Heifers in the RNSM group were fed raw colostrum whereas heifers in MR and PNSM groups were fed pasteurized colostrum. Warm colostrum (> 50 g/L of immunoglobulin G, 1.5 gallons total) was provided at $\leq 2, 6,$ and 12 hours after birth. All milk treatments were fed at 99°F 3 times per day. The NSM was obtained from the dairy, and was sampled weekly before ($4.12 \pm 0.37\%$, $3.59 \pm 0.28\%$, and $1,662 \pm 771$ cells/ μ L for fat, true protein, and SCC content, respectively) and after pasteurization ($4.14 \pm 0.35\%$, $3.61 \pm 0.29\%$, and $1,575 \pm 704$ cells/ μ L for fat, protein, and SCC content, respectively). The MR (Mother's Pride, Hubbard Feeds, Mankato, MN; 28% protein and 18% fat on a DM basis) was mixed according to the manufacturer's recommendations. The reconstituted milk replacer (14.2% total solids) provided the same metabolizable energy concentration as milk; therefore, treatments were fed on an equal-volume basis. Low BW heifers (< 80 lb) were fed 3 pints at each feeding until they reached 80 lb (thereafter fed 4 pints/feeding), whereas high BW heifers (≥ 80 lb) were fed 4 pints at each feeding. Body weight and shoulder and hip heights were recorded at birth and then once a week until heifers were 8 weeks old and every 4 weeks thereafter, until heifers were 24 weeks old.

After weaning (≥ 42 d of age and consuming at least 2 lb grain mix for 3 consecutive days), all heifers were uniformly managed according standard procedures. Weaned heifers were moved to sod pens, grouped according to BW, and fed diets formulated to supply their nutrient requirements. Heifers were rotated among sod pens according to growth and reproductive status. Two months before the expected calving date, heifers were moved to a maternity pen bedded with straw where they were frequently monitored for signs of calving. Upon calving, heifers were moved to free-stall barns equipped with sprinklers and fans, and fed a totally mixed ration (TMR) formulated to meet nutrient requirements for lactating dairy cows. Cows were milked 3 times daily. Milk yield and composition data used for 305-day ME yield data were derived from monthly testing by the Dairy Herd Improvement Association. For ME milk, protein, and fat yield data, the predicted transmitted ability of the corresponding variable was used as covariate to account for genetic differences between animals. Cull dates and reasons for culling were also obtained from the PC-DART.

Results

The type of milk fed (MR or NSM) did not affect average daily gain (ADG) or weaning age (Table 1), but heifers fed MR instead of NSM ate less grain mix (0.76 vs. 0.95 lb/d). The effect of pasteurization was impacted by BW group. Low BW heifers fed RNSM

had lower ADG than high BW heifers fed the same type of milk (1.33 vs. 1.76 lb/d). However, no difference in ADG was observed between low BW and high BW heifers fed PNSM (1.54 vs. 1.44 lb/d for low and high-BW heifers, respectively). Similar effects were observed for ADG measured from birth to 24 weeks of age (Table 1). When fed PNSM, low BW heifers consumed more grain than high BW heifers, but not when they were fed RNSM; consequently, the odds of low BW heifers fed PNSM to be weaned at 6 weeks of age were ~3 times greater compared with low BW heifers fed RNSM.

Neither the type nor the amount of milk fed (nor their interaction) impacted shoulder and hip heights during the first 24 weeks of age (Table 1). The number of AI required to attain first pregnancy was not affected by treatments, and all heifers had their first calf at a similar age (22.6 ± 0.3 months).

First lactation 305-day ME milk yield was substantially diminished in low BW heifers fed RNSM compared with high BW heifers fed RNSM (28,785 vs. 32,542 lb, Table 1). Similarly, ME fat was also compromised when RNSM was fed to low BW heifers (1,094 vs. 1,244 lb for low and high BW heifers, respectively). In contrast, when fed PNSM, low and high BW heifers produced similar amounts of ME milk and fat (Table 1). The type and quantity of milk fed did not impact reproductive efficiency, as no difference was observed in days open. Finally, survival in the herd did not differ between treatments (Figure 1).

Discussion

Our results indicate that feeding a high protein MR, characteristic of an accelerated feeding program, compared with feeding NSM, regardless of pasteurization, did not have any benefit on preweaning and first lactation performance.

In this study, low BW heifers were fed lesser amounts of milk (9 pints/d) before they reached 80 lb to attempt to prevent potential digestive problems associated with excess intake relative to body size. This population (21% of the total enrolled heifers), uniquely benefited from pasteurization of colostrum/NSM. Low BW heifers fed PNSM ate more grain than their weight-matched peers fed RNSM (+0.29 lb/d) and more than high BW heifers fed PNSM (+0.28 lb/d), improving their opportunity for early weaning. Furthermore, the greater intake of solid feed may have contributed to growth rates similar to those of high BW heifers fed PNSM, which were not matched by low BW heifers fed RNSM.

Importantly, the feeding of raw colostrum and RNSM impaired not only the preweaning performance of these low BW heifers, but also had detrimental effects on their first lactation. Heifers that were fed PNSM, no matter their BW at birth, produced similar amounts of ME milk and fat, whereas low BW heifers fed RNSM produced 3,757 and 150 lb less ME milk and fat, respectively, compared with high BW heifers fed RNSM.

Conclusions

Feeding raw NSM may impair the long-term productivity of low BW heifers whereas the same effect appeared not to affect high BW heifers. Pasteurized NSM and an accelerated MR supported similar growth and first-lactation performance across heifers of low and high BW.

Table 1. Performance of heifers fed milk replacer (MR) or pasteurized or raw non-saleable milk (PNSM and RNSM, respectively) from birth to weaning (≥ 6 weeks)

	Milk replacer		Pasteurized NSM		Raw NSM			<i>P</i> -value ²				
	LBW ¹	HBW	LBW	HBW	LBW	HBW	SEM	TM	Past	BW	TM × BW	Past × BW
From birth to 42 d of age												
BW, lb	71.2	87.6	69.8	88.5	72.7	88.2	1.6	0.77	0.49	< 0.01	0.80	0.34
Average daily gain, lb/d	1.58	1.60	1.54	1.44	1.33	1.76	0.10	0.47	0.60	0.12	0.33	0.01
Grain intake, lb/d	0.78	0.74	1.12	0.84	0.83	0.99	0.08	0.01	0.43	0.38	0.84	0.01
Weaning by 42 d, HR ³	1.65	0.98	3.15	1.34	1.00	1.34	-	0.25	0.01	0.04	0.77	0.01
From birth to 24 weeks of age												
ADG, lb/d	1.94	1.90	1.95	1.87	1.77	2.02	0.07	0.81	0.84	0.52	0.29	0.03
Shoulder height, inches	34.2	35.4	34.2	35.3	34.3	35.5	0.2	0.97	0.53	< 0.01	0.78	0.89
Hip height, inches	36.0	37.5	35.9	37.2	36.3	37.4	0.2	0.84	0.16	< 0.01	0.53	0.75
At first calving												
Numbers of AI	1.7	1.8	1.9	2.1	1.1	2.1	0.2	0.33	0.13	0.18	0.42	0.26
Age, months	22.3	22.8	22.6	22.7	22.4	22.8	0.3	0.83	0.90	0.21	0.53	0.73
First lactation												
305-day ME ⁴ milk, lb	30,393	31,560	31,709	31,165	28,785	32,542	879	0.92	0.46	0.06	0.77	0.04
305-day ME fat, lb	1,188	1,227	1,217	1,197	1,094	1,244	36	0.54	0.37	0.08	0.67	0.05
305-day ME protein, lb	897	922	886	906	852	939	21	0.46	0.99	0.02	0.44	0.18
Days open	103.1	98.2	89.3	112.2	95.1	119.8	9.1	0.82	0.68	0.26	0.24	0.99

Heifers born < 80 lb (LBW) were fed 9 pints/d of milk until they reached 80 lb, whereas high BW (HBW) heifers were fed 12 pints/d (HM). Heifers were uniformly managed after weaning.

¹LBW = low birth weight, < 80 lb; HBW = high birth weight, ≥ 80 lb.

²Contrasts: TM, type of milk = MR vs. (PNSM + RNSM); Past, effect of pasteurization = PNSM vs. RNSM; BW, birth weight group = 9 vs. 12 pints/d based on BW until calves were ≥ 80 lb and were all fed 12 pints/d.

³HR = Hazard ratio describing the relative odds of weaning at this age; the RNSM-LBW group is the referent.

⁴ME = mature equivalent.

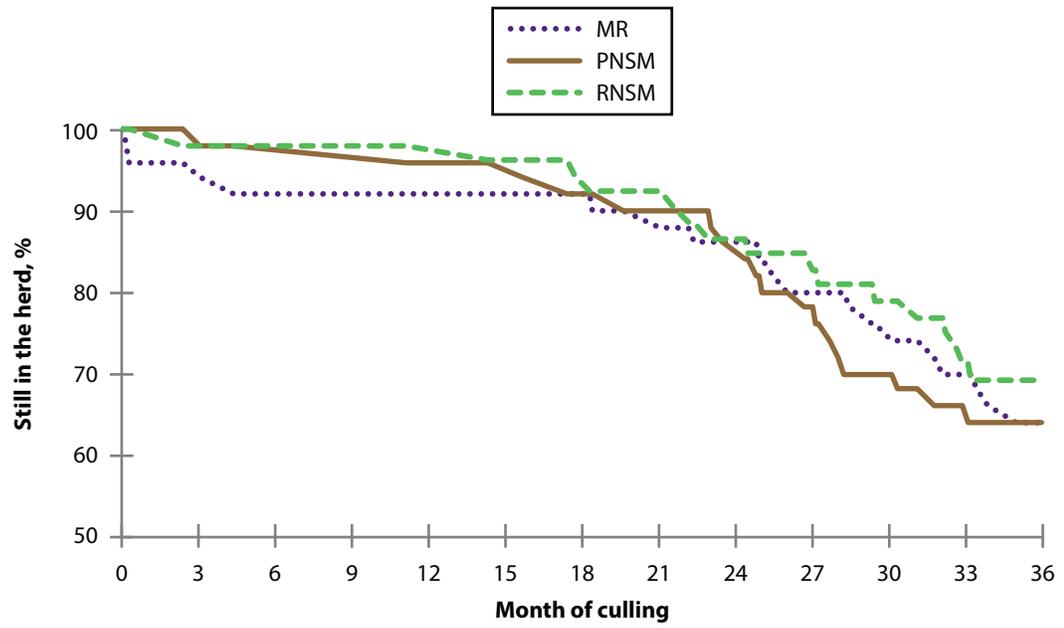


Figure 1. Retention in the herd of heifers fed milk replacer (MR), pasteurized or raw non-saleable milk (PNSM and RNSM, respectively) from birth to weaning (≥ 6 weeks). Heifers were uniformly managed after weaning. MR vs. (PNSM + RNSM), $P = 0.92$; PNSM vs. RNSM, $P = 0.69$.

Productivity of a Triticale and Crimson Clover Winter Cover Crop for Dairies

K.E. Olagaray, C. Takiya, M. Scheffel, T. Brown,¹ J.S. Stevenson, D. Min, and B.J. Bradford

Summary

The potential for a winter cover crop to align with agronomic objectives and to support milk production was evaluated at the Kansas State University Dairy Teaching and Research Center, Manhattan, KS. August planting of a triticale and crimson clover blend following corn silage harvest resulted in production of more than 3.5 tons of dry matter prior to subsequent corn planting. After ensiling, the impact of triticale/crimson clover silage (TCS) on milk production was evaluated in 48 mid- to late-lactation Holstein cows. Cows were blocked by parity (1 and 2+) and milk production, then randomly assigned within block to treatment sequence and pen. The crossover design consisted of two 21-day periods, with 17 days of diet adaptation and 4 days of sampling. Treatments were a diet which included TCS at 15% of diet dry matter (DM) and a control ration in which TCS was primarily replaced by alfalfa and grass hays. The TCS diet included additional bypass soybean meal in an attempt to balance metabolizable protein supply across diets. Samples of rations, feed refusals, and milk were obtained daily, and milk yield was recorded. The TCS diet decreased dry matter intake (48.4 vs. 55.9 ± 3.4 lb/d; $P = 0.02$), but did not alter milk yield ($P = 0.97$); therefore, feed efficiency was greater for the TCS diet ($P = 0.04$). Milk fat concentration tended to increase on the TCS diet ($P < 0.10$) whereas milk lactose yield tended to be lesser for TCS ($P = 0.09$), but other milk components analyzed (milk protein, MUN, SCC) did not differ between diets ($P > 0.15$). Utilization of TCS also impacted the dairy's nutrient management plan, as the winter forage harvest removed 40 and 340 lb/a of phosphorus and potassium, respectively. Overall, the blend of triticale and crimson clover as a winter cover crop produced good quality silage that maintained high milk production while also removing key nutrients from the soil to benefit nutrient management planning.

Introduction

Double cropping with winter forages provides the opportunity to maximize forage production while also removing phosphorus from manured soils, a key element in the nutrient management plan of dairies. Compared to wheat and barley, triticale produces more dry forage and removes more phosphorus. Mixing in a legume like crimson clover introduces the nitrogen fixing capability of legumes while also increasing the protein content of the forage. The combination of the high fiber and protein content in the forage makes it a good option to partially substitute for alfalfa hay. The objective of the study was to determine the effect of feeding TCS on milk production, while also examining impacts on soil nutrients.

¹Landus Cooperative, Ames, IA.

Experimental Procedures

Crop Production

The K-State Dairy Teaching and Research Center planted 110 acres of triticale/crimson clover in 2 separate fields on September 1, 2016. Beardless triticale (*Triticosecale*) and crimson clover (*Trifolium incarnatum*) were drilled into untilled ground at 100 and 5 lb/a, respectively, following corn silage harvest. No fertilizer was applied to the fields prior to planting. Lagoon water was applied on one field over the course of the growing season. The second field did not receive lagoon water but solid manure was spread on this field.

Animals and Treatments

The potential of TCS to maintain milk production was evaluated in 48 mid- to late-lactation Holstein cows (223 ± 67 DIM) in a study conducted from June to August 2017. Cows were blocked by parity and milk production, randomly assigned to treatment sequence within block, then randomly assigned to 1 of the 2 freestall pens assigned to that particular treatment sequence. Treatments were applied to pen ($n = 4$). The cross-over design consisted of 2 periods of 21 days, with the first 17 days for diet adaptation and the final 4 days used for sample collection. Cows were fed once daily and milked three times a day. Treatments were control or TCS diets; nutrient analysis of the TCS is shown in Table 1 and it was incorporated in the TCS diet at 15% of DM. Therefore, the TCS diet was adjusted by reducing proportions of the alfalfa and grass hays and adding bypass protein. Metabolizable protein, estimated using the Cornell model (version 6.55) as implemented in NDS software (RUM&N Sas, Reggio Emilia, Italy), was balanced across diets.

During the sampling period, TMR samples were taken daily and composited by period for nutrient analysis by Dairy One Forage Laboratory (Ithaca, NY). Samples of feed refusals from each pen were taken daily to determine pen dry matter intake; this value was divided by the number of cows in the pen on that day to determine dry matter intake per cow. In addition, milk yield was recorded and milk samples were taken at each milking for composition analysis (MQT Lab Services, Kansas City, MO). Fat-corrected milk (FCM) was calculated as $(0.432 \times \text{milk yield}) + (16.216 \times \text{fat yield})$, and energy-corrected milk (ECM) was calculated as $(0.327 \times \text{milk yield}) + (12.95 \times \text{fat yield}) + (7.65 \times \text{protein yield})$. Two cows were removed from the study due to mastitis in period 2.

Results and Discussion

Forage Production

On November 5, 2017, hay was harvested from the 110 acres, producing 120 round bales of hay, averaging 1,100 lb each at approximately 64% DM. Forage dry-down was a challenge at this time of year, resulting in excessive moisture and generating some Maillard products in the baled forage. Hay quality was further impacted by substantial weed carryover from the summer crop. However, harvesting hay in the fall resulted in a very clean forage crop in the spring. On April 22, 2017, the cover crop was swathed and allowed to partially dry, chopped at a 0.75-inch cut, and stored in silage bags with an inoculant. Fermentation analysis by Dairy One Forage Laboratory (Ithaca, NY) is shown in Figure 1. This crop produced 1,001 tons of silage (33% DM). Overall costs for the

production of the TCS crop totaled between \$30,000–\$35,000, equating to \$90–\$106 per dry matter ton invested in the production of the feed.

In addition to forage production, this cover crop played a role in the dairy's nutrient management plan through its ability to extract phosphorus. Table 2 summarizes the amount of phosphorus and potassium removed from the soil. Across both harvests, the cover crop removed almost 40 lb of phosphorus per acre and over 320 lb of potassium per acre. The ability of this crop to remove those nutrients creates the opportunity to spread more manure or lagoon water on these fields. Additional potential benefits of the cover crop include prevention of soil erosion, better weed control, and improvements in subsequent summer crop yield.

Lactating Cow Responses

A treatment diet was formulated to evaluate responses to TCS, primarily replacing alfalfa hay, with some other adjustments designed to balance diets for similar fiber, protein fractions, and energy (Table 3). The DMI and milk production variables are summarized in Table 4. Dry matter intake was lesser for the triticale diet than control diet (48.36 vs. 55.90 ± 3.44 lb/d; $P = 0.02$; Figure 2A). Despite lesser intake, milk yield did not differ between triticale and control (80.86 vs. 80.75 ± 2.07 lb/d; $P = 0.97$). Milk fat concentration tended to be greater on triticale than control (3.84 vs. 3.76 ± 0.08 ; $P < 0.10$), and milk lactose yield tended to be lesser on the triticale diet (3.92 vs. 3.79 ± 0.11 lb/d; $P = 0.09$). The other milk components analyzed including milk protein and lactose concentration, milk fat and protein yield, milk somatic cell linear score, and milk urea nitrogen did not differ between diets (all $P > 0.15$). Fat-corrected and energy-corrected milk yield (Figure 2B) were similar across diets (both $P > 0.50$). Because dry matter intake was lesser for the triticale diet but milk production did not differ, feed efficiency, defined as energy-corrected milk yield/dry matter intake, was greater for the triticale diet (1.71 vs. 1.48 ± 0.04 ; $P = 0.04$; Figure 2C). The DMI response was somewhat surprising and it would be interesting to see if it is repeated in a more intensive study measuring intake of individual cows. The fact that milk yield was not different and milk fat tended to increase supports the utility of TCS in lactation rations at up to 15% of the diet DM.

Conclusions

A winter cover crop blend of triticale and crimson clover produced more than 3 tons DM/a of a silage containing more than 20% crude protein. Soil phosphorus and potassium removed through both the hay and silage totaled 38 and 320 lb/a, respectively. Mid- to late-lactation cows fed TCS at 15% of diet DM had reduced feed intake but similar energy-corrected milk yield, resulting in greater feed efficiency. Overall, double cropping corn with a winter triticale/crimson clover mix produced additional forage of sufficient quality to sustain high milk yields in a carefully-formulated diet, while also removing soil nutrients that are of concern when considering manure management.

Following the 2016-2017 trial, several management changes were implemented for the crop planted in 2017. Nitrogen was applied prior to planting at a rate of 50 lb/a to promote both forage yield and greater P uptake. Instead of no-tillage management, vertical tillage was used to reduce weed problems and improve the seed bed. The seeding rate of triticale was decreased to 90 lb/a and crimson clover increased to 10 lb/a,

because in some locations in the previous year, clover growth appeared to be suppressed by the triticale. Due to the low quality of the fall-harvested hay in 2016, no fall harvest will be taken, although light-intensity grazing may be considered for heifers. It is anticipated that a similar winter cropping strategy will help the K-State Dairy Teaching and Research Center to meet its forage and nutrient management goals for the foreseeable future.

Table 1. Nutrient composition of the triticale/crimson clover silage

Nutrient analysis, % of DM (unless otherwise specified)	
Dry matter, % as-fed	32.7
Crude protein	21.1
Acid detergent fiber	35.4
Neutral detergent fiber (amylase-treated)	52.6
Non-fiber carbohydrate	8.20
Net energy for lactation, Mcal/kg	1.41

Table 2. Phosphorus and potassium removal from the 110 acres of triticale/crimson clover hay (cut November 2016) and silage (chopped April 22, 2017)

	Triticale/crimson clover hay ¹	Triticale/crimson clover silage ²
DM harvested, ton/a	0.38	3.0
Phosphorus, % DM	0.61	0.56
P removed, lb/a	4.68	33.63
Potassium, % DM	5.56	4.70
Potassium removed, lb/a	42.70	282.28

¹120 round bales at 1100 lb each (64% DM).

²1,001 as-fed tons harvested (33% DM).

Table 3. Ingredient and nutrient composition of the control and triticale diets

Item	Control	Triticale/crimson clover
Ingredient, % of DM		
Corn silage	24.9	22.5
Triticale/crimson clover silage	---	15.0
Alfalfa hay low ¹	9.73	3.11
Alfalfa hay high ²	9.34	3.11
Grass hay	1.56	
Wet corn gluten feed ³	22.8	22.8
Cottonseed	3.98	3.97
Expeller soybean meal ⁴	---	1.90
Lactation grain mix ⁵	27.6	27.6
Nutrient concentration, % of DM (unless otherwise specified)		
DM, % as-fed	60.5	52.7
Crude protein	17.3	17.9
Acid detergent fiber	17.8	18.0
Neutral detergent fiber	28.4	29.9
Non-fiber carbohydrate	39.7	37.0
Starch	24.6	23.8
Crude fat	4.96	5.71
Ash	9.71	9.46
NE _L , ⁶ Mcal/lb	0.74	0.76

¹Lower quality alfalfa hay.

²Higher quality alfalfa hay.

³Sweet Bran (Cargill Inc., Blair, NE).

⁴Soy Plus (Landus Cooperative, Ames, IA).

⁵Grain mix contained 61.5% fine ground corn, 22.3% Soy Plus (Landus Cooperative, Ames, IA), 3.24% Kruse Lact. PMX, 3.86% ground limestone, 2.46% sodium bicarbonate, 2.46% Ca salts of long-chain fatty acids (Megalac R, Arm & Hammer Animal Nutrition, Princeton, NJ), 1.40% XP Yeast (Diamond V, Cedar Rapids, IA), 0.56% Vitamin E (9070 IU/kg), 0.56% stock salt, 0.56% trace mineral salt, 0.89% magnesium oxide, 0.09% 4 Plex C (Zinpro Corp., Eden Prairie, MN), 0.05% Zinpro 120 (Zinpro Corp.), and 0.02% Rumensin 90 (Elanco Animal Health, Greenfield, IN).

⁶Net energy for lactation.

Table 4. DMI, milk yield, milk composition, and feed efficiency (ECM:DMI) for cows fed either the control or triticale diet

Item	Control	Triticale	SEM ¹	P-value
Dry matter intake, lb/day	55.90	48.36	3.44	0.02
Milk yield, lb/d	80.75	80.86	2.07	0.97
Milk fat, %	3.76	3.84	0.08	< 0.10
Milk protein, %	3.13	3.10	0.09	0.40
Milk lactose, %	4.90	4.88	0.04	0.47
Milk fat yield, lb/day	2.89	2.89	0.04	0.97
Milk protein yield, lb/day	2.49	2.38	0.09	0.21
Milk lactose yield, lb/day	3.92	3.79	0.11	0.09
Milk somatic cell linear score	2.86	2.90	0.42	0.90
Milk urea nitrogen, mg/dL	11.98	12.19	1.17	0.19
Fat-corrected milk yield, lb/day	81.61	81.61	1.50	1.00
Energy-corrected milk yield, lb/day	82.80	81.98	1.54	0.54
ECM:DMI ¹	1.48	1.71	0.11	0.04

¹Energy-corrected milk divided by dry matter intake.

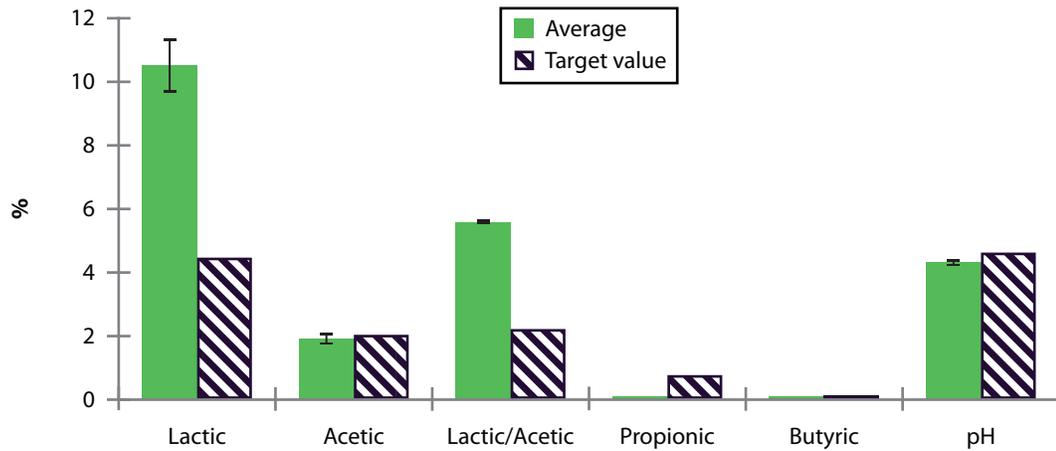


Figure 1. Fermentation analysis of the triticale/crimson clover silage. Solid bars are the average of the 3 samples sent in for analysis. Striped bars show the target value provided by Dairy One Forage Laboratory (Ithaca, NY).

NUTRITION AND FEEDING

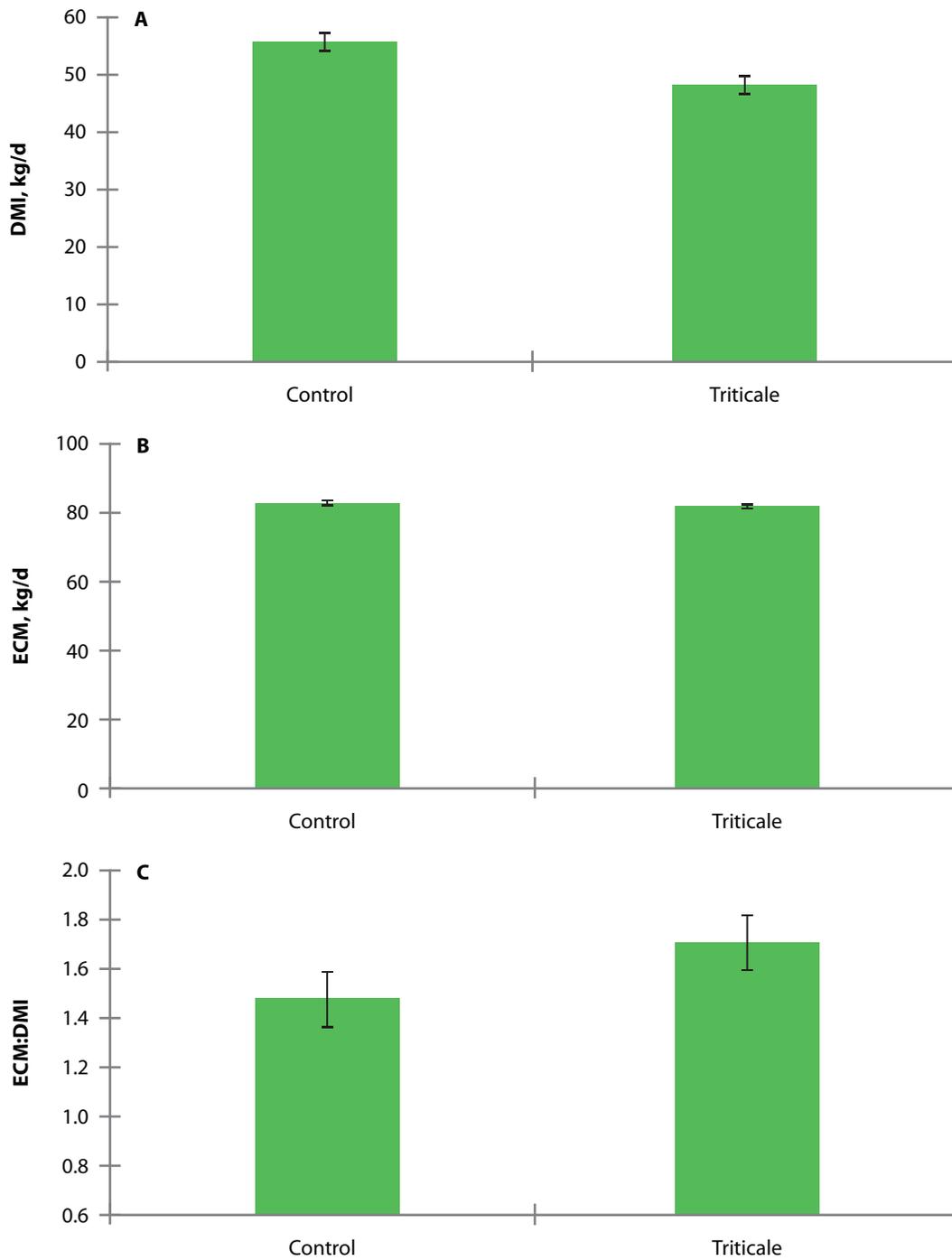


Figure 2. A) DMI was lesser for the triticale diet than the control ($P = 0.02$). B) Energy-corrected milk (ECM) was not different between diets ($P = 0.54$). C) Feed efficiency in cows on the triticale diet was greater than the control ($P = 0.04$). * $P < 0.05$.

Development of a Berry Processing Score for Sorghum Silage and Assessment of Processing Effects on Sorghum Silage Starch Digestibility

J.R. Johnson, J.P. Goeser, and M.J. Brouk

Summary

The objectives of this study were to develop a berry processing score (BPS) for sorghum silage, similar to the kernel processing score currently used for corn silage, and to evaluate the effects of processing on starch digestibility. Sorghum silage samples were collected from commercial farms in Kansas and randomly assigned to 1 of 4 processing levels differing in roll gap spacing: unprocessed (UNP), 1.5 (1.5P), 1.0 (1.0P), or 0.5 (0.5P) mm. Differences in BPS and starch digestibility were found—as the roll gap decreased, both BPS and starch digestibility increased. Thus, by processing sorghum silage during harvest and measuring the extent of processing, sorghum silage starch digestibility can be greatly enhanced. Sorghum silage may serve as a viable alternative to corn silage in the diets of lactating dairy cows in areas of the country where corn silage is a high-risk forage crop due to lack of water.

Introduction

Sorghum has become an increasingly important forage crop for dairy producers, particularly in the Midwestern and plains regions of the United States that routinely experience conditions of insufficient water. When compared to corn silage, sorghum silage uses 30–50% less water, making sorghum more heat- and drought-tolerant. This is especially important in areas where irrigation is limited and where elevated temperatures combined with drought are common.

Sorghum silage has long been known to have reduced whole-plant digestibility compared to corn silage, and therefore milk yield often decreases when sorghum silage is fed. A primary reason for reduced digestibility is that the starch contained within the berry is extremely dense, hard, and resistant to digestion. The protein matrix binds starch more tightly in sorghum than in corn, leading to lower digestibility and milk yield when feeding sorghum.

Kernel processing via on-board kernel processors has been used extensively in the harvest of corn silage, in an effort to better expose the starch within grain (increase surface area), and ultimately increase total tract starch digestibility for the dairy cow. Ten years ago, a method was established to determine the degree of kernel processing, or breakage, in whole plant corn harvested as silage. However, no such method has been developed for sorghum silage. Therefore, the objectives of this study were to develop a similar scoring system for sorghum silage and to evaluate its relationship with starch digestibility.

Experimental Procedures

A total of 72 samples were collected from 6 commercial dairy farms in Kansas. Upon arrival at the Kansas State University Grain Science and Industry grain processing laboratory, samples were either left unprocessed and used as the control, or run through a 9 × 6 inch roller mill using a roll gap setting of 1.5 mm, 1.0 mm, or 0.5 mm. The 12 samples from each farm were split into 4 treatments based on the level of processing: unprocessed (UNP), 1.5 mm processed (1.5P), 1.0 mm processed (1.0P), and 0.5 mm processed (0.5P). This resulted in 3 samples for each treatment from each farm in the study. One sample was analyzed to determine 7-hour *in situ* starch digestibility as an estimate of ruminal starch digestibility. Remaining samples were dried in a forced-air oven at 55°C for 72 hours to ensure complete removal of moisture, resulting in samples weighing ~100 g on a DM basis. Dry samples were separated for 10 minutes using a Ro-Tap 3-dimensional separator (W. S. Tylor, Mentor, OH) fitted with screens containing square apertures of 9.50, 6.70, 4.75, 4.00, 3.35, 2.80, 2.36, 1.70, 1.18, and 0.6 mm (in addition to a pan). Following separation of the sorghum silage samples, samples were divided into material retained above and below the 1.7 mm screen. Samples were then analyzed for starch content at Rock River Laboratories (Watertown, WI) to determine the percent of total starch passing through the 1.7 mm screen to determine the BPS for each sample. A BPS was calculated as follows:

$$\text{BPS} = (\text{Starch passing through 1.7 mm screen (g)} / \text{Total sample starch (g)}) \times 100$$

Results and Discussion

As shown in Figure 1, BPS increased as the level of processing increased (26.28, 34.64, 40.30, and 55.05 ± 0.04% for UNP, 1.5P, 1.0P, and 0.5P, respectively; $P < 0.001$). The unprocessed sample represents sorghum silage as it was collected from on-farm silage bunkers and indicates that processing of the sorghum berries could be greatly improved in the field. While BPS was improved when processed at either 1.5 or 1.0 mm compared to UNP, berry particle size could be reduced even further when processed at a roll gap spacing of 0.5 mm to enhance starch digestibility. Applying this to a forage harvester in the field will no doubt be more difficult when considering the amount of silage material that must pass through the processing unit.

As a result of the increased BPS, 7-h *in situ* starch digestibility also increased as the level of processing increased ($P < 0.01$) because of the reduced particle size of the starch present in the sorghum berries (Figure 2). Seven-hour *in situ* starch digestibility was lowest for UNP (50.54 ± 4.94%), intermediate for 1.5P and 1.0P (66.76 and 68.95 ± 4.94%) and greatest for 0.5P (82.07 ± 4.94%). These data are in agreement with previous research showing that processing increases the rate of starch digestion with the effects being greater for grains with more vitreous endosperm, such as sorghum. While little work has been conducted with sorghum silage, to our knowledge, similar results have been found when processing corn silage, where processing during harvest reduced the kernel particle size and increased total-tract starch digestibility. Improving starch digestibility via processing not only will affect milk production, but also ruminal pH and fiber digestibility, and the type, amount, and absorption of fuels (e.g. acetate, propionate, lactate, and glucose) available to the cow.

Based on the results for BPS and its relationship with greater 7-hour *in situ* starch digestibility (Figure 3; $R^2 = 0.43$), we recommend that for sorghum silage samples to be considered adequately processed, $\geq 50\%$ of the starch should pass through the 1.7 mm screen. As shown in Figure 2, 7-hour *in situ* starch digestibility can exceed 80% when processed at 0.5 mm. A common goal recommended for 7-h *in situ* starch digestibility is $\sim 85\%$. Therefore, the current data show that sorghum starch can become quite digestible—similar to starch digestibility in corn—when adequately processed. When $< 30\%$ of the starch is able to pass through the 1.7 mm screen, these samples should be considered poorly processed and will have poor digestibility ($\sim 50\%$) in the rumen of the dairy cow (Figure 2). This confirms producers' and nutritionists' concerns about the reduction in starch digestibility observed when replacing a portion of the corn silage in the diet with sorghum silage. When BPS is between 30 and 50%, samples should be considered intermediately processed. Seven-hour *in situ* starch digestibility was greater for 1.5P and 1.0P compared to UNP, but still lower than 0.5P. Therefore, sorghum silage should be harvested using a sorghum silage processor with the roll gap spacing set as tightly as possible, approximately 0.5 mm.

Conclusions

From these data, we were able to develop a method to calculate a BPS for sorghum silage samples measured as the percent of starch passing through a 1.7-mm screen. The development of a BPS for sorghum silage will give the industry a standard by which to measure the degree of processing in sorghum silage. Data also showed that 7-hour *in situ* starch digestibility was increased as BPS increased. Therefore, by increasing the level of processing in sorghum silage, we may be able to enhance starch digestibility sufficiently to allow sorghum silage to replace at least a portion of corn silage in the diet without the commonly-seen decrease in starch digestibility, and therefore milk production. This may be especially important in areas of the country that are at increased risk of drought-like conditions and may have limited access to water during the growing season.

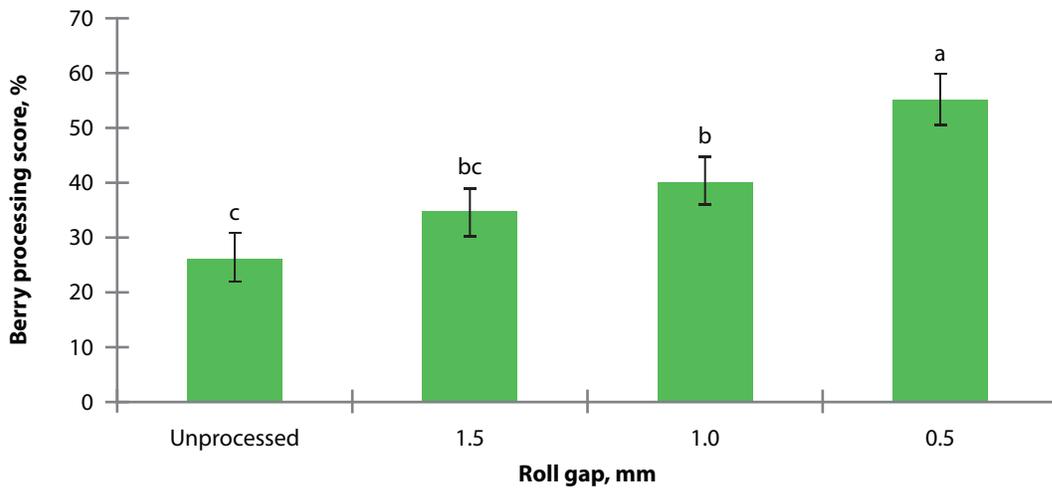


Figure 1. Berry processing score (BPS) by roll gap spacing (unprocessed, 1.5, 1.0, or 0.5 mm) measured as a percent of total starch passing through the 1.7 mm screen. Treatment effect: $P < 0.001$, unprocessed vs. processed (1.5, 1.0, and 0.5 mm); $P < 0.001$; linear, $P < 0.001$.

^{a,b,c}Means differ ($P < 0.05$).

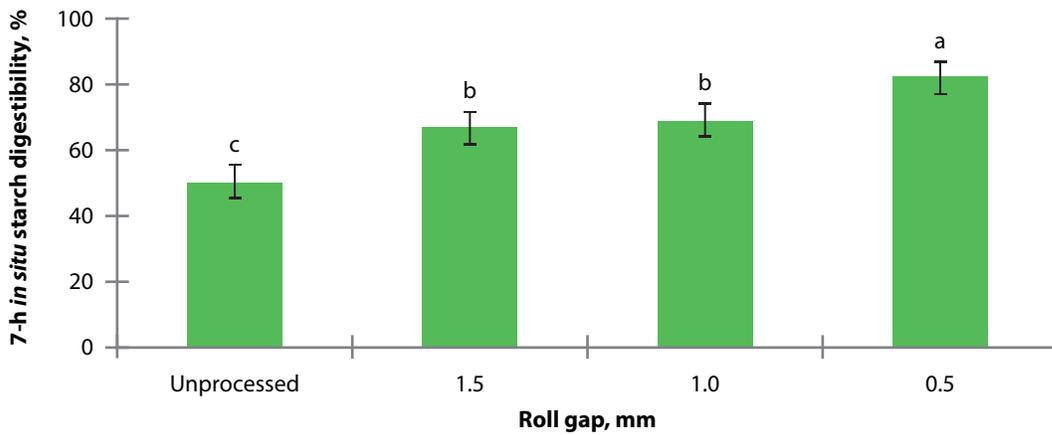


Figure 2. Least squares means for 7-h *in situ* starch digestibility by roll gap spacing (unprocessed, 1.5, 1.0, or 0.5 mm). Treatment effect: $P < 0.01$, unprocessed vs. processed (1.5, 1.0, and 0.5 mm); $P < 0.01$; linear, $P = 0.04$.

^{a,b,c}Means differ ($P < 0.05$).

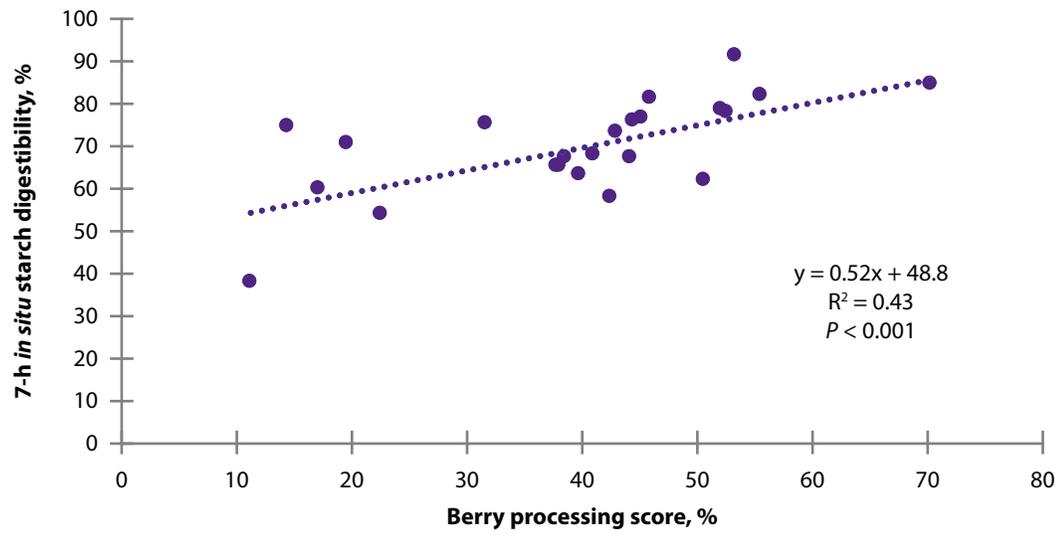


Figure 3. Relationship between 7-h *in situ* starch digestibility and berry processing score (BPS). Berry processing score was defined as the percent of starch passing through the 1.7 mm screen.

Effects of Dietary Supplementation of *Scutellaria baicalensis* Extract During Early Lactation on Milk Production of Dairy Cattle

K.E. Olagaray, M.J. Brouk, F. Robert,¹ E. Dupuis,¹ and B.J. Bradford

Summary

Multiparous Holstein cows (n = 122) were used in a randomized block design to determine the effect of short-term and long-term postpartum administration of *Scutellaria baicalensis* extract (SBE) on 305-day milk yield, 120-day milk component yield, and early lactation milk markers of inflammation and metabolic function. Treatments were (1) control, (2) short-term (5-day) administration of the SBE (SBE5), and (3) long-term (60-day) administration of the SBE (SBE60). Treatments were included in a treatment pellet that was identical to the control pellet in ingredient source and composition except for the extract, and both pellets were provided via an automated milking system. Milk samples were collected on day 1, 3, and once during days 5–12 of lactation, followed by weekly sampling for the remainder of the 120 days collection period. Milk samples collected in the first 2 weeks were used for biomarker analysis (haptoglobin and β -hydroxybutyrate [BHBA]), and all samples were used for composition analysis. Cows were scored for body condition every 2 weeks prepartum and postpartum. Milk production, programmed pellet allocation, and actual provision of both pelleted feeds were recorded daily. There was no difference in daily treatment pellet feeding between SBE5 and SBE60 for the first 5 days of lactation. Total pellet intake was greater for SBE60 than SBE5 and control cows during the treatment period (weeks 1–9), but not during the carryover period (weeks 10–36). No treatment effects were observed for body condition, milk haptoglobin, or milk BHBA. Whole-lactation milk yield was increased for SBE60 compared to control, but SBE5 did not differ from control. Milk lactose and fat yields were significantly greater and milk protein yield tended to be greater for SBE60 than control. Treatment SBE60 decreased somatic cell count (SCC) compared to control during weeks 3–5 and 8, whereas SBE5 did not affect SCC. Mastitis incidence was lesser for both SBE5 and SBE60 compared to control. Time to pregnancy did not differ, but retention in the herd tended to be greater for SBE60 than control. In conclusion, despite no detected treatment effects on BCS or milk biomarkers of inflammation and metabolic status, supplementation of postpartum dairy cows with *Scutellaria baicalensis* extract for 60 days was effective at decreasing mastitis incidence and increasing milk yield.

Introduction

Inflammation during the transition period has been well established and is associated with reduced milk yield and reproductive performance. Previous research demonstrated that short-term postpartum administration (3 days) of the nonsteroidal anti-inflammatory drugs (NSAID) sodium salicylate and meloxicam increases whole-lactation milk and protein yields. The fact that use of NSAIDs during early lactation is considered

¹Groupe CCPA, Janzé, France.

off-label drug use, has encouraged investigation of plant extracts as a natural alternative. Extracts from the *Scutellaria baicalensis* plant, containing several flavonoids, have shown anti-inflammatory and antioxidant properties in cell culture experiments.

The objective of this study was to determine the effect of short-term (5-day) and long-term (60-day) administration of *Scutellaria baicalensis* extract (SBE) after calving on milk yield and milk markers of inflammation and metabolic function. Secondary outcomes examined were effects of SBE on milk components, somatic cell count, time to pregnancy, disease incidence, and retention in the herd.

Experimental Procedures

Multiparous Holstein cows ($n = 122$) on a commercial farm were used in a randomized block design to determine the effects of short-term (5-day) and long-term (60-day) postpartum administration of SBE on 305-day milk yield and early lactation milk markers of inflammation and metabolic function. Cows were blocked by parity (2 and 3+), calving date, and risk factors (high risk block: calving difficulty score ≥ 3 or twins), then randomly assigned within block to one of three treatments. Upon calving, cows were moved into a fresh pen where they had free access to an automatic milking system (AMS; Austronaut A3, Lely Ltd., Maassluis, The Netherlands), but were encouraged through the AMS if their voluntary attendance was less than 3 visits that day. Cows were managed per site standard operating procedures.

Cows were fed a partial mixed ration (PMR) twice daily and were provided with pelleted concentrate feed in the AMS. The *S. baicalensis* extract (Groupe CCPA, Janze, France) was combined with the dairy's standard robot feed formulation and pelleted. The control and treatment pelleted feeds were stored in two feed bins that independently supplied the milking robots. Treatments were (1) control ($n = 39$), (2) short-term (5-day) administration after calving of the SBE pellet ($n = 42$; SBE5), and (3) long-term (60-day) administration after calving of the SBE pellets ($n = 40$; SBE60). Treatments began within 24 hours after calving. All cows received the control pellet, with the amount based on stage of lactation and milk production. Treatment cows were allocated 1.8 kg of the treatment pellet (delivering 100 g test material/day) in place of an equal amount of control pellet across all milkings for either 5 or 60 days. Pellet allocation was based solely on days in milk (DIM) during the first 50 days of lactation, then from day 51 until 2 weeks prior to dry off, total pellet allocation was based on a feed table, which incorporated milk production. The feeding program distributed the target amount of treatment feed across the average number of daily milkings per cow. Due to the nature of AMS, voluntary deviations from a cow's average number of milkings resulted in slight excesses or shortfalls in actual provision of pellet compared to the targeted allocation, and instances when not all the feed allocated for that particular milking was dispensed were recorded as rest feed. Reported pellet intake is the difference between total pellet allowance and rest feed.

The PMR, control pellets, and treatment pellets were sampled every 2 weeks and composited by month for nutrient analysis by Dairy One Forage Laboratory (Ithaca, NY). Nutrient analyses are reported as averages across the study for the PMR in Table 1 and the pelleted feeds in Table 2.

Milk samples were collected on days 1, 3, and once during days 5–12 of lactation, followed by weekly sampling for the remainder of the 120-day collection period. Milk samples collected during the first 2 weeks of lactation were used for both biomarker analysis (haptoglobin and β -hydroxybutyrate [BHBA]) and component analysis; subsequent samples were used only for composition analysis. Milk composition was analyzed by MQT Lab Services (Kansas City, MO).

Cows were scored every 2 weeks for body condition score (BCS) on a 5-point scale (1 = extremely thin to 5 = extremely obese) from week -3 to week 17 relative to calving. Daily milk production, DIM, number of milkings per day, programmed feed daily allocated and feed provided for both pelleted feeds, and rumination data were recorded on an individual cow basis and collected using the management software, Time for Cows (T4C, Lely Ltd., Maassluis, The Netherlands). Culling data were reported in PC Dart by the farm staff.

Results and Discussion

Treatment Provision and Total Pellet Offered

Test material delivered for the first 5 DIM was not different between SBE5 and SBE60 ($P = 0.41$; 80.8 and 83.1 ± 0.34 g/day, respectively). Mean test material provision for SBE60 ranged between 92 and 98 g/d during weeks 1–9 of lactation. Pellet feeding records (T4C) confirmed that no treatment feed was allocated to control cows nor to SBE5 cows after day 5 of lactation. Total pellet offered over the first 63 DIM (Table 3) differed by treatment and week, and had a treatment \times week interaction (all $P < 0.001$; Figure 1). Pellet offered was greater for SBE60 cows compared to control cows during week 1–9 ($P < 0.001$) and tended to be increased across week 1–36 ($P < 0.10$). Daily rumination time through 120 DIM was not different for control cows compared to either SBE5 or SBE60 over weeks 1–9 or 10–17 (all $P > 0.55$) and no treatment \times week interaction was observed ($P = 0.39$; Table 3).

Milk Production and Composition

Milk yield did not differ between SBE5 and control, during the treatment period (weeks 1–9; $P = 0.35$) or the carryover period (weeks 10–43; $P = 0.73$). Milk yield tended to increase for SBE60 compared to control during weeks 1–9 ($P = 0.07$) and was significantly increased during week 10–43 ($P = 0.04$; Figure 2). Whole-lactation milk yields (305-day) were 24,795, 25,596, and $27,924 \pm 1,026$ lb for control, SBE5, and SBE60; significant differences were detected between SBE60 and control ($P = 0.03$), but not between SBE5 and control ($P = 0.60$). Milking frequency was not affected by either SBE5 ($P = 0.60$) or SBE60 ($P = 0.19$) during the first 63 DIM, but milking frequency was increased for SBE60 during the carryover period compared to control ($P = 0.04$) whereas no difference was detected between SBE5 and control ($P = 0.48$). As expected, milking frequency differed by week ($P < 0.001$), but no overall treatment \times week interaction was observed ($P = 0.11$). Despite the difference in milking frequency, milk yield per milking did not differ by treatment during the treatment or carryover periods (all $P > 0.65$).

Milk composition data during the first 17 weeks of lactation are summarized in Table 4. There were no treatment effects on milk fat or protein concentration during the treatment or carryover periods (all $P \geq 0.15$). Milk lactose concentration tended to be in-

creased for SBE60 compared to control during the treatment period ($P = 0.06$), but not the carryover period ($P = 0.25$), and was not affected by SBE5. Milk fat yield was increased in SBE60 during both the treatment and carryover period compared to control (both $P = 0.04$), whereas SBE5 was not different from control in either period (both $P \geq 0.50$). Milk protein yield tended to be increased for SBE60 compared to control in the treatment period ($P = 0.09$) and was statistically greater during the carryover period ($P = 0.01$), but again did not differ between SBE5 and control ($P \geq 0.13$). Milk lactose yield was increased for SBE60 but not SBE5 compared to control during the treatment period ($P = 0.03$ and 0.26 , respectively). During the carryover period, milk lactose yield continued to be greater for SBE60 compared to control ($P = 0.02$), and SBE5 tended to increase milk lactose yield compared to control ($P = 0.07$).

Somatic cell count was decreased by SBE60 compared to control during the treatment period ($P = 0.02$) with a tendency for a difference in week 3 and significant effects in weeks 4–6 and 8 (Figure 3). Treatment SBE5 did not affect SCC ($P = 0.37$) during weeks 1–9, and neither SBE5 or SBE60 affected SCC during the carryover period ($P = 0.29$ and 0.13 , respectively).

Overall there was no treatment effect on BCS ($P = 0.44$) with means being 3.40, 3.30, and 3.31 ± 0.06 for control, SBE5, and SBE60. As anticipated, body condition score differed by week ($P < 0.001$), but there was no treatment effect on prepartum or postpartum BCS (treatment \times week: $P = 0.57$).

Milk Markers of Inflammation and Metabolism

Neither milk haptoglobin nor milk BHBA showed significant treatment effects ($P = 0.97$ and 0.89 , respectively; Table 5) or treatment \times DIM effects ($P = 0.45$ and 0.47). Milk haptoglobin concentrations were greatest the day after calving (when inflammation is greatest) and subsequently declined for day 3 and day 5–12 milk samples ($P < 0.001$). The BHBA concentration also had a DIM effect ($P < 0.0001$), increasing from day 1 to day 5–12 samples.

Time to Pregnancy, Disease Incidence, and Herd Retention

Survival analyses through 305 DIM were completed for time to pregnancy and removal from the herd. There was no treatment effect on time to pregnancy ($P = 0.34$). At 365 days after treatment initiation, 13 of 40 control, 15 of 44 SBE5, and 6 of 38 SBE60 cows had left the herd, and after accounting for other risk factors, SBE60 tended to decrease the risk of removal from the herd by 64% compared to control ($P = 0.07$; risk ratio for removal: 0.41, 95% confidence interval: 0.11, 0.99). Treatment SBE5 did not affect retention in the herd. Incidence of several diseases are reported in Table 6. The only disease incidence affected by treatment was mastitis, being lesser for both SBE5 and SBE60 compared to control ($P = 0.04$ and 0.05 , respectively). Treatment SBE60 tended to decrease the hazard of leaving the herd compared to control and SBE5 ($P = 0.07$).

Conclusions

Supplementation of dairy cows with *Scutellaria baicalensis* for 60 days increased whole-lactation milk yield compared to control cows. Milk fat, protein, and lactose yields increased through 120 DIM and SCC was decreased during the treatment period for

the 60-d treatment compared to control cows. Milk production parameters were not different for short-term administration (5-day) compared to control cows. Other than milk SCC and reduced incidence of mastitis, there were no suggestions of impacts on health outcomes. Time to pregnancy was unaffected, but retention in the herd was increased. Overall, long-term administration of *S. baicalensis* effectively increased milk production, although the mechanism by which this was achieved is unknown.

Table 1. Nutritional composition of the partial mixed ration (PMR)

Nutrient	% of dry matter (DM)	Standard deviation
DM, % as-fed	57.06	0.27
Crude protein	18.71	0.37
Acid detergent fiber	20.89	1.54
Neutral detergent fiber	31.96	2.31
Net energy for lactation, Mcal/kg	1.65	0.04

Table 2. Ingredient and nutritional composition of the control and treatment pellet

Item	Control pellet	Treatment pellet	Standard deviation
Ingredient, % of dry matter (DM)			
Ground corn	42.47	42.44	
Wheat middlings	27.76	27.23	
Wheat flour	15.16	10.10	
Soybean meal (47.5%)	10.92	10.92	
Molasses	3.16	3.16	
Super bind ¹	0.53	0.53	
Test feed premix ²	---	5.62	
Nutrient, analyzed, % of DM (unless otherwise specified)			
DM, % as-fed	87.60	87.44	0.81
Crude protein	17.33	17.30	0.38
Acid detergent fiber	6.77	5.30	0.70
Neutral detergent fiber	15.33	14.52	0.94
NE _L , ³ Mcal/kg	1.94	1.94	0.02

¹Modified lignin sulfonate pellet binder (Bonaventure Chemicals, Inc., Weston, FL).

²Test feed premix included wheat flour, calcium carbonate, natural flavoring and *Scutellaria baicalensis* extract.

³Net energy for lactation.

Table 3. Treatment means for weekly total pellet offered, milk yield, and milking frequency for cows fed control or *S. baicalensis* extract for either 5 days (SBE5) or 60 days (SBE60) following calving

	Control	SBE5	SBE60	SEM ¹	<i>P</i> -values	
					Con vs. SBE5	Con vs. SBE60
Total pellet offered, lb/d						
d 1-63	11.6	11.7	12.5	0.31	0.77	< 0.01
d 64-301	11.0	11.4	11.6	0.33	0.13	0.02
Milk yield, lb/d						
d 1-63	93.6	99.1	104.1	4.4	0.35	0.07
d 64-301	78.0	79.9	88.2	4.2	0.73	0.04
Milking frequency/d						
d 1-63	3.24	3.34	3.48	0.21	0.60	0.19
d 64-301	2.56	2.67	2.84	0.18	0.48	0.04
Milk per visit, lb						
d 1-63	30.6	31.2	31.1	1.65	0.70	0.75
d 64-301	31.0	30.6	31.0	1.39	0.92	0.99

Table 4. Rumination time through 120 DIM and milk composition for the first 17 weeks of lactation of control cows and cows supplemented with *S. baicalensis* extract (SBE) for either 5 days (SBE5) or 60 days (SBE60) following calving

	Control	SBE5	SBE60	SEM	<i>P</i> -values	
					Con vs. SBE5	Con vs. SBE60
Rumination, min/d						
d 1–63	429.9	427.3	429.0	8.20	0.76	0.92
d 64–120	410.3	405.8	409.9	7.30	0.58	0.95
Milk fat, %						
d 1–63	3.84	3.84	3.84	0.17	0.95	0.99
d 64–120	3.24	3.08	3.29	0.18	0.28	0.77
Milk protein, %						
d 1–63	3.16	3.10	3.12	0.06	0.40	0.54
d 64–120	2.97	2.89	2.97	0.05	0.15	0.99
Milk lactose, %						
d 1–63	4.87	4.89	4.95	0.04	0.54	0.06
d 64–120	4.92	4.95	4.97	0.04	0.46	0.25
Milk fat, lb/d						
d 1–63	3.55	3.68	3.90	0.18	0.50	0.04
d 64–120	2.98	3.04	3.33	0.18	0.73	0.04
Milk protein, lb/d						
d 1–63	2.95	3.09	3.22	0.13	0.42	0.09
d 64–120	2.71	2.95	3.11	0.11	0.13	0.01
Milk lactose, lb/d						
d 1–63	4.63	4.92	5.20	0.22	0.26	0.03
d 64–120	4.56	5.03	5.18	0.20	0.07	0.02
SCC, log ₁₀ cells/mL						
d 1–63	2.19	2.07	1.86	0.13	0.37	0.02
d 64–120	2.13	1.98	1.91	0.14	0.29	0.13

SCC = somatic cell count.

Table 5. Milk haptoglobin and BHBA on days 1, 3, and 5–12 of lactation for control cows and cows receiving *S. baicalensis* extract (SBE) for either 5 days (SBE5) or 60 days (SBE60) after calving

	Control	SBE5	SBE60	SEM	<i>P</i> -values ¹		
					Trt	DIM	Trt × DIM
Haptoglobin, µg/mL					0.97	< 0.001	0.45
d 1	4.98	3.54	5.47	1.04			
d 3	1.53	1.70	1.44	0.35			
d 5–12	0.59	0.69	0.50	0.13			
BHBA, µM					0.89	< 0.001	0.47
d 1	264.0	265.3	249.4	23.6			
d 3	639.7	609.7	632.2	22.6			
d 5–12	729.1	746.7	717.8	18.6			

¹Treatment: *P*-value for treatment effect; DIM: *P*-value for time (days in milk) effect.

Table 6. Disease incidence through 250 DIM for control cows and cows receiving *S. baicalensis* extract (SBE) for either 5 days (SBE5) or 60 days (SBE60) after calving

	Control	SBE5	SBE60
At-risk	39	43	40
Fever	3	1	1
Milk fever	1	2	2
Displaced abomasum	0	0	0
Retained placenta	2	5	4
Metritis	3	4	6
Lame	2	2	0
Off feed	3	2	1
Mastitis ¹	13	6*	6*
Other	0	1	2

¹Mastitis incidence tended to differ by treatment ($P = 0.06$).

*Control vs. SBE5: $P = 0.04$.

*Control vs. SBE60: $P = 0.05$.

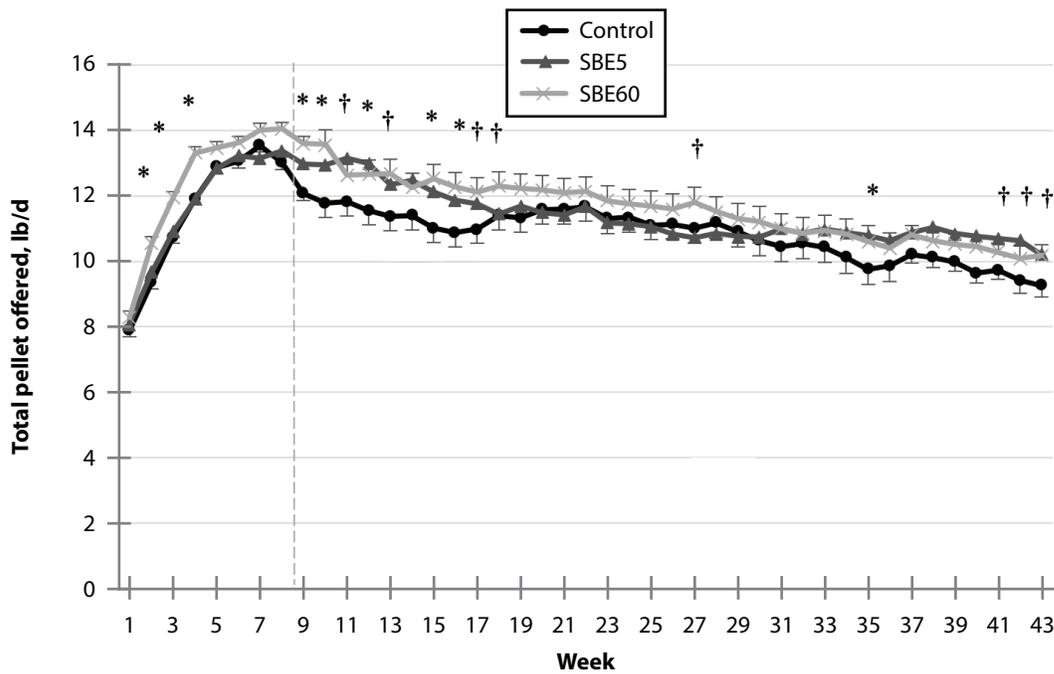


Figure 1. Weekly total pellet offered (control + treatment) of control cows and cows supplemented with *S. baicalensis* during the first 5 day (SBE5) or 60 day (SBE60) of lactation. Data were analyzed by treatment period (weeks 1–9) and carryover period (weeks 10–36). Total pellet offered was increased for SBE60 compared to control during the weeks 1–9 ($P < 0.01$) and from weeks 10–43 ($P = 0.02$). Total pellet offered was not different between SBE5 and control during either weeks 1–9 ($P = 0.777$) or weeks 10–43 ($P = 0.13$). A treatment \times week interaction was detected ($P < 0.001$), and differences between SBE60 and control are indicated by * ($P < 0.05$) and † ($P < 0.10$).

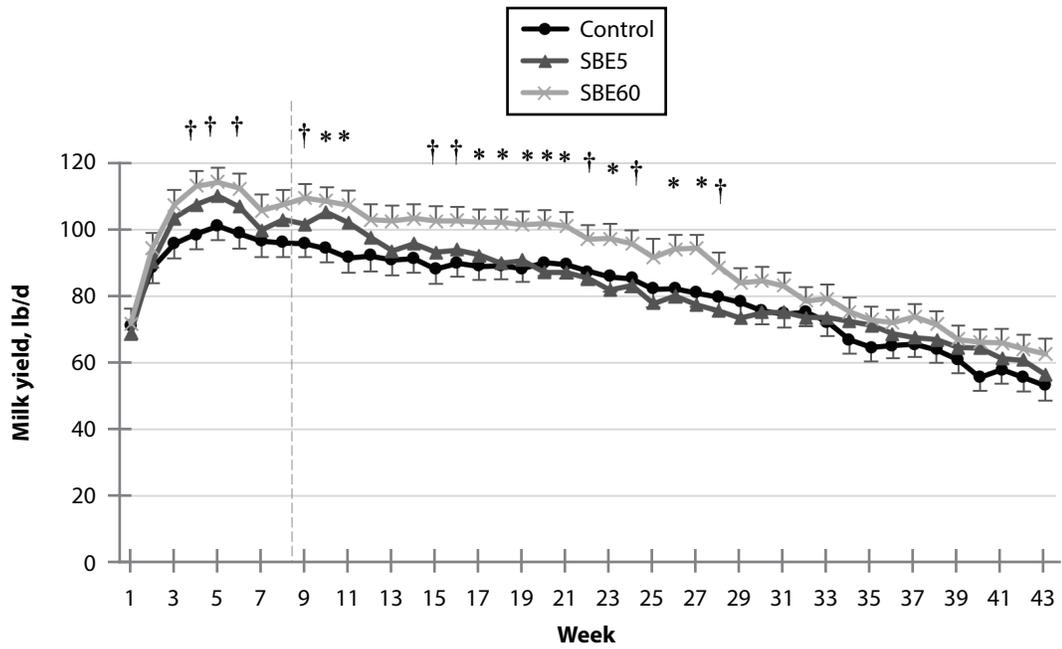


Figure 2. Milk yield of control cows and cows supplemented with *S. baicalensis* extract (SBE) during the first 5 days (SBE5) or 60 days (SBE60) of lactation.

Data were analyzed by treatment period (weeks 1–9) and carryover period (weeks 10–43). Milk yield tended to be increased for SBE60 compared to control from weeks 1–9 ($P = 0.07$) and was significantly increased from weeks 10–43 ($P = 0.04$). Milk yield was not different between SBE5 and control during weeks 1–9 ($P = 0.35$) or weeks 10–43 ($P = 0.73$). A treatment \times week interaction was detected ($P < 0.03$), and differences between SBE60 and control are indicated by * ($P < 0.05$) and † ($P < 0.10$).

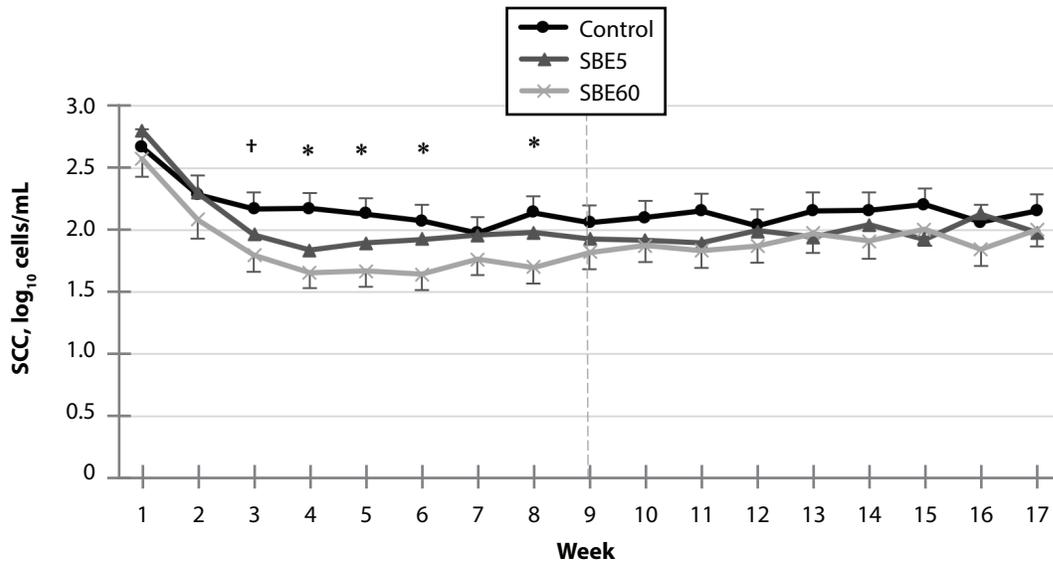


Figure 3. Somatic cell count (SCC) of control cows and cows supplemented with *S. baicalensis* extract (SBE) during the first 5 days (SBE5) or 60 days (SBE60) of lactation. Data were analyzed for the treatment period (weeks 1–9) and carryover period (weeks 10–17). Somatic cell count was not different between SBE5 and control during weeks 1–9 ($P = 0.37$) or weeks 10–17 ($P = 0.29$). Somatic cell count was decreased for SBE60 compared to control during weeks 1–9 ($P = 0.02$), but not during weeks 10–17 ($P = 0.13$). No treatment \times week interaction was detected ($P = 0.16$). Differences between SBE60 and control are indicated by * ($P < 0.05$) and † ($P < 0.10$).

Acknowledgments

Appreciation is expressed to the following organizations for their support of dairy teaching, research, and extension at Kansas State University during 2016-2017.

Absolute Innovations, Osceola, IN	K-State Research and Extension, Manhattan, KS
Aerotech, Mason, MI	KanEquip, Wamego, KS
AgTech, Inc., Manhattan, KS	Kansas Dairy Commission, Hays, KS
Alta Genetics, Watertown, WI	Kansas Department of Health and Environment, Topeka, KS
Arm & Hammer Animal Nutrition, Princeton, NJ	Kemin Industries, Des Moines, IA
Balchem Corporation, New Hampton, NY	Land O'Lakes Animal Milk Products, Shoreview, MN
Bayer Animal Health, Shawnee Mission, KS	Landus Cooperative, Ames, IA (Tim Brown, Westmoreland, KS)
BouMatic, Madison, WI	Livestock and Meat Industry Council, Manhattan, KS
Built So-Well, Manhattan, KS	Merck Animal Health, Whitehouse Station, NJ
Cargill, Inc., Wayzata, MN	Mid Kansas Cooperative, Manhattan, KS
CTI John Deere, Clay Center, KS	Miguel Dairy Service, Hereford, TX
Dairy Farmers of America, Kansas City, MO	MS Biotec, Wamego, KS
Dairymaster, County Kerry, Ireland	NutriQuest, Mason City, IA
Dekalb Asgrow, St. Louis, MO	Phibro Animal Health, Teaneck, NJ
DeLaval, Kansas City, MO	Poet Nutrition, Sioux Falls, SD
Deltavit Group, Janzé, France	Rabo AgriFinance, Manhattan, KS
Diamond V Mills, Cedar Rapids, IA	Rota-Mix, Dodge City, KS
Dupont Pioneer, Johnston, IA	Select Sires, Plain City, OH
Evonik Industries AG, Essen, Germany	Sweet Bran, Blair, NE
Grain States Soya, West Point, NE	USDA National Institute of Food and Agriculture, Washington, D.C.
Heart of America Dairy Herd Improve- ment Association, Lincoln, NE	White Star, Manhattan, KS
High Plains Dairy Management Conference	Whorton, Inc., Horton, KS
Hubbard Feeds, Mankato, MN	Zoetis Animal Health, Florham Park, NJ
Iowa Limestone, Des Moines, IA	

The Department of Biological and Agricultural Engineering and the College of Veterinary Medicine at Kansas State University are recognized for their cooperation and contributions to our dairy research and teaching program.

Biological Variability and Chances of Error

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

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

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

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

Using many animals per treatment, replicating treatments several times, and using uniform animals 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 the experiment. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

The Livestock and Meat Industry Council Inc.

The Livestock and Meat Industry Council Inc. (LMIC) is a nonprofit charitable organization supporting animal agriculture research, teaching, and education. This is accomplished through the support of individuals and businesses that make LMIC a part of their charitable giving.

Tax-deductible contributions can be made through gifts of cash, appreciated securities, real estate, life insurance, charitable remainder trusts, and bequests as well as many other forms of planned giving. The LMIC can also receive gifts of livestock, machinery, or equipment. These types of gifts, known as gifts-in-kind, allow the donor to be eligible for a tax benefit based on the appraised value of the gift.

Since its inception in 1970, the LMIC has provided student scholarships, research assistance, capital improvements, land, buildings, and equipment to support students, faculty, and the industry of animal agriculture. If you would like to be a part of this mission or would like additional information, please contact the Livestock and Meat Industry Council/Animal Sciences and Industry, Weber Hall, Manhattan, KS, 66506 or call 785-532-1227.

LMIC Board Members

David Clawson	Roy Henry	Lisa Moser
Doug Deets	Patsy Houghton	Stanton O'Neil
Mark Gardiner	Virgil Huseman	Rich Porter
Craig Good	Justin Janssen	Jim Riemann
Ken Grecian	Debbie Lyons-Blythe	Randall Spare
Kim Harms	Steve Mangan	Tom Toll
Frank Harper	Bill Miller	Warren Weibert

Royal Board Members

Dell Allen	Greg Henderson	Tom Perrier
Kyle Bauer	Steven Hunt	Phil Phar
Jerry Bohn	Steve Irsik	Harland Priddle
Richard Chase	Larry Jones	Lee Reeve
Calvin Drake	Kenny Knight	Don Smith
Stan Fansher	Mark Knight	Ken Stielow
Galen Fink	Pat Koons	Mikel Stout
Randy Fisher	Kelly Lechtenberg	Kathleen Strunk
Lyle Gray	Jan Lyons	Duane Walker
Sam Hands	Gina Miller	
Bernie Hansen	Andrew Murphy	

DAIRY RESEARCH 2017

Copyright 2018 Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Contents of this publication may be freely reproduced for educational purposes. All other rights reserved. In each case, give credit to the author(s), Dairy Research 2017, Kansas State University, January 2018. Contribution no. 18-267-S from the Kansas Agricultural Experiment Station.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned.

Publications from Kansas State University are available at: *www.ksre.ksu.edu*