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2022 North Dakota Livestock Research Report

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(Photo by Sarah Underdahl, NDSU)

2022 North Dakota Livestock Research Report

It is hard for me to believe that this is the 11th year that I have been the coordinator and editor of this report. I would suggest that the old adage of "time flies when you are having fun" applies for me here. One of the activities I enjoy most about my job is helping others with writing and editing scientific reports and manuscripts. I especially enjoy editing the North Dakota Livestock report because I know that it is an important means to report our research findings to producers and industry personnel across North Dakota and beyond.

Although the report has expanded its scope through the years, evolving from the North Dakota Beef Report to the North Dakota Beef and Sheep Report and now to the North Dakota Livestock Research Report, the goal of providing current research results to those that are interested has not changed. I hope that this report will continue to remind all of us of the quality and breadth of our livestock research and Extension programs in North Dakota. I am excited that this year's report is larger than last year's report, and my hope is that we are rebounding after the challenges of a pandemic and economic uncertainty resulting in decreases in research personnel and funding for our research programs.

For this year's report, we again are including some selected Extension programming updates. As you will see, our Extension programming covers a broad range of topics and in many cases is tightly linked with our research programs. Please consider participating in Extension events or accessing Extension publications and materials in the coming year.

I want to thank Elizabeth Cronin and Deb Tanner for their great assistance in editing and formatting the reports so that we can publish a great statewide publication. Also, thanks to the contributors to the report, and to the staff and students who help with livestock research, teaching and Extension activities.

Finally, thanks to the funders of the grants that help support the research projects and students/staff working on the projects. We truly appreciate your contributions to our research programs. Without this support, the research would not be possible.

If you should have any questions about the research reported in this report, please do not hesitate to contact me or any of the authors of the individual reports. Thanks for your encouragement and support of livestock research in North Dakota.

Kendall Swanson
North Dakota Livestock Research Report Editor
Professor
Department of Animal Sciences
Phone: 701-231-6502
email: kendall.swanson@ndsu.edu

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Effect of colostrum insulin on intestinal carbohydrase activity of neonatal Holstein calves

Mustapha Yusuf[1], Koryn Hare[2], Mike Nagorske[3], Katie M. Wood[2], Michael Steele[2], Kendall C. Swanson[1]

The objective of this study was to evaluate the effect of increasing basal colostrum insulin concentration on small intestinal carbohydrase activity in neonatal Holstein calves. Lactase activity in the proximal jejunal, but not maltase, isomaltose and glucoamylase activity, increased with increasing levels of colostrum insulin.

Summary

Receptors for insulin are known to be present in the gastrointestinal tract, and insulin is thought to be beneficial in gastrointestinal development. This study evaluated the effect of three levels of colostrum insulin on the activity of intestinal carbohydrases in neonatal Holstein calves. We hypothesized that increasing colostrum insulin will increase the activity of carbohydrases in the small intestine of neonatal Holstein calves. Twenty-six calves (108 ± 7 lb) were removed from their dam after calving. They were fed 3 meals of colostrum (7% BW or 0.68 ± 0.004 gal) at 2, 14 and 26 hours after birth containing one of three insulin concentrations: basal (2.24×10^{-6} oz/gal; n = 8), or supplemental colostrum containing either at 5× (1.11 × 10^{-5} oz/gal; n = 10) or 10× (2.24×10^{-5} oz/gal; n = 8) increase in colostrum insulin respective to basal concentrations. At 30 hours, the animals were euthanized, and the gastrointestinal tract (GIT) was dissected for the analysis of maltase, isomaltase, glucoamylase and lactase. Lactase activity in the small intestine (proximal jejunum) increased with increasing insulin inclusion and there was no effect of insulin inclusion on the activity of maltase, isomaltase and glucoamylase in any of the small intestinal segments. More research is needed to determine if the observed increases in lactase activity are associated with improvements in the digestion of lactose and overall milk or milk replacer in newborn calves.

[1]Department of Animal Sciences, NDSU
[2]University of Guelph Department of Animal Bioscience
[3]Saskatoon Colostrum Company

Introduction

There is high concentration of colostrum insulin (327 ng/ml) in bovine at birth which declines to around 50% after 24 hours and 25% at day 3 (Aranda et al., 1999). Concentration of insulin in milk is about 100 times the amount found in the serum which suggests that there might be a mechanism of transfer of insulin from blood to milk. The digestive system of a calf is like that of a monogastric and it is believed that colostrum insulin may be absorbed directly into the small intestine.

Insulin also has been reported to influence the intestinal mucosa development. Previous studies conducted in 8-day old mice injected with insulin showed stimulation of disaccharidases and some effect on crypt cell proliferation (Menard and Malo, 1979; Menard et al., 1981). Other studies in porcine have shown that milk-borne insulin enhances postnatal gut development in suckling animals (Xu, 1996; Wang et al., 2004). The objective of this study was to examine the influence of colostrum insulin on intestinal carbohydrases (maltase, isomaltase, glucoamylase and lactase) of neonatal Holstein calves.

Experimental Procedures

Twenty-six calves (108 ± 7 lb) were removed from their dam after calving (Hare et al. 2022). They were fed three meals of colostrum (7% BW or 0.68 ± 0.004 gal) at 2, 14 and 26 hours after birth containing one of three insulin concentrations: basal (2.24×10^{-6} oz/gal; n = 8), or supplemental colostrum containing either a 5× (1.11×10^{-5} oz/gal; n = 10) or 10× (2.24×10^{-5} oz/gal; n = 8) increase in colostrum insulin respective to basal concentrations. At 30 hours, the animals were euthanized, and the gastrointestinal tract (GIT) was dissected. The small intestine was separated from the abomasum and cecum by cutting the pyloric and ileocecal junctions, respectively. Small intestinal length was determined, and samples were collected from the duodenum, proximal jejunum and ileum, and the mucosa was scraped and used for analysis. The samples were analyzed for carbohydrase activity using a microplate spectrophotometer. Enzyme activity data are expressed as units per gram of tissue.

Results and Discussion

Carbohydrase (maltase, isomaltase, lactase and glucoamylase) activity in the segments (duodenum, proximal jejunum and ileum) of the small intestine is presented (Table1).

There was no treatment effect on the activity of maltase, isomaltase and glucoamylase (enzymes responsible for digestion of starch breakdown products) in the segments of the small intestine examined. However, a linear increase in the activity of lactase, (the enzyme responsible for the breakdown of milk sugar, lactose) in the proximal jejunum was observed. Higher activity of lactase (U/g) of the proximal jejunum may suggest that there was enhanced development of the intestinal mucosa of the proximal jejunum in the calves. This suggests that there could have been a higher capacity for digestion of lactose in the small intestine which is the primary source of glucose in neonatal calves. In early postnatal life, lactase is the most important carbohydrase because lactose is the primary carbohydrate ingested (Van Beers et al., 1995). Insulin injected to adult rats stimulated lactase activity in the jejunum of 14-day old rats (Mahmood et al., 1978). The increase in lactase activity in the rats was attributed to insulin aiding in development and maintenance of hydrolytic functions in the intestinal mucosa. Baumrucker et al. (1994) observed increased gastrointestinal mucosal growth, brush-border enzymes activity, and intestinal DNA synthesis when insulin-like growth factor (IGF-I) was added to milk replacer fed to neonatal calves. Although, in their study, IGF-I was fed, but the mechanism of action could be similar to that of insulin since both hormones are pleiotropic hormones that have multiple roles in regulating vital metabolic and developmental processes (Werner et al., 2008). More studies are needed to elicit the mechanisms resulting in the observed increase in lactase activity with increasing insulin inclusion in young neonatal calves.

Table 1. Effect of colostrum insulin supplementation on intestinal carbohydrase activity of neonatal Holstein calves

	Treatment				Contrast *P*-value	
Carbohydrase[1]	**Control**	**5BI**	**10BI**	**SE**	**Linear**	**Quadratic**
Maltase						
U/g of duodenum	0.27	0.24	0.38	0.12	0.37	0.35
U/g of proximal jejunum	0.11	0.34	0.29	0.12	0.16	0.16
U/g of ileum	0.54	0.48	0.57	0.17	0.89	0.59
Isomaltase						
U/g of duodenum	1.08	1.01	1.17	0.15	0.55	0.36
U/g of proximal jejunum	1.00	1.07	1.09	0.13	0.49	0.77
U/g of ileum	0.95	1.11	0.99	0.15	0.82	0.24
Lactase						
U/g of duodenum	123.28	121.52	116.23	4.95	0.17	0.65
U/g of proximal jejunum	105.89	118.11	123.04	3.60	0.0001	0.21
U/g of ileum	121.97	113.13	122.66	7.58	0.93	0.13
Glucoamylase						
U/g of duodenum	0.85	0.87	0.61	0.21	0.27	0.40
U/g of proximal jejunum	0.76	0.62	0.50	0.31	0.41	0.97
U/g of ileum	1.20	0.91	0.98	0.52	0.68	0.66

U/g = unit per gram, SE= standard error, 5BI = 5 times basal insulin, 10 BI= 10 times basal insulin

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Cow Herd Appraisal Performance Software (CHAPS) 2022 benchmarks: reliable data helps producers make informed decisions and navigate uncertainty in the beef business

Jennifer Ramsay[1], Lee Tisor[2], Kris Ringwall[1,2], Zachary Carlson[1,3]

The Cow Herd Appraisal Performance Software (CHAPS) benchmarks have been a hallmark of the beef industry for almost four decades, providing reliable data to help producers make informed management decisions. We present the 2022 CHAPS benchmarks with five-year average percentiles for each production trait to help producers better understand where their herd ranks among CHAPS herds. Today's producers face volatile cattle markets, high feed costs, and increasingly severe weather/climate. CHAPS data provides a solid foundation for producers to navigate uncertainty, improve operations, and positively impact their business.

Summary

Beef producers have relied on the Cow Herd Appraisal Performance Software (CHAPS) to inform their herd management decisions since 1985. Yearly average beef production benchmarks, including calving distributions, reproductive percentages, and mean weights, growth and ages, are calculated from producer-submitted data. The CHAPS benchmarks are calculated as five-year rolling averages of the yearly herd averages to which producers can compare their herd values and determine areas for improvement. We present the 2022 CHAPS benchmarks as five-year averages (means), with five-year average minimums, maximums, and 25th, 50th (median) and 75th percentiles. With severe drought in many areas of the country, high feed prices and volatile cattle markets, producers can continue to rely on CHAPS as a tool for making informed decisions to improve operations and economic success.

Introduction

The Cow Herd Appraisal Performance Software (CHAPS) was developed by NDSU Extension and the North Dakota Beef Cattle Improvement Association as a beef herd management tool to collect, store and evaluate beef production data, and establish reproduction and production benchmarks (Ramsay et al., 2016; Ringwall, 2018). The CHAPS benchmarks, including critical success factors (Ringwall & Berg, 1991), are calculated using integrated resource management standardized performance analysis (McGrann & Bevers, 2006). The current CHAPS benchmarks (five-year averages) are published on the CHAPS homepage (ndsu.edu/chaps/benchmarks/).

In the 2021 North Dakota Livestock Report, we presented the five-year average (mean) benchmarks and introduced five-year average minimum and maximum 25th, 50th (median) and 75th percentiles for each benchmark (Ramsay et al., 2021). With little change in the five-year average benchmarks over the past 15 years, benchmark percentiles offer a different way for producers to see how their herd ranks among other CHAPS herds, motivating producers to improve their herd further.

The beef industry faces numerous challenges, particularly with cow-calf production. Extreme weather and climate, such as late-spring snowstorms and drought, cause stress to cows and calves, which can impact reproduction and growth and subsequently increase production costs (Patalee & Tonsor, 2021). Shutdowns during the COVID-19 pandemic disproportionately affected the cow-calf sector which has long production times, greater fixed costs and is affected by losses in other sectors (Martinez et al., 2021). CHAPS helps producers navigate uncertainty with reliable data to better understand their herd performance and make management decisions to improve their operation and business success.

Procedures

The development of CHAPS has been described previously (Ramsay et al., 2016). CHAPS calculates individual herd calving distribution, reproductive percentages (pregnancy, pregnancy loss, calving, calf death loss, weaning and replacement percentages), and production benchmarks (herd average birth and weaning weights, average daily gain and weight per day of age, frame

[1]Extension Agriculture and Natural Resources, NDSU
[2]Dickinson Research Extension Center, NDSU
[3]Animal Sciences Department, NDSU

score, age at weaning, cow age, weight and condition, and pounds weaned per cow exposed).

From individual herd averages, yearly averages are calculated. CHAPS includes herds with a minimum of 50 cows and three consecutive years of data submitted to NDSU Extension, when calculating yearly averages. Five-year average benchmarks are calculated from the previous five yearly averages. Additionally, we calculated the five-year average minimum and maximum benchmarks as well as the five-year average 25th, 50th (median) and 75th percentiles for each benchmark.

Results and Discussion

The 2022 CHAPS benchmarks were derived from 52,313 cows exposed to bulls from 2017 to 2021. Table 1 displays the 2022 benchmarks with the five-year average minimums, maximums and percentiles. These percentiles reflect the distribution of the CHAPS benchmarks. The 50th percentiles (median) and 2022 benchmarks (mean) are similar, indicating a symmetrical data distribution. This validates using the five-year means when computing the five-year average benchmarks.

The 2022 benchmarks are similar to the 2021 benchmarks following recent observations of relatively stable five-year benchmarks year to year with greater changes expected over longer periods of time (Ramsay et al., 2021). Similar to the 2021 benchmarks, some benchmark percentiles reflect a wide distribution (minimum to maximum) of values (for example, early heifer calving distributions range from 0.2% to 97.6%, while other distributions are narrower). Some notable changes include an 18% increase in the maximum calf death loss percentile, from 13.1% to 16%. While it is difficult to understand all the factors that influence calf death, high sulfate in water may have contributed to livestock deaths during the drought of 2020 and 2021. Many livestock producers experienced poor water quality with high sulfates in livestock water sources in 2020 and 2021 (Meehan et al., 2021). Additionally, the maximum age at weaning decreased 5%, from 268 to 255 days. Perhaps more livestock producers utilized early-weaning practices due to limited pasture and hay production in 2020 and 2021.

It has been questioned whether the five-year average benchmarks could be further improved or if the genetic potential has been fully realized given the resources and environment. Individual herd improvement has been the foundation of CHAPS and will continue to serve producers in achieving this goal. Benchmark percentiles (minimum to maximum) may provide producers with further incentive to improve their herds beyond the averages. CHAPS will continue to provide reliable data which is important for navigating uncertainty and helping producers make sound management decisions to improve operations and positively impact their business.

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Table 1. 2022 Cow herd appraisal performance software (CHAPS) benchmarks (five-year rolling average of yearly herd averages from 2017-2021), including standardized performance analysis (SPA) and critical success factors (CSF), with five-year average minimums (min.), maximums (max.), and percentiles (25th, 50th – median, 75th).

		PERCENTILES				
SPA	**2022 Benchmark**	**min.**	**25th**	**50th**	**75th**	**max.**
Pregnancy, %	94.3	82.1	91.6	94.6	97.0	100
Pregnancy loss, %	0.77	0	0	0.1	1.0	7.3
Calving, %	93.6	79.8	91.0	94.2	96.4	100
Calf death loss[a], %	3.2	0	1.5	2.6	3.8	14.9
Calf crop – weaning, %	91.4	74.4	88.9	91.9	94.2	100.6
Female replacement, %	16.3	3.8	12.8	15.4	17.4	38.4
Calf death loss[b], %	3.4	0	1.6	2.8	4.1	16.0
Age at weaning, days	188	146	167	189	204	255
Calving distribution, %						
21 days	63.5	17.4	55.0	66.0	74.3	89.5
42 days	88.8	50.2	85.8	90.6	93.6	99.4
63 days	96.6	67.6	95.6	98.1	99.3	100
after 63 days	3.4	0	0.5	1.95	3.9	32.4
Weaning weight, lb						
Steers	588	443	532	565	595	761
Heifers	550	433	505	539	575	715
Bulls	607	447	580	645	672	757
all calves	561	441	521	556	604	739
Pounds weaned/cow exposed, lb	505	370	455	502	544	684
CSF						
ADG, lb	2.6	2.0	2.4	2.6	2.7	3.1
WDA, lb	3.0	2.4	2.8	3.1	3.2	3.6
Birth weight, lb	82	72	79	82	85	94
Adjusted 205-day weight[c], lb	645	515	609	654	676	769
Frame score[c]	5.4	4.1	4.8	5.6	6.0	6.2
Heifers calving, %						
Early	43.5	0.2	14.8	45.7	70.0	97.6
21 days	77.1	20.2	68.8	83.3	92.7	100
42 days	91.6	46.2	87.8	96.7	100	100
Cows calving, %						
21 days	60.6	8.6	50.7	63.2	75.1	88.4
42 days	88.0	46.2	84.9	89.7	94.3	99.2
Cow age, years	5.6	3.6	5.2	5.5	5.9	7.2
Cow weight, lb	1430	1209	1402	1443	1474	1565
Cow condition score[c]	6.0	5.6	5.7	6.1	6.3	6.5
Culled, %	13.1	1.0	9.8	12.9	15.8	35.3

[a]relative to the number of females exposed
[b]relative to the number of calves born
[c]BIF Guidelines Wiki (2021)

Dry matter intake in beef cows is influenced by weather variables

Mustapha Yusuf[1], Kendall C. Swanson[1], Lauren L. Hulsman Hanna[1], Marc L. Bauer[1]

This study examined how dry matter intake (DMI) in cows is influenced by weather variables like ambient temperature, wind speed, dewpoint, solar radiation and range of temperature. Ambient temperature interacted with wind speed, and range of temperature also interacted with wind speed to affect DMI of beef cows. Weather variables alone accounted for 9% additional variation in DMI of beef cows. This will assist in better understanding the environmental factors influencing DMI in cows and may ultimately increase the accuracy of cow DMI nutrient models.

Summary

The Northern Great Plains experiences extreme weather and the current nutrient requirement models may not be a good fit for cows in this region. The objective of this study was to evaluate how DMI of cows is influenced by weather variables. The weather variables considered for this study were ambient temperature, wind speed, dew point, solar radiation, range of temperature, and two week and monthly lag of each of the weather variables. Intake data collected through a smart feeding system in the years of 2011, 2015 and 2020 were condensed into weekly intakes (2,161 cow-weeks). Other parameters included in the model to account for DMI are body weight (BW), dietary energy density based on intake (NEm intake), and effects of time of the year. It was observed that weather variables alone accounted for 9% of the variation in DMI while weather and other parameters (BW and NEm intake) accounted for 70% of the variation in DMI of cows. This study may ultimately help producers to better estimate the nutrient requirement of their cows through improved nutrient requirement models.

Introduction

Temperature is known to affect feed intake of cattle. The NRC (1981) reported that with decreasing the ambient temperature to 5 degrees Fahrenheit, intake by beef cattle increases, but at very low effective ambient temperature (EAT), decreases in DMI are observed. The decrease in DMI at very low EAT could be because of behavioral patterns such as standing to shiver which causes animals to spend less time eating. Daily gains have also been reported to decrease by as much as 70% when ambient temperature reached -2 degrees Fahrenheit in mid-winter. We believe that other weather variables interact with temperature to influence feed intake, which is also dependent on the time of the year. For instance, in locations with cold winters in the Northern Great Plains, like North Dakota, the wind (wind chill effect) influences body temperature maintenance, and there is a wide variation in temperature from hot to cold in these regions.

The objective of this study was to examine how weather variables affect DMI of beef cows and identify the important weather variables that may have the largest effects in influencing DMI in beef cows

Experimental Procedure

Intake data collected from the Beef Cattle Research Complex of North Dakota State University using a smart feeding system (RIC feeding system; Hokofarm Group, Marknesse, The Netherlands), which records the amount of feed intake for each animal. The data used were from three experiments that were conducted in 2011, 2015 and 2020.

Data for weather variables were obtained from the North Dakota Agricultural Weather Network (NDAWN) station for each experiment period included in this study. The non-weather variables considered for this experiment included weekly average dry matter intake (DMI), weekly average body weight (BW), dietary net energy of maintenance intake (NEm intake), experimental treatment, and the week of the year. The daily feed intake data were averaged into weekly averages to reduce the day-to-day fluctuation. Data were modeled as a repeated measures design using the MIXED procedures of SAS (SAS Institute, Inc., Cary, NC) in a stepwise fashion.

Results and Discussion

The descriptive statistics of the variables modeled in this study are shown in (Table 1). Only one form of each weather variable was added to the model to prevent multicollinearity. For example, between no-lag, two-week lag and monthly lag of

[1]Department of Animal Sciences, NDSU

ambient temperature, only no-lag of ambient temperature was added to the model because it accounted for the most variation in DMI. Absolute dew point and solar radiation did not improve ($P > 0.05$) the DMI model in the stepwise addition of main effects to the base model, so they were removed. The variables in the final model are provided in Table 2.

As ambient temperature increased, DMI decreased, and as range of temperature increased, DMI increased. The observed interaction between ambient temperature and wind speed occurred because at colder temperatures, DMI decreases with increasing wind speed (Figure 1). On the other hand, at warmer temperatures, DMI increases with increasing wind speed. The effect of temperature and wind speed has been reported previously (NRC, 1981). Wind speed is known to exacerbate the effect of cold temperatures. In hot weather, wind speed is known to increase the rate of evapotranspiration, thereby reducing the effect of heat load on animals. In this study, we believe that the reduction in DMI observed as wind speed increases in cold weather could be because of the effect of wind chill, which causes acute cold stress in animals, thereby affecting their DMI. Acute cold stress has been reported to cause feed intake changes in grazing cows (Adams, 1987). Stanton (1985) also reported that feed intake in cold-stressed feedlot beef cattle decreases in cold weather, which is similar to what we observed.

Table 1. Descriptive statistics of the variables in this study

Variable[1]	Minimum	Mean	Maximum	SD[2]	SE[3]
BW, lb	1,003	1,528	1957	159	3.4
DMI, lb/d	20	36	61	9	0.2
NE_m intake, Mcal/d	9	23	46	8	0.2
Ambient temperature, °F					
No lag	-2.0	38.4	75.0	19.6	0.4
Two-week lag	3.5	39.5	76.1	19.7	0.4
Monthly lag	9.6	40.5	74.4	19.7	0.4
Range of temperature, °F					
No lag	8.2	17.9	24.9	3.6	0.1
Two-week lag	9.1	17.8	23.8	3.0	0.1
Monthly lag	11.4	18.1	23.1	3.0	0.1
Wind speed, mph					
No lag	5.1	7.6	12.1	1.5	0.03
Two-week lag	5.6	7.7	10.8	1.3	0.03
Monthly lag	5.6	7.7	9.8	1.0	0.02
Solar radiation, W/m^2					
No lag	31.0	118.1	292.6	76.7	1.7
Two-week lag	34.6	118.2	288.6	74.9	1.6
Monthly lag	43.9	121.8	282.7	76.3	1.6
Dew point, °F					
No lag	-6.6	29.8	66.5	18.4	0.4
Two-week lag	-0.9	30.7	66.1	18.3	0.4
Monthly lag	5.3	31.4	64.0	17.8	0.4

[1]Variable with 2,161 observations.
[2]SD = Standard error.
[3]SE = Standard deviation.

Table 2. Final model with significant variables using REML estimation

Variable[1]	Estimates	SE[2]	F-value	P-value
Intercept	-1.863	1.168		0.17
Base model				
Week of the year			30.13	<0.001
BW, lb	0.001695	0.000554	9.38	0.002
NEm intake, Mcal/day				
Linear	0.8391	0.2054	1668.53	<0.001
Quadratic	-0.00597	0.00037	265.51	<0.001
Weather variable				
Ambient temperature, °F	-0.2329	0.0838	7.72	0.006
Range of temperature, °F	0.3236	0.0699	21.46	<0.001
Ambient temperature × Monthly lag of wind speed, °F × mph	0.05970	0.02286	6.82	0.009
Range of temperature × Monthly lag of wind speed, °F × mph	-0.07236	0.01892	14.63	<0.001

[1]Variable with 2,161 observations.
[2]SE= standard error

The observed interaction between range of temperature and wind speed on DMI occurred because with increasing wind speed, DMI is higher at lower range of temperature and DMI decreases as range of temperature increases (Figure 2). This indicates that higher wind speed has a negative effect on DMI, but when temperature fluctuations are greater, the negative effect of wind speed on DMI is larger. Fluctuation in temperature impacts the physiological mechanism of temperature regulation in cattle because generally cattle adjust to changes in temperature gradually over time. Also, the temperature an animal has been previously exposed to affects its current basal metabolism (NRC, 1981). Total heat production and external insulation are physiological changes that determine the amount of increased energy needed when temperature is below the lower critical temperature. In hot weather, lowering metabolic heat production to combat heat stress results in a reduction in DMI. Therefore, high fluctuations in temperature could alter metabolism, leading to decreases in DMI.

Intake was affected by ambient temperature and range of temperature but not by dew point or solar radiation. In addition, wind speed interacted with ambient temperature and range of temperature, and this accounted for additional variation in DMI by beef cows. Our model adds range of temperature and the interactions between wind speed and ambient temperature and range of temperature to previous models of weather effects on DMI of beef cows. The results of this study should be interpreted with caution because of the low number of data points used to develop the model compared to some other models developed by the same authors in growing cattle.

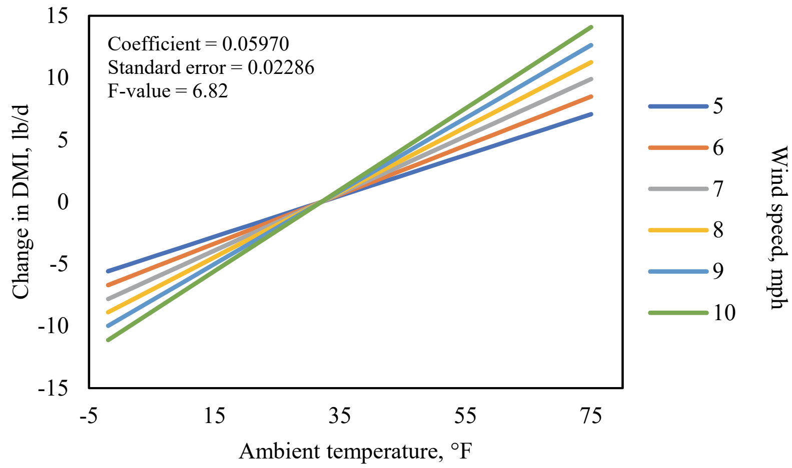

Figure 1. How ambient temperature and wind speed interacts to affect dry matter intake of beef cows.

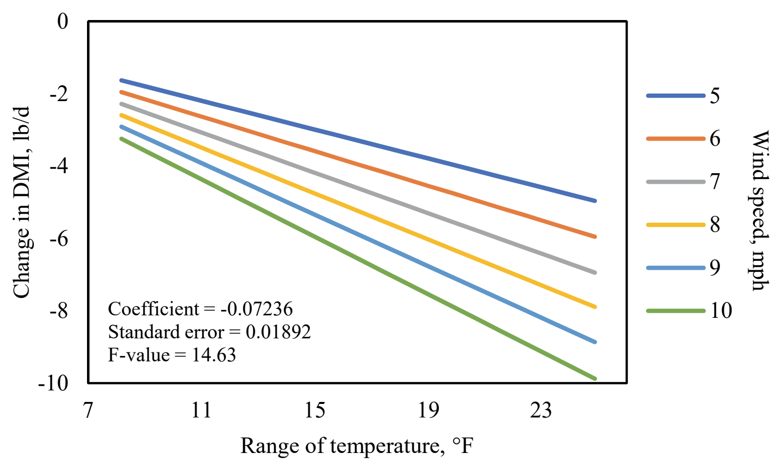

Figure 2. How range of temperature and wind speed interacts to affect dry matter intake of beef cows.

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NDSU Extension program "Mineral Nutrition for the Beef Cow Herd" helps livestock producers evaluate and improve mineral supplementation strategies

Janna Block[1], Adele Harty[2]

Minerals are a small but critical component of beef cow diets necessary to optimize growth, health, and reproduction. The goal of the multi-state Extension program "Mineral Nutrition for the Beef Cow Herd" is to help producers evaluate their current mineral supplementation program through workshops, one-on-one interactions, and mineral analysis of forages, commercial feeds and water sources. Evaluation of mineral analyses for mixed grass pasture samples collected during the grazing seasons from 2017 through 2022 indicated that North Dakota and South Dakota forages are often deficient in copper, zinc and phosphorus, and may contain excess iron, sulfur and molybdenum.

Summary

The "Mineral Nutrition for the Beef Cow Herd" program was initially offered in South Dakota by SDSU Extension in 2017. In 2018, the program expanded to include North Dakota producers through NDSU Extension. To date, over 100 beef cattle operations from the two states have participated. The core components of the program include workshop sessions, individual ranch visits for each operation, and sampling of feeds, forages and water for laboratory analysis of mineral content. Since the beginning of the program, nearly 300 forage samples (standing and harvested) and 100 water samples have been submitted by participants for laboratory analysis of mineral content. Mineral imbalances or deficiencies may or may not produce clinical signs of deficiency; but can still have impacts on growth, health and reproduction. A "primary" mineral deficiency occurs when the diet is not adequate in mineral content to meet requirements. A "secondary" mineral deficiency can be induced through the presence of antagonists, which are minerals or components of the diet that can interfere with the function and/or absorption of other minerals. Results from forage analyses indicate potential for both primary and secondary deficiencies for grazing beef cattle in North Dakota and South Dakota.

Introduction

The mineral content of forages across an individual ranch or even within a pasture can vary based on plant species, stage of maturity, soil characteristics, precipitation and other factors. Commercial mineral supplements are commonly provided to make up deficiencies; however, finding the right product for a given situation is not an easy task. Providing appropriate mineral supplements is complicated by changing cattle requirements due to stage and level of production, and the potential for interactions among minerals and other nutrients that may impact bioavailability within the animal.

A large number and variety of commercial mineral products are available. Most are formulated for a certain stage of production or time of year and sometimes for a specific geographical area. However, these products may not be a good fit for every situation due to the factors described above. Although it may seem like a daunting task, the best way to determine the mineral needs for an individual ranch involves testing forages, feeds and water for mineral content.

The "Mineral Nutrition for the Beef Cow Herd" program was developed in response to producer questions and concerns regarding how to provide effective mineral supplements to livestock. Results of forage analysis indicate that forages may not effectively meet livestock mineral requirements, even during times of peak forage quality. Utilizing results of forage and feed analysis to evaluate mineral supplementation strategies allows Extension personnel to guide producers in choosing supplements and adjusting delivery strategies that will minimize cost and maximize livestock performance. The ultimate goal of the program is to conduct a thorough evaluation of the current mineral supplementation program and provide recommendations for changes if necessary to meet mineral requirements more effectively.

[1]NDSU Extension Livestock Systems Specialist
[2]Adele Harty, SDSU Extension Cow/Calf Field Specialist

Procedures

Components of the "Mineral Nutrition for the Beef Cow Herd" program include online workshops, face-to-face ranch visits, and laboratory analysis for mineral content of feed and water. The first set of workshop sessions are held in the spring and focus on understanding livestock mineral requirements, basic mineral nutrition, product options, reading and understanding mineral tags and dealing with consumption challenges. Topics covered in the fall include interpretation of lab analyses, diagnosing and managing mineral consumption issues, and planning for fall/winter mineral needs. Scientific and Extension publications and tools for tracking mineral consumption and evaluating overall mineral supplementation strategies are provided to participants through an online data storage site. Extension personnel work closely with producers to ensure that representative forage, feed, and water samples are collected for analysis of mineral content.

Ranch visits are personalized to address individual producer concerns and challenges. Extension personnel learn about the operation's current mineral strategies and goals, observe livestock, assist with sample collection and/or evaluate results of laboratory analyses. Additional follow-up consultations are conducted as requested.

Results and Discussion

Participants in the NDSU and SDSU Extension program "Mineral Nutrition for the Beef Cow Herd" have submitted approximately 175 mixed grass pasture samples that were collected during the growing seasons (May to September) between 2017 and 2022. These samples were sent to a certified laboratory for mineral analyses. Overall, only 4% of samples contained adequate copper to meet requirements (≥10 ppm) and 22% were adequate in zinc (≥30 ppm). Almost all forage samples were adequate or excess in calcium (≥0.28%); however, only 14% were adequate in phosphorus (≥0.22%). In addition, potential antagonists were detected in many of the samples. Twenty seven percent of samples contained high levels of iron (>250 ppm), with 5% at potentially toxic levels (>500 ppm). Sulfur requirements (>0.15%) for livestock were exceeded in 39% of samples, and 55% of samples contained excess molybdenum (>2 ppm, up to 11 ppm).

Please refer to Figures 1 to 4 for a summary of mineral analysis results. The livestock requirement noted on each of the figures refers to lactating cows. It is important to remember that laboratory analysis will provide an indication of the minerals available to livestock; however, it does not account for biological availability within the animal, which is the amount of mineral that livestock can absorb and utilize from the digestive tract. Mineral bioavailability depends on multiple factors in the animal (stress, production level, age, breed, environment, etc.), as well as the solubility of the mineral and the presence of antagonists in the diet. In general, bioavailability of minerals in forages is assumed to be around 50%. This is an important consideration when evaluating mineral supplementation programs.

Analytical results for calcium and phosphorus are shown in Figure 1. Calcium (Ca) is a major component of bones and teeth, and is also important for blood clotting, muscle contraction, nerve impulses, secretion of hormones, and enzyme activation. The minimum requirement for calcium for lactating cows is approximately 0.28% and may be up to 0.58% for higher producing, larger-framed cows. Most of the samples in this dataset would be considered adequate in Ca.

Like calcium, phosphorus (P) is a major component in bone structure, and is necessary for cell growth and differentiation, energy utilization, cell structure and acid-base and osmotic balances. Phosphorus requirements range from approximately 0.22% to 0.39% for lactating

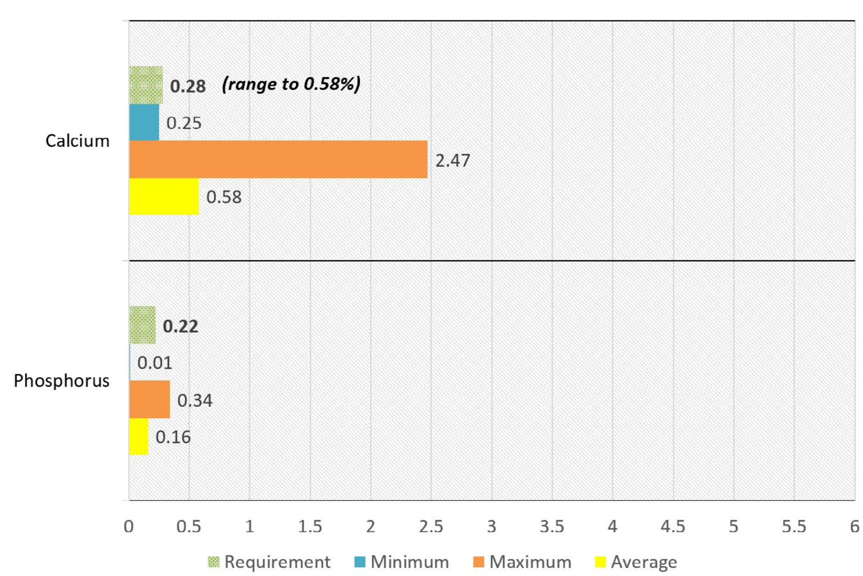

Figure 1. Macromineral content (%) of 175 forage samples collected in North and South Dakota from 2017-2022

cows. Many of the samples submitted would be considered deficient in P. This could result in weak bones, reduced feed intake and feed efficiency, reduced milk production and infertility.

The analytical results for sulfur, magnesium and potassium are shown in Figure 2. Sulfur is needed for synthesis of methionine and cystine (sulfur-containing amino acids), B vitamins, thiamin and biotin. Sulfur is also necessary for normal growth and metabolism of rumen microbes. There is a very narrow margin between the sulfur (S) requirement and the maximum tolerable level. On average, samples submitted were just above the suggested requirement, which may contribute to polioencephalomalacia (PEM) or sulfur toxicity if water contains high levels of sulfate or if producers are feeding byproducts such as distillers grains that may have high sulfur content. High sulfur can also contribute to a secondary copper deficiency.

Magnesium is important for energy metabolism, nerve function and enzyme activation. There is a small difference between the livestock requirement and maximum tolerable level (MTL) for magnesium (Mg). Although the MTL is listed at 0.4%, issues are seldom observed until levels are over 1%. The most likely adverse effect of high Mg is diarrhea. Most of the samples in this database were low in Mg. Magnesium deficiency is a contributing factor to grass tetany issues, particularly in the early spring for older, high-producing cows.

Potassium (K) has a role in acid-base balance, muscle contractions, nerve impulses and enzymatic reactions. The MTL for potassium (K) is approximately 2%, or around twice the NRC suggested requirement. High levels of K can negatively impact magnesium absorption, which can increase the risk of milk fever and grass tetany. Diets containing higher levels of K can be fed to lactating cows without adverse effects if magnesium supplementation is increased appropriately.

The analytical results for iron, copper, manganese and zinc are shown in Figure 3. Iron is critical for transportation and utilization of oxygen in the body, and is also a component of many enzymes. The MTL for iron (Fe) is approximately 500 ppm, which is about 10 times the NRC suggested requirement. Feeding high levels of iron for long periods, combined with marginal dietary copper, can deplete liver copper stores and create a copper deficiency.

Copper is an important cofactor in many enzyme systems and necessary for proper immune function.

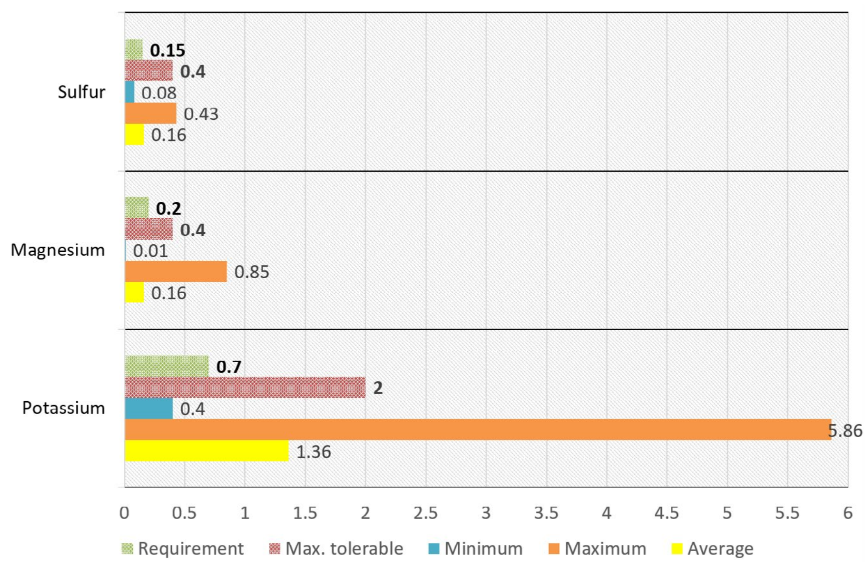

Figure 2. Macromineral content (%) of 175 forage samples collected in North and South Dakota from 2017-2022

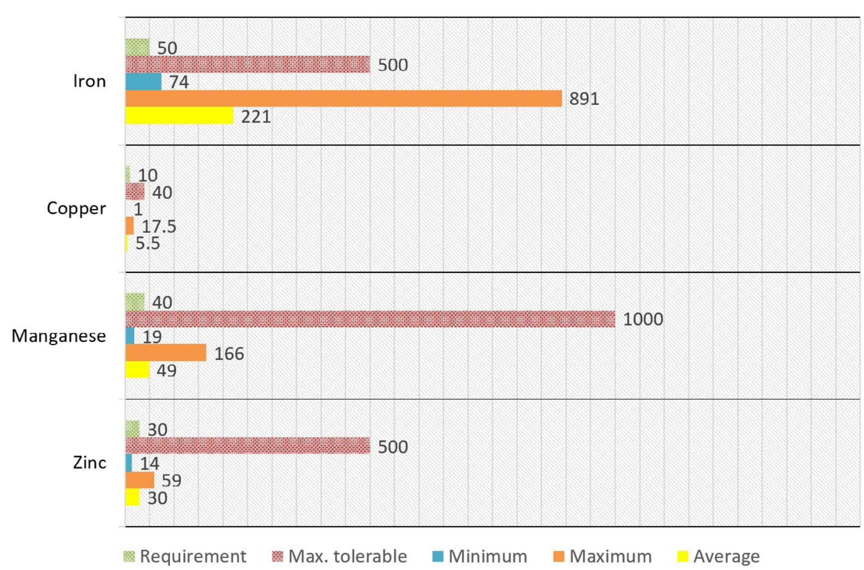

Figure 3. Trace mineral content (ppm) of 175 forage samples collected in North and South Dakota from 2017-2022

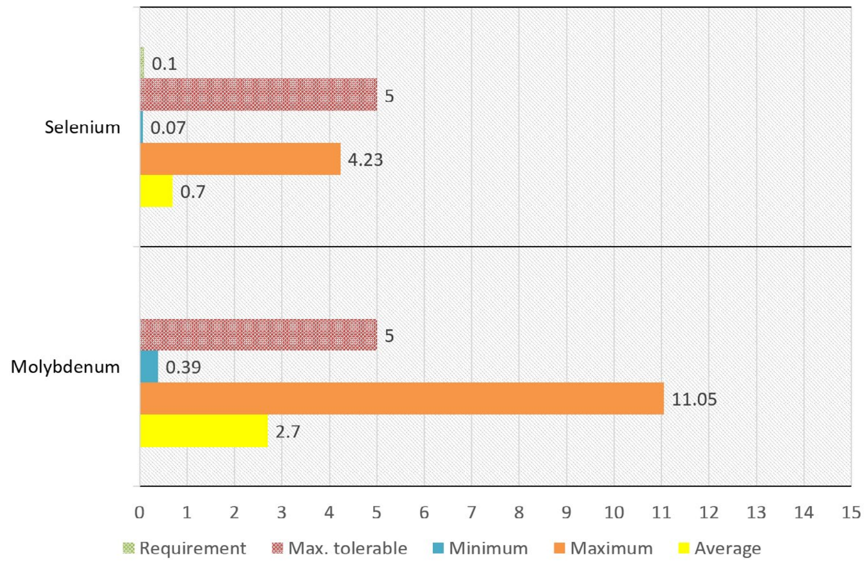

Figure 4. Trace mineral content (ppm) of 175 forage samples collected in North and South Dakota from 2017-2022

Copper status in cattle is affected by multiple antagonists, including molybdenum, sulfur and iron. Copper deficiency is a common problem throughout North Dakota and South Dakota due to low levels of copper in forages as well as the presence of antagonists. Copper deficiency is often a cause of poor growth rates, reduced immune function and impaired reproductive performance of cows.

Manganese helps maintain proper metabolism, optimizes fertility, and plays a role in bone growth and formation in young animals. A manganese (Mn) toxicity is very unlikely in beef cattle due to low absorption rates. At high levels, manganese can interfere with absorption of other minerals and cause a secondary deficiency.

Zinc is an essential component of metabolic enzymes and it also activates enzymes involved in metabolism and immune function. The MTL for zinc (Zn) is approximately 500 ppm, or about 10 times the NRC suggested requirement. Copper and zinc are absorbed through similar pathways, and excess of one can reduce absorption of the other. Mineral supplements should be formulated with a copper to zinc ratio of approximately 1:3.

The analytical results for molybdenum and selenium are shown in Figure 4. Molybdenum is a component of several enzymes; however, no dietary requirement for molybdenum has been established. The MTL for molybdenum (Mo) is approximately 5 ppm, primarily due to the negative effects on copper absorption which often leads to a copper deficiency. True molybdenum toxicity probably occurs at much greater concentrations in the diet. Livestock producers feeding high levels of Mo may need to increase amount of Cu in the diet.

Selenium, along with vitamin E, reduce harmful effects of oxidizing agents in the body. The requirement for selenium is approximately 0.1 ppm, and the MTL is approximately 5 ppm. Selenium can be extremely toxic to animals, often leading to death within hours of consuming a toxic dose. Chronic exposure to much lower dietary concentrations of selenium also can lead to death. Most toxicity issues are due to selenium accumulator plants such as prince's plume, Astragalus and some woody asters, which are usually rare; however, there are areas in both North Dakota and South Dakota where these can be present in rangelands. Western wheatgrass, barley, wheat, and alfalfa are secondary accumulators. Almost all forage samples submitted through this program would exceed livestock requirements for selenium, which can lead to accumulation in the body and contribute to livestock performance and health issues.

Although not an extensive data set, results of forage analysis in this program indicate several mineral deficiencies and antagonists that could impact livestock production and performance if minerals are not properly supplemented.

Benefits reported from participants as a result of evaluating and modifying their mineral programs include increased overall herd health, reduced pinkeye and foot rot, and improved conception rates. In many cases, participants have continued to monitor and fine tune their supplementation strategies after the program has ended, and have maintained contact with Extension personnel in both states.

The process of sampling and measuring mineral content is time and labor intensive. However, the "Mineral Nutrition for the Beef Cow Herd" program offers the potential to improve livestock performance and reduce costs by allowing producers to choose the correct mineral formulation to complement what animals are consuming and meet requirements.

Acknowledgements

We would like to thank Micronutrients (a Nutreco company) and Ward Laboratories, Inc. for their sponsorship and support of this program.

NDSU Extension responds to highly pathogenic avian influenza outbreak

Mary Keena[1], Miranda Meehan[2]

Highly Pathogenic Avian Influenza (HPAI) impacted 167,030 domestic birds in North Dakota this spring. NDSU Extension aided in response efforts, creating educational resources and providing local support for cases, building awareness about the disease, and reducing the number of cases in the state. Poultry owners should continue to practice good biosecurity measures to keep their birds healthy. In addition, they should remain vigilant as there is a risk of HPAI during active migration periods during the spring and fall.

Introduction

Highly Pathogenic Avian Influenza (HPAI) spread across the United States in the spring of 2022, wreaking havoc on commercial and backyard poultry owners alike. As of July 7, 384 confirmed flocks (186 commercial and 198 backyard) have been affected in 36 states. Over 40 million birds have been affected by this HPAI outbreak. Avian influenza is caused by influenza Type A virus (influenza A). Avian influenza viruses are classified as either "low pathogenic" or "highly pathogenic" based on their genetic features and the severity of the disease they cause in poultry.

The first confirmed case of HPAI in North Dakota was in a wild snow goose on March 24 followed by a backyard flock on March 29. Eleven counties had reported cases of HPAI from March 29 thru June 7 in either commercial or backyard flocks at 16 sites consisting of 167,030 birds (Figure 1).

Extension Response

NDSU Extension agents and specialists were an integral part of the disaster response team for poultry owners in North Dakota. The response efforts ranged from awareness and preparedness prior to outbreaks, information sharing and quarantine zone contacts during outbreaks, and disposal efforts after outbreaks.

Results and Discussion

NDSU Extension specialists prepared and disseminated four press releases prior to and during the onslaught of HPAI. These press releases consisted of general virus knowledge, information regarding flock biosecurity, action steps if infection was suspected, and information on wild flock infection and response. These press releases led to eight radio, podcast and television interviews along with the creation of two publications, "*Handling Wild Bird Carcasses, Guidance for Highly Pathogenic Avian Influenza (HPAI) Outbreaks*" and "*Protect your Flock from Highly Pathogenic Avian Influenza (HPAI).*" Over 1,000 copies of each publication (1,075 and 1,150, respectively) were sent to NDSU Extension offices. All of this information was shared via NDSU Extension social media platforms and the NDSU Ag Hub (https://www.ndsu.edu/agriculture/ag-hub/highly-pathogenic-avian-influenza).

From January through May, NDSU Extension created 68 posts for sharing on their Facebook and

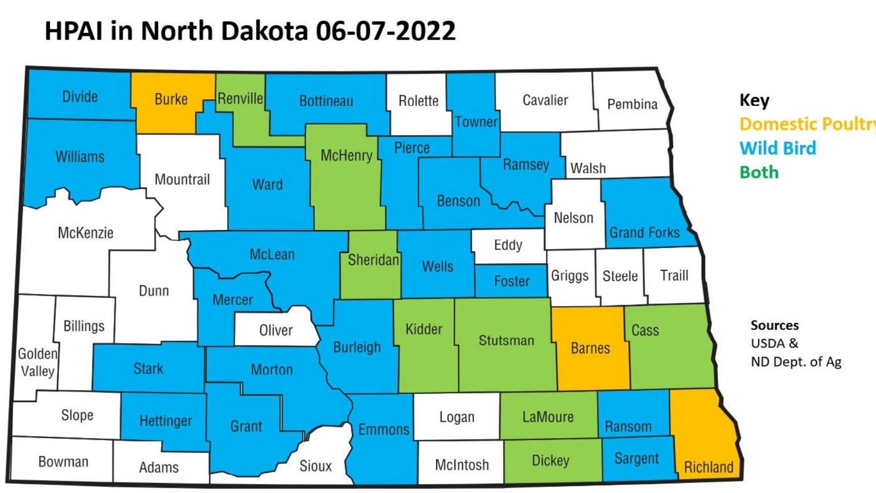

Figure 1. Map depicting where positive cases of highly pathogenic avian influenza were detected in domestic poultry and wild bird populations in North Dakota during the 2022 outbreak.

[1]Carrington Research Extension Center, NDSU
[2]Animal Sciences Department, NDSU

Twitter accounts reaching 82,015 followers, leading to 3,528 engagements, including reactions, comments and sharing of information. In addition, the Ag Hub webpage received 2,150 pageviews by 565 individuals (of which 32% were returning visitors) accessing HPAI resources.

In an effort to share resources with those concerned about their poultry flocks contracting HPAI, NDSU Extension created a voluntary survey and sent email updates on the status of HPAI and available resources to those wishing to receive them. The survey was completed by 61 poultry owners.

NDSU Extension was on site aiding in response efforts in counties with active cases in backyard and commercial flocks. NDSU Extension agents assisted with contacting individuals within the control zone (quarantine area) associated with each case; sharing information and resources with poultry owners within this area and reporting back to the North Dakota Department of Agriculture, Animal Health Division. An NDSU Extension specialist also coordinated, assisted with, monitored and reported the carcass disposal efforts for commercial flocks in coordination with the North Dakota Department of Agriculture, Animal Health Division, the North Dakota Department of Environmental Quality, Division of Water Quality and the United States Department of Agriculture Animal and Plant Health Inspection Service veterinarians and staff.

Conclusion

The resources and support provided by NDSU Extension during the HPAI outbreak this spring aided in building awareness about the disease and reducing the number of cases in the state. Poultry owners should continue to practice good biosecurity measures to keep their birds healthy. In addition, they should remain vigilant as there is a risk of HPAI during active migration periods during the spring and fall.

Acknowledgments

Thank you to everyone who partnered with us in these response efforts, including NDSU Extension agents, specifically those in counties with positive cases; NDSU Agriculture Communication staff including Stacy Wang, Kristin Harner, Dave Haasser and Sonja Fuchs; Leigh Ann Skurupey; Gerald Stokka; North Dakota Department of Agriculture, Animal Health Division; North Dakota Game and Fish Department; and North Dakota Department of Environmental Quality, Division of Water Quality.

CHAPS Online: an updated, web-based application of the Cow Herd Appraisal Performance Software

Jennifer Ramsay[1], Zachary Carlson[1,2]

The Cow Herd Appraisal Performance Software (CHAPS) has been an essential herd management tool to help beef producers better understand their herd through data. Since its creation in 1985, CHAPS has been updated to function for new operating systems. NDSU Extension has developed CHAPS Online, a web-based application accessible through a web browser and internet connection. CHAPS Online calculates the same benchmarks CHAPS has been reporting for almost forty years. Herein, we outline some of the main features of CHAPS Online and future plans for development. CHAPS Online will continue to serve the herd management needs of today's beef producers, helping them manage what they measure using the most current technologies.

Summary

For almost 40 years, the Cow Herd Appraisal Performance Software (CHAPS) has provided beef producers with a reliable herd management tool, including benchmarks to assess herd performance. Since its initial development, NDSU Extension has updated CHAPS to CHAPS II (with improvements to the original program), followed by an update to CHAPS 2000, a program for Windows 2000. Online data management and analysis programs are increasingly common in agriculture. To serve this need, NDSU Extension has developed CHAPS Online, a web-based application in which users log in via a web browser, to enter, store securely and access data; this eliminates the need to install and use CHAPS on a single computer and allows data access from any location through an internet connection. We briefly overview the current features of CHAPS Online and outline the scope of future development. CHAPS Online will continue to serve beef producers and help them manage what they measure through accessible and reliable data.

Introduction

The Cow Herd Appraisal Software (CHAPS) was developed by NDSU Extension through the North Dakota Beef Cattle Improvement Association (NDBCIA). Originally developed in MS-DOS in 1985, CHAPS was updated to CHAPS II (Ringwall et al., 1992), then to CHAPS 2000 for Windows 2000 (Ringwall, 2004). Since the 1990s, NDSU Extension has published annual reproduction benchmarks, including calving distribution, reproductive percentages (pregnancy, pregnancy loss, calving, calf death loss, weaning and replacement percentages), and production benchmarks (herd average birth and weaning weights, average daily gain and weight per day of age, frame score, age at weaning, cow age, weight and condition, and pounds weaned per cow exposed). The CHAPS benchmarks consist of five-year rolling averages of yearly herd averages. Calculations of the benchmarks have been previously described (Ramsay et al., 2016) and can be currently found on the NDSU CHAPS website (https://www.ndsu.edu/chaps/).

Web-based applications (web apps) are now commonplace in agricultural operations and give cattle producers the flexibility of entering and accessing data via a web browser and internet connection. This eliminates the need for software installation and data storage on a single computer. Web apps safely and securely back up data in a centralized database allowing the user to access data online.

NDSU Extension has been working toward developing a CHAPS web app over the past several years (Ramsay et al., 2017). To meet the technological needs of today's beef producers, CHAPS 2000 needed to be updated to a web app. Herein, we briefly describe the newly updated CHAPS websites and features of the newly developed web app. Additionally, we describe the future scope for development to better serve beef producers.

Procedures

The first step in developing a CHAPS web app was to create a new NDSU CHAPS website to replace the CHAPS 2000 website, which reported the annual CHAPS benchmarks. The NDSU CHAPS website aims to provide information about CHAPS, including its history, the benchmarks, and links to the CHAPS web app. Agriculture Com-

[1]Extension Agriculture and Natural Resources, NDSU
[2]Animal Sciences Department, NDSU

munication at NDSU facilitated the development of the NDSU CHAPS website.

NDSU Extension contracted a software development company, Codelation (Fargo, ND), who are a web app and mobile app development agency, to develop a web app for CHAPS. DBeaver (Apache License), an SQL database tool, was used in the development of CHAPS into a web-based, cross-platform application. We developed a trial version of CHAPS as well as a production version of CHAPS.

Results and Discussion

The homepage for the NDSU CHAPS website (ndsu.edu/chaps) is displayed in Figure 1. The homepage briefly describes the CHAPS program and its history, discussing the importance of collecting data for sound herd management deci-

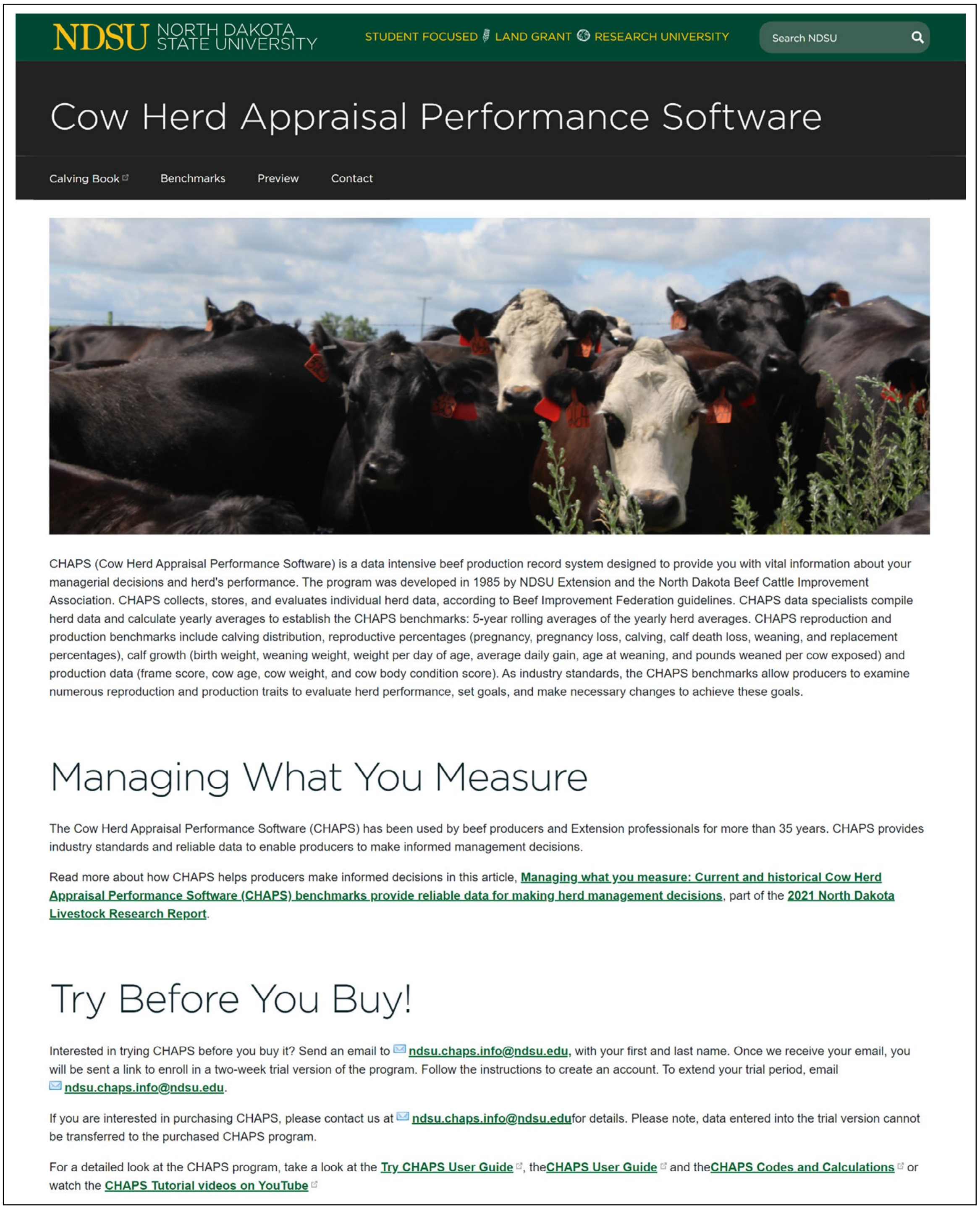

Figure 1: NDSU Cow Herd Appraisal Performance Software (CHAPS) homepage (ndsu.edu/chaps) with a history of CHAPS, links to a calving book, benchmarks, preview, contacts, trial version, user guides, codes and calculations, and tutorial videos

sions. A link to the NDSU Extension Calving Book is provided on the homepage, as well as a link to the current CHAPS benchmarks and recent article on the benchmarks (Ramsay et al., 2021). Links to a preview of the CHAPS web app and contact information are also provided. At the bottom of the NDSU CHAPS homepage is information on the trial version of CHAPS, as well as information on purchasing an annual subscription to CHAPS. Links to CHAPS Users Guides and CHAPS Codes and Calculations provide users with information on how CHAPS data is managed. CHAPS Tutorial Videos provide step-by-step instructions on how to use CHAPS, from account set-up to data entry and running reports.

We updated CHAPS 2000 to a web app, now known as CHAPS Online (chaps.ndsu.edu), displayed in Figure 2. This update moves CHAPS from a desktop program to a web-based application, eliminating software installation and allowing access to CHAPS from any location with a web browser and internet service. The web-based CHAPS Online stores data safely and securely, backing it up in a centralized database. CHAPS Online provides an overview of the importance of keeping good records. Additionally, there is a link for new users to get started with CHAPS as well as existing users to log in to CHAPS Online. Additional links, including "What is CHAPS?" provide resources for those interested in CHAPS history and publications.

Unlike CHAPS 2000, users of CHAPS Online must create an account and password to log in to their CHAPS account. Multiple herds can be added to each account if desired and are part of the active inventory of the account. Bulls are also part of the active inventory and may be used in multiple herds, if desired.

With CHAPS 2000, breed entry was done manually. CHAPS Online requires breeds and crossbreeds to be selected from a list of breeds to standardize breeds across users. Additionally, a bull turnout date must be added to the herd before a calf can be entered into this herd. The management codes present in CHAPS 2000, are not used in CHAPS Online. Instead, aborted and stillborn calves are indicated in the "Birth Circumstance" field when adding a calf. Twin, foster and embryo transplant calves are selected under the "Other Situations" field when adding a calf. Calves that die after birth are culled from the herd (reason culled – died). Calves not weighed at weaning can be selected as such under "Weight Type."

CHAPS Online offers a variety of herd reports. The "Calf Performance Report" displays the number of calves born, died and sold as

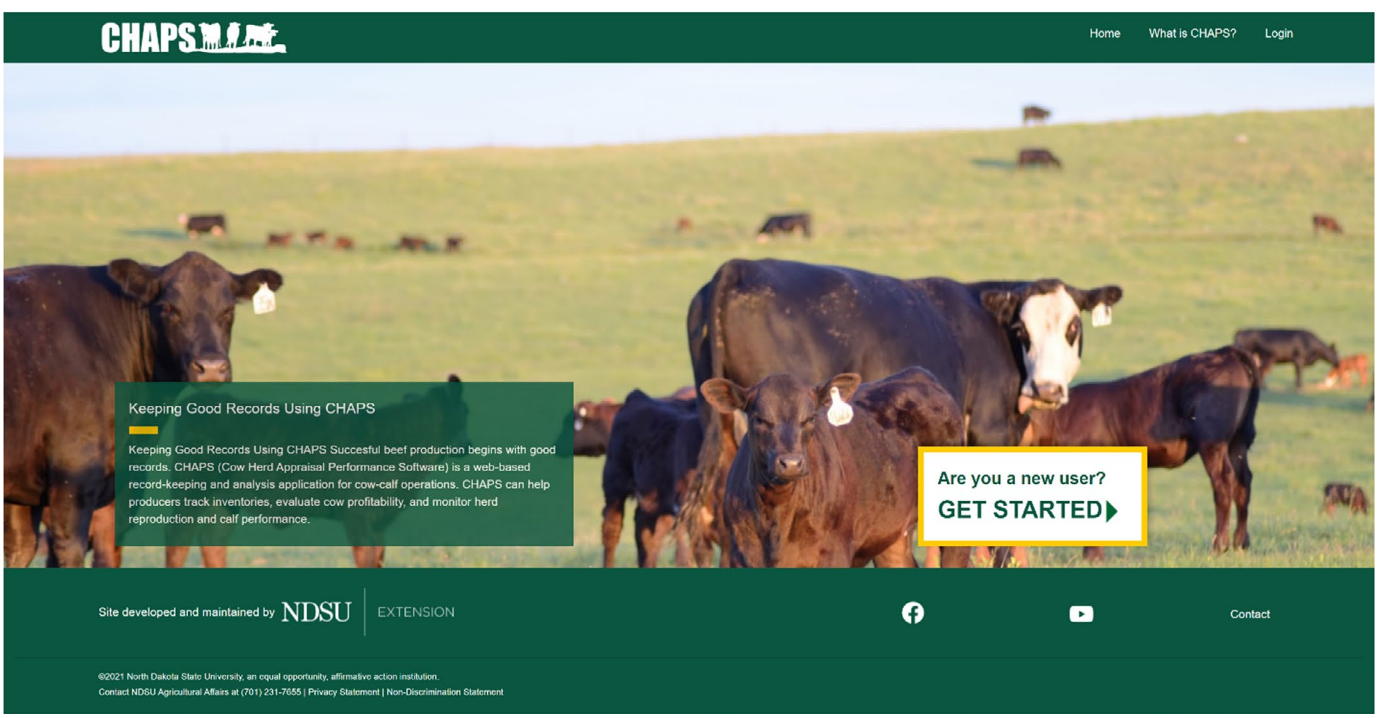

Figure 2: Cow Herd Appraisal Performance Software (CHAPS) Online homepage (chaps.ndsu.edu), including information about CHAPS, a login link, as well as a link for new users to get started. CHAPS is developed and maintained by NDSU Extension.

well as averages for calf weight and growth benchmarks; individual calf birth and weaning data are also listed. The "Calving Distribution Table" displays the number of cows presently in the herd and the number of cows leaving the herd (culled) since the selected bull turnout date. Additionally, calving data is displayed by cow age and the number of calves born each 21-day period; average birth dates and weaning weights are displayed for each age, as well as totals and average wean weight for each calving period. The Cow Lifetime Progeny Report lists all cows in the herd, including cow data and average calf performance data and individual calf data for each cow. The "Herd Performance Comparison" and "NCBA-IRM SPA Summary of Herd Production and Production Performance" list herd performance compared to the five-year CHAPS benchmarks.

The future scope for CHAPS Online includes developing methods to upload electronic data, eliminating the need for manual data entry. We anticipate developing modules to focus on herd reproduction and health, as well as looking at regional benchmarking to serve specific regions. The future scope also includes the development of a mobile app. CHAPS Online is available worldwide and offers producers a way to connect their data to a system that will continue to grow and learn to assist them with their herd management decisions.

Acknowledgements

We are indebted to Kris Ringwall for his work toward creating CHAPS and consistent promotion of the program, including consulting during the development of CHAPS Online. We thank Charles Stoltenow for his persistent promotion of CHAPS development, including the contracting of Codelation. We are grateful for the thoughtful and enduring work of the developers and project managers from Codelation (Robert Chamberlain, Suman Koirala, Laura Backhaus and Kelly Deltener). We thank Bob Bertsch (Agriculture Communication) for his help in publishing the NDSU CHAPS website.

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Dakota Feeder Calf Show Feedout 2021-2022: Discovering performance and value in North Dakota calves

Karl Hoppe[1] Colin Tobin[1] and Dakota Feeder Calf Show Livestock Committee[2]

North Dakota cattle producers are identifying cattle with superior growth and carcass characteristics by participating in the Dakota Feeder Calf Show. Average difference in profitability between consignments from the top five herds and the bottom five herds was $179.66 per head for the 2021-2022 feeding period.

Summary

The Dakota Feeder Calf Show feedout project helps North Dakota cattle producers discover the actual value of their spring-born beef steer calves, provide comparisons among herds, and benchmark feeding and carcass performance. Cattle consigned to the feedout project were delivered to the Carrington Research Extension Center livestock unit on Oct. 16, 2021. After a 220-day feeding period with 1.21% death loss, cattle averaged 1,290 pounds (shrunk harvest weight). Feed required per pound of gain was 7.6 (dry-matter basis). Overall pen average daily gain was 3.16 pounds. Feed cost per pound of gain was $0.894 and total cost per pound of gain was $1.219. Profit ranged from $169.71 per head for pen-of-three cattle with superior growth and carcass traits to a loss of $86.04 per head (no death loss). Substantial variability in the feeding and carcass value of spring-born calves continues to be discovered when producers participate in the feedout project.

[1]Carrington Research Extension Center, NDSU
[2]Turtle Lake, N.D.

Introduction

Cow-calf producers need to remain competitive in high feed cost situations. By determining calf value through a feedout program, cow-calf producers can identify profitable genetics under common feedlot management. Substantial marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

Cost-effective feeding performance is needed to justify the expense of feeding cattle past weaning. Price premiums are provided for cattle producing highly marbled carcasses. Knowing production and carcass performance can lead to profitable decisions for North-Dakota-born and -fed calves.

This ongoing feedlot project provides cattle producers with an understanding of cattle feeding and cattle selection in North Dakota.

Procedures

The Dakota Feeder Calf Show was developed for cattle producers willing to consign steer calves to a show and feedout project. The calves were received in groups of three or four on Oct. 16, 2021, at the Turtle Lake Weighing Station, Turtle Lake, North Dakota, for weighing, tagging, veterinary processing and showing. The calves were evaluated for conformation and uniformity, with the judges providing a discussion to the owners at the beginning of the feedout. The number of cattle consigned was 165, of which 146 competed in the pen-of-three contest.

The calves then were shipped to the Carrington Research Extension Center, Carrington, North Dakota, for feeding. Prior to shipment, calves were vaccinated, implanted with Synovex-S, dewormed and injected with a prophylactic long-acting antibiotic.

Calves then were sorted and placed on corn-based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.62 megacalorie of net energy for gain (Mcal NEg) per pound finishing diet. Cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were reimplanted with Synovex-Choice on Jan. 26, 2022.

The center held an open house on Feb. 7, 2022 for cattle owners to review calves, ponder performance and discuss marketing options.

The cattle were harvested on May 25, 2022 (162 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Nebraska, on a grid basis, with premiums and discounts based on carcass quality. One calf was harvest locally due to lameness. Carcass data were collected after harvest.

Ranking in the pen-of-three competition was based on the best overall score. The overall score was determined by adding the index values for feedlot average daily gain (25% of score), marbling score (25% of score) and profit (25% of score) and subtracting index value for calculated yield grade (25% of score). The Dakota Feeder Calf Show provided awards and recognition for the top-ranking pen of steers.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 580 pounds upon delivery to the Carrington Research Extension Center livestock unit on Oct. 16, 2021. After an average 220-day feeding period, cattle averaged 1,290 pounds (at plant, shrunk weight). Death loss was 1.21% (two head) during the feeding period.

Average daily feed intake per head was 36.3 pounds on an as-fed basis and 24.0 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 11.5 on an as-fed basis and 7.60 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.894. The overall yardage cost per pound of gain was $0.124. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other

Table 1. Feeding performance — 2021-2022 Dakota Feeder Calf Show Feedout

Pen of three	Best Three Score Total	Average Birth Date	Average Weight per Day of Age, lbs	Average Harvest Weight, lbs.	Average Daily Gain, lbs.	Average Marbling Score[1]	Ave Calculated Yield Grade	Ave Feeding Profit or Loss / Head
1	2.780	21-Mar-21	2.9	1259	3.1	689	3.39	$169.71
2	2.773	27-Mar-21	3.1	1320	3.5	625	3.22	$149.57
3	2.500	13-Mar-21	3.1	1363	3.4	538	3.03	$118.99
4	2.469	6-Apr-21	3.4	1397	3.6	509	3.20	$122.27
5	2.426	14-Mar-21	3.2	1373	3.4	495	2.55	$77.81
Average Top 5 herds	2.59	22-Mar-21	3.2	1343	3.4	571	3.08	$127.67
6	2.381	19-Apr-21	3.5	1402	3.7	467	2.86	$79.16
7	2.336	12-Apr-21	3.3	1344	3.6	506	3.12	$78.32
8	2.251	9-Apr-21	3.2	1290	3.4	455	2.39	$39.30
9	2.248	4-Mar-21	2.9	1296	3.5	538	3.88	$108.00
10	2.245	8-Mar-21	3.0	1327	3.3	619	3.17	$23.22
11	2.201	25-Apr-21	3.3	1312	3.5	469	2.82	$41.05
12	2.194	1-Apr-21	3.1	1288	3.3	540	2.78	$20.79
13	2.182	5-Mar-21	2.8	1263	3.1	579	3.33	$60.20
14	2.162	20-Mar-21	3.3	1407	3.4	520	3.32	$55.89
15	2.148	30-Mar-21	2.9	1232	3.2	610	3.66	$46.73
16	2.032	15-Mar-21	3.1	1343	3.4	515	3.38	$27.24
17	1.999	21-Apr-21	3.3	1323	3.3	498	2.85	$(10.38)
18	1.975	25-Mar-21	3.1	1306	3.4	473	3.54	$50.11
19	1.969	3-Apr-21	3.2	1346	3.0	423	3.12	$76.34
20	1.966	25-Apr-21	3.2	1275	3.2	490	3.48	$52.22
21	1.960	7-Apr-21	3.2	1304	3.5	405	2.90	$25.53
22	1.918	2-Apr-21	3.1	1307	3.1	466	3.68	$72.08
23	1.898	3-Apr-21	2.9	1222	3.1	455	2.82	$4.39
24	1.880	24-Mar-21	3.0	1266	3.1	570	3.49	$(11.85)
25	1.834	28-Mar-21	3.0	1246	3.2	449	3.29	$17.05
26	1.786	25-Apr-21	3.3	1299	3.4	361	2.67	$(14.99)
27	1.76	19-Mar-21	3.2	1360	3.1	559	4.08	$14.86
28	1.54	25-Apr-21	3.0	1182	3.1	452	3.56	$(28.09)
29	1.49	14-Mar-21	2.9	1263	2.9	452	2.95	$(82.37)
30	1.47	27-Mar-21	3.1	1296	3.2	493	3.57	$(78.68)
31	1.18	2-Apr-21	3.1	1311	2.8	490	4.03	$(86.04)
Average bottom 5 herds	1.49	29-Mar-21	3.1	1282	3.0	489	3.64	$(52.06)
Overall average - pens of three	2.06	30-Mar-21	3.13	1,307.22	3.29	506.73	3.23	$39.30
Standard deviation		15.6	0.2	53.0	0.2	69.6	0.4	62.0
number		31	31	31	31	31	31	31

[1]Marbling score 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700-799 = low prime

expenses except interest, was $1.219.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = [-0.03939045* initial calf weight, pounds] + 190.7454305) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

Overall, the carcasses contained U.S. Department of Agriculture quality grades at 4.3% Prime, 76.0% Choice (including 25.3 percent Certified Angus Beef), 18.5% Select and 1.2% ungraded, and USDA yield grades at 3.7% YG1, 40.1% YG2, 49.4% YG3, and 6.8% YG4. Carcass value per 100 pounds (cwt) was calculated using the actual base carcass price plus premiums and discounts for each carcass. The grid price received for May 25, 2022 was $228.90 Choice YG3 base with premiums: Prime $15, CAB $6, YG1 $6.50 and YG2 $3, and discounts: Select minus $13, Standard (ungraded - no roll) minus $15, YG4 minus $8, dark cutter minus $55 and carcasses lighter than 650 pounds minus $20.

Results from the calves selected for the pen-of-three competition are listed in Table 1. Overall, the pen-of-three calves averaged 421 days of age and 1,307 pounds per head at harvest. The overall pen-of-three feedlot average daily gain was 3.29 pounds, while weight gain per day of age was 3.13 pounds. The overall pen-of-three marbling score was 507 (average choice, modest marbling).

Correlations between profit and average birth date, harvest weight, average daily gain, weight per day of age or marbling score are shown in Table 2. Average slaughter weight, average daily gain and marbling score had higher correlations to profitability than average birth date, average weight per day of age or yield grade.

The top-profit pen-of-three calves with superior genetics returned $169.71 per head, while the bottom pen-of-three calves returned a loss of $86.04 per head. The average of the five top-scoring pens of steers averaged $127.67 per head, while the average of the bottom five scoring pens of steers averaged a loss of $52.06 per head. For the pen-of-three competition, average profit was $39.30 per head. The spread in profitability between the top and bottom five herds was $179.66 per head.

Calf value is improved with superior carcass and feedlot performance. Exceptional average daily gains, weight per day of age, harvest weight and marbling score can be found in North Dakota beef herds. Feedout projects continue to provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

Table 2. Correlations between profit and various production measures (pen of three)

	Correlation coefficient
Profit and average birth date	-0.1660
Profit and average slaughter weight	0.3490
Profit and average daily gain	0.4975
Profit and weight per day of age	0.1608
Profit and marbling score	0.4371
Profit and yield grade	-0.0823

Influence of orally-dosed *Megasphaera elsdenii* culture on cattle performance, carcass characteristics, and frequency of bloat in heifers rapidly adapted to a finishing diet.

Madeliene Nichols[1], Yssi Entzie[1], Lydia Hansen[1], Jessica Syring[1], Mustapha Yussuf[1], Zachary E. Carlson[1]

The objective of this experiment was to determine the effects of orally drenching a probiotic Megasphaera elsdenii culture (Lactipro NXT) to concentrate-naïve two-year old heifers during an accelerated 11-day step-up program from a grass hay diet to concentrate-based diet, and in doing so reduce the amount of forage required during the finishing period. Results from this experiment suggest yearling-type cattle maintained on a forage-based diet, can follow an accelerated step-up program when drenched with M. elsdenii culture without impacting growth performance or carcass characteristics and reduce the amount of forage required during the step-up program.

Summary

Thirty-two crossbred heifers (approximately two years old) were assigned randomly to one of two treatments: 1) a conventional 21-day step-up period consisting of four step-up diets followed by the finishing diet for the remainder of the study (Control), or 2) an accelerated 11-day step-up period consisting of three step-up diets and dosed with 40 mL (2×10^{10} CFU/dose) of *M. elsdenii* NCIMB 41125 culture (Lactipro NXT; MS Biotec, Inc., Wamego, Kansas) at initial processing (ME). During the experiment, individual feed intakes (DMI) were measured daily via Calan headgates (American Calan Inc., Northwood, New Hampshire). Cattle were fed for 70 days and were slaughtered at the end of the trial to evaluate carcass characteristics and liver scores. Bloat scores were taken twice daily (four- and eight-hours post-feeding) throughout the experiment. Data were analyzed as a generalized randomized design using the MIXED procedure of SAS (9.4 SAS Inst. Inc., Cary, NC). There were no differences ($P \geq 0.18$) in final body weight (BW), average daily gain (ADG), dry matter intake (DMI), feed conversation (F:G), hot-carcass weight (HCW), carcass characteristics or liver abscess rate. Orally drenching two year old heifers with a *M. elsdenii* culture and accelerating them onto a finishing diet did not impact growth performance or carcass characteristics and reduced the amount of grass hay required to transition the heifers to a finishing diet.

Introduction

Forages are required in finishing diets to maintain rumen function and manage ruminal acidosis or low pH in the rumen. Forages are relatively expensive, on a nutrient basis, compared to other ingredients in finishing diets. The adaptation period from forage-based to concentrate-based diets requires the greatest amount of forage to allow ruminal microbes and the animals to adapt gradually to high-concentrate diets. If cattle are not gradually adapted to high-starch diets, undesirable lactic-acid-producing microbes can grow rapidly and produce relatively large quantities of lactic acid in the rumen, leading to subacute or acute ruminal acidosis. Similarly, high-starch diets also pose the risk of grain bloat. The microbial digestion of starch in the rumen generates a foaming factor preventing eructation. However, unlike other forms of bloat, grain bloat is typically chronic.

Lactipro NXT (MS Biotec, Inc., Wamego, Kansas) is a probiotic drench containing a patented strain of *Megasphaera elsdenii* NCIMB 41125 (ME) approved for use in beef and dairy cattle. *Megasphaera elsdenii* has three key properties: 1) it preferentially utilizes lactate; 2) it grows effectively in low pH environments; and 3) certain strains are native to the rumen. The objective of this experiment was to determine if Lactipro NXT could be utilized to accelerate the adaptation of two-year old heifers from a grass hay diet to concentrate-based diet, and in doing so reduce the amount of forage required during the finishing period.

Experimental Procedures

Thirty-two crossbred heifers (approximately two years old; initial BW = 978 lb; SD = 73) were assigned randomly to one of two treatments: 1) a conventional 21-day step-up period consisting of four step-up diets followed by the finishing diet for the remainder of the study (Control), or 2) an accelerated 11-day step-up pe-

[1]Department of Animal Sciences, NDSU

riod consisting of three step-up diets and dosed with 40 mL of *M. elsdenii* culture (Lactipro NXT). There were 16 heifers per treatment. Diet formulations were based on dry-rolled corn, corn silage, dried distillers grains and supplement (Table 1). Heifers received 25 grams/ton of monensin (Rumensin-90, Elanco Animal Health, Greenfield, Indiana), 6.4 grams/ton of tylosin (Tylan-40, Elanco Animal Health), and 0.4 mg/heifer/day of melengestrol acetate (MGA200, Zoetis, Parsippany, New Jersey). Heifers were fed individually in a Calan gate system (American Calan Inc., Northwood, New Hampshire) and were fed once daily to provide ad libitum access to their respective diet. Daily orts were collected and weighed each morning before feeding and dried with forced air at 60 degrees Celsius for 48 hours to measure dry matter.

Body weights were collected on days -1, 0, 1, 15, 28, 56 and 71. Initial body weights were measured for three consecutive days while heifers were limit-fed for five days a diet of grass hay provided at 2% of their expected BW. Heifers were implanted prior to the start of the experiment with 200 mg trenbolone acetate, 20 mg estradiol and 29 mg tylosin tartate (Component TE-200, Elanco Animal Health).

Bloat scores were taken twice daily (four- and eight-hours post-feeding) throughout the experiment. Heifers were observed and scored for bloat using visual scoring of zero to three (Paisley and Horn, 1998). Scores one and two were classified as sub-acute bloat and three as acute bloat. The total days on which a bloat score greater than zero was recorded (bloat days) was divided by the total days observed to determine percentage of bloat. The sum of daily bloat scores divided by bloat days was considered the mean bloat score. A relative bloat index, combining incidence and severity, was calculated by multiplying percentage bloat by mean bloat score.

Table 1. Diet composition and timeline of transition of treatment groups

Ingredient, % of dry matter	Step 1	Step 2	Step 3	Step 4	Finisher
Alfalfa Hay	39.8	26.0	20.0	9.9	--
Dry Rolled Corn	24.9	38.3	44.2	54.2	64.6
DDGS[1]	9.9	10.0	9.9	10.0	10.3
Corn Silage	20.4	20.8	20.9	20.9	20.1
Supplement[2]	5.0	5.0	5.0	5.0	5.0
Days Fed					
Control	d 1 to 5	d 6 to 10	d 11 to 15	d 16 to 20	d 21 to 70
ME	d 1 to 5	--	d 6 to 8	d 8 to 10	d 11 to 70

[1]Dried distillers grains plus solubles (DDGS)
[2]Formulated to supply 25 g/ton monensin (Rumensin-90, Elanco Animal Health, Greenfield, Indiana), 6.4 g/ton tylosin (Tylan-40, Elanco Animal Health), 0.4 mg/animal/day melengestrol acetate (MGA200, Zoetis, Parsippany, New Jersey)

At the end of the 70-day feeding period, heifers were slaughtered at a commercial abattoir (Tyson Fresh Meats; Dakota City, Nebraska). On day of slaughter, hot-carcass weight (HCW) was collected and liver abscess scores were recorded immediately after evisceration. Following a 24-hour chill, longissimus muscle area, 12th rib fatness, marbling score and yield grade were measured. Carcass-adjusted final BW was calculated using a common dressing percent (62.5%). Carcass-adjusted final BW was used to determine average daily gain (ADG) and feed conversion (F:G).

Performance, carcass and bloat score data were analyzed as a generalized randomized design using the MIXED procedure of SAS (9.4 SAS Inst. Inc.) with individual animal as the experimental unit. Heifers were stratified by weight, as such no block was used. One carcass on the ME treatment was removed from analysis due to excessive trim prior to the carcass scale. There were no liver abscesses detected in this experiment, therefore liver abscess occurrence was not analyzed statistically.

Results and Discussion

Final BW, ADG and DMI were not different ($P \geq 0.18$) between treatments (Table 2). The gains observed in this experiment are likely the result of the heifers being in a state of compensatory growth. The compensatory gain effect likely occurred due to heifers being in an extended limit-fed state prior to the experiment, resulting in a lower maintenance requirement due to shrunken visceral mass (Yambayamba et al., 1996). During the experiment, heifers were allowed ad libitum intake which resulted in compensatory growth and daily BW gains greater than five pounds.

By design, heifers on the conventional 21-day step-up program consumed 48% more grass hay ($P < 0.01$) than heifers dosed with *M. elsdenii* culture and accelerated onto the finishing diet over 11 days. There were no differences ($P = 0.60$) in feed conversion (F:G) of heifers between treatments. Drouillard et al. (2012) and Ellerman et al. (2017) reported similar results with steers dosed with *M. elsdenii* culture and accelerated over eight or ten days, respectively, demonstrating no negative effects with accelerated step-up programs.

Treatment did not affect HCW, dress percent, ribeye area, 12th rib fatness, marbling score or calculated yield grade ($P \geq 0.35$; Table 2). There were no recorded liver abscesses from either treatment. The lack of liver abscesses may be in part because the diet and the step-up protocols implemented in the current experiment were not aggressive enough to cause acidotic conditions, which would lead to damage of the ruminal wall, allowing bacteria to pass from the rumen to the blood and transported to the liver, to colonize and form abscesses. Additionally, the inclusion of tylosin (Tylan-40, Elanco Animal Health) in the diet would help reduce the occurrence of liver abscesses.

Although no direct measure of ruminal acidosis was measured in the current experiment (i.e., rumen pH), ruminal acidosis and bloat are interrelated digestive disorders, and bouts of ruminal acidosis can predispose cattle to bloat (Meyer and Bryant, 2017). Percentage bloat (Table 3), expressed as the occurrence of bloat over the duration of the experiment, indicated that *M. elsdenii* culture reduced the occurrence of bloat by 24%, although differences were not significant ($P = 0.55$) between treatments. Mean bloat score and relative bloat index did not differ ($P \geq 0.52$) between treatments. However, over the duration of the experiment, four heifers were treated for acute bloat symptoms, one from the Control and three from the ME treatment.

Overall, the results from this experiment suggest that yearling-type cattle maintained on a forage-based diet, can follow an accelerated step-up program when drenched with *M. elsdenii* culture without impacting growth performance or carcass characteristics and reduce the amount of forage required during the step-up program.

Table 2. Carcass-adjusted performance of two-year old heifers orally dosed with Lactipro at initial processing and accelerated onto a finishing diet in 11 days

	Treatments[1]			
Item	**Control**	**ME**	**SEM**	***P* - value**
Days on feed, n	70	70	--	--
Performance[2]				
Initial BW[3], lb.	979	977	18.6	0.93
Final BW[4], lb.	1361	1328	27.0	0.39
ADG, lb.	5.46	5.02	0.23	0.18
DMI, lb.	32.8	31.6	0.95	0.37
Hay DMI[5], lb.	100.6	52.0	1.55	< 0.01
F:G[6]	6.01	6.20	--	0.60
Carcass Characteristics[7]				
HCW, lb.	851	830	16.9	0.39
Dress %	59.5	59.0	0.41	0.35
LMA, in^2	13.6	13.6	0.31	0.93
12th rib fat, inch	0.63	0.69	0.05	0.37
Marbling Score[8]	606	604	28.3	0.98
Calculated yield grade[9]	3.00	3.09	0.139	0.65
Liver abscesses[10], %	0.0	0.0	--	--

[1]Treatments include: 1) a conventional 21-day step-up period consisting of four step-up diets followed by the finishing diet for the remainder of the study (Control); or 2) an accelerated 11-day step-up period consisting of three step-up diets and dosed with 40 mL of Lactipro NXT (2×10^{10} CFU/dose; MS Biotec, Inc., Wamego, Kansas).

[2]Performance parameters: initial body weight (BW), final BW, dry-matter intake (DMI), average daily gain (ADG), feed conversion (F:G).

[3]A 4% shrink was applied to account for gastrointestinal tract fill.

[4]Calculated from hot-carcass weight, adjusted to a common dressing percent (62.5%).

[5]Amount of grass hay (dry-matter basis) consumed during the step-up program.

[6]Statistics based on Gain:Feed.

[7]Carcass characteristics: hot-carcass weight (HCW), dressing percent (Dress %), Longissimus muscle area (LMA).

[8]Marbling score: 400 = Slight00, 450 = Slight50, 500 = Small00, etc.

[9]Calcualted as 2.5 + (2.5 x 12th rib fat, in) + (0.02 x 3.0 [kidney, pelvic, heart fat, %]) + (0.0038 x HCW, lb)— (0.32 x LM area, in2; USDA, 2016).

[10]No liver abscesses were found for either treatment.

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Table 3. Occurrence and severity of ruminal bloat of two-year old heifers orally dosed with Lactipro at initial processing and accelerated onto a finishing diet in 11 days[1]

	Treatments[2]			
Item	**Control**	**ME**	**SEM**	***P* - value**
No. of heifers	16	16	--	--
No. of heifers that bloated[3]	12	12	--	--
Percentage bloat[4]	12.68	9.64	3.584	0.55
Mean bloat score[5]	1.03	1.07	0.121	0.82
Relative bloat index[6]	11.94	8.64	3.570	0.52

[1]Bloat scores were visual scores on a scale of zero to three, in accordance with Paisley and Horn, 1998. Scores one and two were classified as sub-acute bloat and three as acute bloat. Scores were recorded twice daily (four- and eight-hours post-feeding) throughout the experiment.

[2]Treatments include: 1) a conventional 21-day step-up period consisting of four step-up diets followed by the finishing diet for the remainder of the study (Control); or 2) an accelerated 11-day step-up period consisting of three step-up diets and dosed with 40 mL of Lactipro NXT 2×10^{10} CFU/dose; MS Biotec, Inc., Wamego, Kansas).

[3]Heifers given a bloat score greater than zero on one or more days

[4]Calculated as the total days observed on which a bloat score greater than zero was recorded and divided by the total days observed to determine percentage of bloat

[5]The sum of daily bloat scores divided by the number of days which bloat occurred was considered the mean bloat score.

[6]A relative bloat index, combining incidence and severity, was calculated by multiplying percentage bloat by mean bloat score.

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Effects of ground hybrid rye as a partial or complete replacement of corn as the concentrate source in high forage backgrounding rations

Colin Tobin[1], Zachary Carlson[2,3], Kendall Swanson[2], Karl Hoppe[1,3]

The objective of this experiment was to determine the effects of hybrid rye inclusions on dry matter intake (DMI), growth performance and feed efficiency in backgrounding beef steers. Results from the study suggest that steers when fed rye as a partial or sole grain in a high forage backgrounding diet weighed similar to calves fed corn as the sole concentrate source at the end of the study.

Summary

Historically, rye use as cattle feed has been limited due to potential of ergot alkaloid ingestion. Alkaloids are toxic to livestock, resulting in decreased performance and health issues. With the new hybrid rye germplasms, producers can increase yield while decreasing ergot infection. Increasing diversity of crop rotations can increase the planting and harvesting of rye cultivars grown within North Dakota. Two hundred cross-bred steers were assigned randomly to one of four treatments: a basal diet formulated with 20% DRC: 0% ground hybrid rye (CON), 13.5% DRC: 6.5% ground hybrid rye (RYE1), 6.5% DRC: 13.5% ground hybrid rye (RYE2), or 0% DRC:20% ground hybrid rye (RYE3) on a dry matter basis. Calves were fed for 56 days during the backgrounding period. During the course of the study, body weight (BW) was measured to assess performance and calculate growth efficiencies. Data were analyzed as a completely randomized design using the MIXED procedure of SAS. There were no effects on final BW, average daily gain (ADG), or the ratio of feed to gain (F:G) detected ($P > 0.05$) due to the feeding of rye. Diets containing rye had higher DMI during the first month of the study ($P = 0.03$) but intake was similar during the second month of the study ($P = 0.16$). Increased DMI during the initial month of backgrounding may promote improved intake and growth.

Introduction

Increasing biodiversity in cropping systems offers benefits over monoculture or two crop rotations including yield increases and resiliency. Cereal rye (*Secale cereale* L.) has been utilized in multiple ways within cropping systems in the northern Great Plains. Rye can be grazed by livestock in an integrated-crop livestock system, harvested for forage as hay or ensiled, or as grain and straw. The use of winter rye can alleviate labor during the growing season as it can be planted at differing times during the fall and harvested prior to other small grains during late spring (Rusche et al., 2020)initial shrunk body weight (BW.

Rye has traditionally not been utilized as a suitable grain for growing and finishing calves. Previously, recommendations have limited the use of rye due to the negative effects of ergot ingestion (Matsushima, 1979). Ergot is associated with cool temperatures and wet conditions during the flowering stage, most commonly found near field edges. Ergot sclerotia contain alkaloids, which, if ingested, are toxic to livestock. Ergot alkaloids cause vasoconstriction which can lead to reduced blood flow to extremities, sloughing of hooves, tails and ears, frostbite, and abortion (Friskop et al., 2018). Recent hybrid rye germplasms have shown increased yields with decreased incidence of ergot.

The objective of this experiment was to determine the effects of hybrid rye inclusions on DMI, growth performance, and feed efficiency in backgrounding beef steers. Our hypothesis was that hybrid rye can be substituted for or replace dry-rolled corn (DRC) in backgrounding beef diets.

Procedures

All procedures involving the use of animals in this experiment were approved by the North Dakota State University Institutional Animal Care and Use Committee. The experiment was conducted at the Carrington Research Extension Center (CREC) near Carrington, North Dakota.

Four treatments were used in a completely randomized block design to evaluate animal performance during backgrounding when fed partial or complete replacement

[1]Carrington Research Extension Center, NDSU
[2]Department of Animal Sciences, NDSU
[3]Extension Agriculture and Natural Resources, NDSU

of corn with rye as the concentrate source. Ground hybrid rye was substituted for DRC as follows: a basal diet formulated with 20% DRC: 0% ground hybrid rye (CON), 13.5% DRC: 6.5% ground hybrid rye (RYE1), 6.5% DRC: 13.5% ground hybrid rye (RYE2), or 0% DRC:20% ground hybrid rye (RYE3) on a dry matter basis (Table 1). All rye grain used was from the same hybrid (KWS Bono, KWS cereals, LLC: Champaign, IL).

Two hundred cross-bred steers (initial BW = 617 ± 64 pounds) were used in this experiment. One hundred sixty steers were collected from the Dakota Feeder Calf Show, Turtle Lake, North Dakota. The steers were vaccinated against infectious bovine rhinotracheitis, bovine viral diarrhea types 1 and 2, parainfluenza-3 virus, *Mannheimia haemolytica* and bovine respiratory syncytial virus (Pyramid 5 + Presponse SQ; Boehringer Ingelheim Animal Health, Duluth, GA; Inforce 3, Zoetis, Parsippany, NJ). They were administered clostridial species (Bar-Vac 7/Somnus; Boehringer Ingelheim) pour-on moxidectin (Cydectin, Bayer, Shawnee Mission, KS), oxytetracycline injection (Noromycin 300 LA, Norbrook Inc., Lenexa, KS) and a steroidal implant (200 mg progesterone and 20 mg estradiol benzoate; Synovex S, Zoetis). Steers ranged from freshly weaned to preconditioned. The remaining 40 steers were sourced from the CREC herd and administered similar processing protocol. Steers were fed in 12 dirt and eight cement-surfaced pens (n = 20). Body weights were collected on two consecutive days, averaged for initial body weights, and calves were sorted into pens. Steers where stratified into four groups by weight and randomly assigned to treatment, resulting in five replications and 50 steers per treatment.

Steers were fed for a total of 56 days beginning Oct. 25, 2021. Interim weights were taken on Nov. 22, 2021 and final weights were taken Dec. 20, 2021. At the conclusion of the feeding period, cattle were weighed on two consecutive days to determine final body weight. Performance data including animal live weights, ADG, DMI and F:G ratio were calculated.

Growth performance data were analyzed with the MIXED procedure of SAS 9.4 (SAS Institute Inc., NC). All data were analyzed, with pen serving as the experimental unit. The model included the fixed effect of feed ration (CON, RYE1, RYE2, RYE3). Least squares means were generated using the LSMEANS statement.

Results and Discussion

The use of rye within the diet did not influence steer weight throughout the study (P = 0.11). During backgrounding, steers on the CON, RYE1, RY2, and RYE3 diets averaged 173 lbs, 175 lbs, 168 lbs, and 176 lbs, respectively. No differences in ADG were detected throughout the study (P = 0.68) During the first 28 days of the study, steers receiving RYE3 diet had the lowest ADG but had the highest ADG during the final 28 days (Table 2). Steers fed diets containing hybrid rye had higher DMI (P = 0.03) and higher F:G (P = 0.04) during the first month of the study. This response

Table 1. Composition of treatment diets

	Treatments			
Ingredient, % DM of diet	**CON**	**RYE1**	**RYE2**	**RYE3**
Corn	20	13.5	6.5	0
Hybrid rye	0	6.5	13.5	20
Corn silage	30	30	30	30
Wheat straw	25	25	25	25
Modified corn distillers grains with solubles	20	20	20	20
Supplement	5	5	5	5

Table 2. Influence of replacing dry rolled corn with ground hybrid rye on interim steer growth performance during backgrounding

	DRC:Rye grain inclusion, % DM basis					*P*-value	
	20:0	**13.5:6.5**	**6.5:13.5**	**0:20**	**SEM**	**Corn vs. rye**	**L**
Initial BW, lbs	614	622	614	617	-	-	-
Initial to day 28							
BW day 28, lbs	713	721	713	707	10.4	0.90	0.84
ADG, lbs	3.55	3.53	3.57	3.17	0.11	0.30	0.03
DMI, lbs	18.3	18.4	18.9	19.32	0.22	0.03	0.005
F:G, lbs	5.32	5.71	5.63	6.36	0.24	0.04	0.02
Day 29-56							
BW day 56, lbs	787	797	782	793	10.1	0.89	0.77
ADG, lbs	2.64	2.72	2.47	3.07	0.12	0.40	0.004
DMI, lbs	22.1	21.9	21.6	21.8	0.22	0.16	0.36
F:G, lbs	9.37	9.28	9.58	7.84	0.54	0.41	0.09

may have been due to higher levels of crude protein within the diet, with the inclusion of rye, resulting in higher intake. Increased DMI during the initial month of backgrounding may promote improved intake and growth. Similar results were found by Rusche et al. (2020)initial shrunk body weight (BW during the first interim period of finishing steers in South Dakota. No differences in diet treatment were detected during the final 28-day period.

Results from the study suggest that steers fed rye as a partial or sole grain in a high forage backgrounding diet weighed similar to calves fed corn as the sole concentrate source at the end of the study. Further research is needed to determine the level of rye grain processing needed to optimize animal performance.

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Grazing Management Practices to Enhance Soil Health in the Northern Great Plains

Erin Gaugler[1], Miranda Meehan[2], Kevin Sedivec[1], Katelyn Landeis[2]

The objective of this project was to identify the impacts of livestock grazing management on environmental and economic sustainability of an integrated crop and livestock system. The integration of crops and livestock has the potential to influence soil health, crop production, livestock performance and economics.

Summary

Cover crops have gained popularity as a practice implemented by producers across the United States. North Dakota is no exception to this trend; acreage reports for North Dakota show an increase in annual crops planted for forage or grazing of 26,241 acres between 2019 and 2021 (USDA-FSA, 2021). Producers incorporate cover crops to improve soil health and increase crop production (USDA, 2019; CTIC, 2017). The economic benefits of cover crops, however, might not be realized if livestock are not incorporated into the system (Costa et al., 2014; Franzluebbers and Stuedemann, 2015).

A producer-led project was developed to assess the impact of livestock grazing on the environmental and economic sustainability of an integrated crop and livestock system (ICLS). An annual forage crop was subjected to two grazing density treatments and two forage utilization rates. Grazing treatments were imposed for two years, followed by cash crop production. In general, the integration of crops and livestock resulted in higher annual forage production than cover cropping alone. Soil nutrient concentrations responded positively to both cover crops and livestock integration after just one year. Soil data from 2022 is still being processed and corn was planted this spring. Initial calculations indicate that incorporating livestock into cropping systems potentially reduces fertilizer costs.

[1]Central Grasslands Research Extension Center, NDSU
[2]Department of Animal Sciences, NDSU

Introduction

The benefits of ICLSs include enhanced nutrient cycling as well as reduced inputs and livestock feed costs. Research on the ecological impacts of ICLSs in semi-arid ecosystems, such as the western part of the Northern Great Plains is limited (Faust et al., 2018). Livestock management decisions like stocking rate, stock density and forage utilization have the potential to influence both environmental and economic sustainability of ICLSs. The objective of this project was to identify the impact of livestock grazing management on environmental and economic sustainability of an integrated crop and livestock system. This producer-led demonstration project will help develop practices for managing grazing livestock on cropping systems to enhance soil health, livestock performance, crop production and economic sustainability.

Procedures

A three-year ICLS project was initiated in the spring of 2020. NDSU Extension partnered with producers to establish six research sites located in central North Dakota, along with a demonstration site near the main campus of NDSU. An annual forage crop was subjected to two grazing density treatments: moderate and high. Additionally, two forage utilization rates were evaluated: 50% and 75%. A non-grazed treatment served as the control. Treatments were imposed for two years, followed by a cash crop.

The annual forage crop planted by mid-June of 2020 and 2021 included oats, sorghum sudangrass, foxtail millet, sunflower, radish, kale, turnip, flax and forage pea seeded at a rate of 18, 3, 2, 1.5, 1, 0.75, 0.75, 2 and 10 lbs/ac, respectively. After two years of an annual forage crop, corn was planted during the spring of 2022.

Beef cattle were randomly assigned to grazing density treatments and carrying capacities were determined based on available forage production and estimated utilization. Cattle were stratified by body weight and body condition score pre- and post-treatment at Fargo, whereas cattle at the producer sites were scored for their body condition only.

Soil samples were collected to characterize physical, chemical and biological properties at each ICLS site as well as from a traditional cash crop system. Soil physical properties included bulk density, infiltration, and aggregate stability collected pre- and post-treatment. Soil chemical properties included soil nutrients, pH and organic matter collected annually with assessment of nutrient distribution only occurring pre- and post-treatment.

Forage production and utilization of the annual crop was estimated by clipping for peak biomass production which occurred during the week before grazing. Clipping to determine forage utilization occurred upon removal of cattle from the grazing treatments.

Results and Discussion

Spring conditions were dry during 2020 and 2021. In fact, the only locations that did not start with a major deficit of moisture were Fargo and Lehr. Aside from precipitation, field conditions were variable and may also be reflected in forage production (Table 1). For example, seeding depth was not consistent during the first year. The annual forage crop was seeded to a depth greater than ¾ inch at Fargo and Jamestown resulting in little to no germination of brassicas, which influenced forage production and quality. Fargo and Jamestown produced the least amount of forage in 2020, averaging 5,600 and 6,800 lbs/acre, while the rest of the sites averaged 6,900 to 12,200 lbs/acre. Though seeding depth was a challenge, strategies for successful field preparation were discussed with the producers or managers of the test sites and the problem did not persist.

Despite widespread drought in 2021, most locations received rain during the fall. The late-season moisture boosted growth and/or re-growth of forages in Fargo, Jamestown, Lehr and Tappen. Even though fall moisture was helpful, the overwhelming lack of subsoil moisture resulted in limited forage production across all sites except Fargo. Average forage production ranged from 3,300 to 7,200 lbs/acre.

Drought conditions during the fall of 2020 and an early September frost slowed down or halted plant growth. While the annual forage mix was designed to meet requirements of beef cattle and maintain or improve ecological benefits, less than ideal conditions made it difficult to meet nutrient requirements of cattle late in the season. Supplementation should be considered when grazing

Table 1. Average forage production (lbs/ac), carrying capacity (AUMs/ac) and degree of use (%) by grazing treatment and location during 2020 and 2021

	Treatment		2020			2021		
Location	Stock Density	Grazing Utilization (%)	Production (lbs/ac)	Carrying Capacity (AUMs/ac)	Degree of Use (%)	Production (lbs/ac)	Carrying Capacity (AUMs/ac)	Degree of Use (%)
Fargo	No grazing	0	3914			5459		
	High	75	5671	2.32	62	8767	3.59	75
		50	4892	1.40	47	5350	1.53	55
	Moderate	75	6249	2.56	68[1]	5681	2.33	65
		50	6940	1.99	56	7972	2.29	61
Jamestown	No grazing	0	6548			3653		
	High	75	6490	2.66	51[1]	5037	2.07	69
		50	7181	2.06	44[1]	6054	1.74	54
McKenzie	No grazing	0	8079			4022		
	High	75	7714	3.16	71	3177	1.3	72
		50	9333	2.68	58	2392	0.69	51
Lehr	No grazing	0	14437			4903		
	Moderate	75	11017	4.52	60	4381	1.80	491
		50	12725	3.65	52	5015	1.44	50
McClusky	No grazing	0	6375			3605		
	Moderate	75	6893[2]	0.99	44[1]	6187	0.89	63
		50	7164	2.06	32	4733	1.36	57
Tappen	No grazing	0	6444			2659[3]		
	Moderate	75	8782	3.60	61[1]	3485[3]	0.57	75
		50	10536	3.02	43[1]	4228[3]	0.49	49

[1]Livestock pulled early due to inclement weather, limited feed or water.
[2]Forage production consisted of 65% weeds. Stocking rate was adjusted accordingly.
[3]Forage production consisted of 60% weeds. Stocking rate was adjusted accordingly.

annual forages during the late fall or early winter months when forage supply or quality is compromised. Livestock response to forage quality was variable (Table 2). It should be noted that livestock weight is subject to considerable fluctuation and weights were taken on a single day in Fargo so care should be taken in interpreting results.

Grazing turnout during 2021 ranged from late July to early October. Producers were encouraged to graze the annual forage cover crop earlier, so that forages would increase in grazing quality. However, persistent drought conditions caused concern for nitrate toxicity and prussic acid poisoning. Samples were collected and tested to ensure that forages were safe. Livestock response to forage quality continued to be variable (Table 2).

Soil samples were collected to characterize physical, chemical and biological properties. Information collected in year one served as a baseline for evaluating response to treatments. Soil nitrogen concentrations responded positively to both cover crops and livestock integration after just one year (Table 3). It will be interesting to more thoroughly assess soil physical and chemical properties after two years of cropping and grazing management treatments. Initial calculations indicate that incorporating livestock into cropping systems potentially reduces fertilizer costs. Soil samples from 2022 are still being processed.

With the exception of Tappen and McClusky, where challenges were evident because of inclement weather, limited feed or water quality, body condition of cattle was maintained. Implementing management strategies, such as altering grazing density and forage utilization, should reflect the goals of an operation. The integration of crops and livestock has the potential to influence soil health, crop production, livestock performance, and economics. This project will equip producers with information to not only meet their goals but also enhance the sustainability of their operation.

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Table 2. Type of cattle, average daily gain (ADG), change in body condition score (BCS) and number of grazing days by treatment and location during 2020 and 2021

	Treatment		2020					2021				
Location	Stock Density	Grazing Utilization (%)	Type of Cattle	Cow ADG (lbs)	Calf ADG (lbs)	Change in BCS	# of Grazing Days	Type of Cattle	Cow ADG (lbs)	Calf ADG (lbs)	Change in BCS	# of Grazing Days
Fargo	High	75	Pairs	-1.8	2.1	1	18	Pairs	-7.0	0.8	0	26
		50		-1.7	1.9	1	11		-5.1	1.4	0	10
	Moderate	75		-4.6	2.0	0	35[1]		-3.0	1.7	-1	34
		50		-4.2	2.4	0	28		-2.7	1.9	0	34
Jamestown	High	75	Pairs and heifers			0	33[1]	Pairs			0	61
		50				0	33[1]				0.5	46
McKenzie	High	75	Heifers			0	41	Heifers			0	17
		50				0	36				0	13
Lehr	Moderate	75	Fall calving cows			0	62	Heifers			0.5	54[1]
		50				0.5	64				0	45
McClusky	Moderate	75	Pairs			-2	24[2]	Pairs			0	25
		50				-1	24[1]				0	20
Tappen	Moderate	75	Pairs and heifers			NA	18[1]	Pairs			0	16[3]
		50				NA	18[1]				0	9[3]

[1]Livestock pulled from grazing trial early due to inclement weather, limited feed or water.
[2]Forage production consisted of 65% weeds. Stocking rate adjusted accordingly.
[3]Forage production consisted of 60% weeds. Stocking rate adjusted accordingly.

Table 3. Soil nutrient and biological analysis at 0-6 inches (in) sampled within a similar soil series at each project location during 2020 (baseline) and 2021 (grazing treatment)

Location	Soil Ecological Type	Grazing Treatment	NO_3-N (lbs/ac)	P (ppm)	K (ppm)	pH	OM (%)	SO_4-S (lbs/ac)	Zn (ppm)	Cu (ppm)
Fargo	Clayey Sub-soil	Baseline	7.0	8.5	315.0	7.3	5.3	14.1	0.9	2.2
		No grazing	17.3	3.7	458.3	7.9	6.9	70.2	0.7	1.6
		High, 75%	26.7	6.8	339.2	7.4	7.3	17.0	0.9	1.2
		High, 50%	32.6	4.0	440.0	7.6	6.6	22.0	1.0	1.6
		Moderate, 75%	19.2	9.2	487.0	7.6	6.1	10.6	0.9	1.5
		Moderate, 50%	25.5	5.5	295.8	7.5	7.0	15.7	0.9	1.0
Jamestown	Loam	Baseline	5.0	16.9	248.0	6.6	3.5	59.3	1.3	0.8
		No grazing	12.5	15.0	183.3	6.7	4.3	163.0	1.2	0.5
		High, 75%	14.7	21.3	188.3	7.0	3.4	105.2	1.2	0.3
		High, 50%	18.4	36.2	242.0	6.3	4.1	147.0	1.6	0.3
McKenzie	Loam	Baseline	14.0	4.2	215.0	5.8	2.6	6.1	0.6	0.5
		No grazing[1]	41.3	8.8	299.2	6.5	4.3	163.3	1.9	0.6
		High, 75%	20.8	2.8	174.0	6.2	2.0	5.4	0.3	0.4
		High, 50%	22.3	2.3	218.3	6.0	2.5	6.0	0.4	0.3
Lehr	Loam	Baseline	17.0	7.2	256.0	7.3	4.3	93.8	1.0	1.0
		No grazing	24.5	3	213.3	7.5	4.9	100.2	0.7	0.4
		Moderate, 75%	22.5	2.3	185.8	7.4	3.0	17.0	0.9	0.5
		Moderate, 50%	26.8	4.7	275.8	7.3	4.0	23.8	0.9	0.5
McClusky	Loam	Baseline	31.0	9.7	427.0	7.0	3.9	27.1	1.0	0.6
		No grazing	15	4.2	315.0	7.4	4.7	20	0.4	0.4
		Moderate, 75%	20.6	7.4	280.0	7.2	5.2	11.8	0.6	0.5
		Moderate, 50%	21.3	6.3	431.7	7.0	5.0	10.3	0.8	0.5
Tappen	Very droughty loam	Baseline	20.0	7.5	243.0	7.5	3.9	7.1	1.4	0.5
		No grazing	22.8	7.2	363.3	7.7	5.1	8.2	1.8	0.5
		Moderate, 75%[2]	16.5	4.8	184.2	8.1	3.3	32	0.3	0.5
		Moderate, 50%[2]	15.5	5.5	305.8	8.1	4.3	6.2	0.3	0.7

[1]Cattle broke into control during final week of grazing in 2020.
[2]Grazing activity was limited due to issues with water toxicity in 2020 and forage production/quality in 2021.

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NDSU Extension evaluates drought management impacts on grassland growth and production

Miranda A. Meehan[1], Kevin K. Sedivec[2]

Grazing management decisions made during drought can have long-term impacts on plant growth and forage production. The goal of this project was to demonstrate the impact of grazing use intensity during the 2021 drought on grassland production and plant development to facilitate drought planning and enhanced climate resilience. Across all species monitored, the highest growth occurred at locations with slight to moderate use and the lowest growth at locations with severe use. The severe use locations had 13% to 57% reduction in forage production when compared to the other levels of use. The results of this program demonstrate the importance of having a drought management plan with well-defined trigger dates to reduce long-term impacts to grazing resources.

Summary

NDSU Extension evaluated the impact of grazing use intensity during the 2021 drought on the growth and production of grasslands following drought during the spring of 2022. County and state Extension personal evaluated 38 locations in ten North Dakota counties. Samples were classified based on county and degree of use. Degree of use was classified using a visual assessment with four categories: 1) Slight to Moderate (<40% use), 2) Full (40%-60% use), Close (60%-80% use), and Severe (>80% use). During a nine-week period from April 8 to June 2, 2022, growth of key grass species was monitored weekly. Prior to initiation of grazing (May 26-June 17), clipping was completed to determine forage production. Grazing management decisions made during drought can have long-term impacts on forage growth and production. The severe grazing intensity pastures reduced forage production during the following spring by as much as 43%. A drought management plan with well-defined trigger dates can help reduce long-term impacts to grazing resources.

[1]Animal Sciences Department, NDSU
[2]School of Natural Resource Sciences, NDSU

Introduction

Grazing management in the fall can have significant impacts on forage production during the subsequent growing season (Heitschmidt et al. 1987; Dormaar et al. 1989). The Northern Plains grasslands are dominated by cool-season grasses, which can make up 85% or more of the species composition. These cool-season grasses can develop tillers in the fall, and the development of these tillers has a direct impact on plant growth the next year. Most tiller development takes place from late August through early October, and again in April and May (Matthew et al. 2000). Plants initiate spring growth from the fall tillers. If these tillers are eaten or die due to drought, then spring growth must occur from new tillers developed in April and May.

If livestock graze tillers below the growing point in the fall (in between the bottom two leaves), they usually will not survive the winter. Drought stress also affects the survival of fall tillers. Fall droughts either don't allow buds to come out of dormancy, thus no new tiller growth, or cause death to those tillers that did grow. If tillers do not establish or survive the fall, a delay in growth and development will occur the following growing season due to new tiller development in the spring. For example, NDSU Extension found that following the 2017 drought, tillers development in the spring occurred two to four weeks later than the previous year's carry-over tillers.

In response to concerns expressed regarding the long-term impacts of grazing management during drought, NDSU Extension launched a program to evaluate the impacts of grazing use intensity on grassland growth and production following the 2021 drought. The goal of this program was to demonstrate the impact of grazing use during the 2021 drought on grassland growth and development during the subsequent spring (2022) to facilitate drought planning and enhanced climate resilience of forage resources.

Experimental Procedures

This spring NDSU Extension evaluated drought management impacts to grassland growth and production at 38 locations in ten counties. Samples were classified based on county and degree of use.

In the fall of 2021, degree of use was classified using a visual assessment adapted from Dyktserhuis (1951) that includes four categories: 1) Slight to Moderate (<40% use), 2) Full (40%-60% use), Close (60%-80% use) and Severe (>80% use). During a nine-week period from April 8, 2022 to June 2, 2022, growth of key grass species was monitored weekly, with growth documented as average grass height in inches. Key grass species monitored included crested wheatgrass, smooth brome, Kentucky bluegrass, and western wheatgrass. Prior to initiation of grazing (May 26-June 17), clipping was completed to determine forage production. Clippings were completed at three plots per location using a 1.92 ft^2, which was clipped to ground level. Samples were then air dried and weighed to determine average forage production for each location.

Results and Discussion

Analysis was completed for growth and production at the end of the monitoring period. Growth of key species and production is depicted using box plots to show median values and variability in the data.

The growth of key grass species was influenced by degree of use during drought. Across all species monitored the highest growth occurred at locations with slight to moderate use and the lowest at locations with severe use (Figure 1). This delay is likely caused by tiller mortality or a loss of plant vigor in the fall of 2021 from high grazing use that either removed the growing points or reduced plant vigor of the cool-season grasses evaluated. Plants that experience tiller mortality are forced to use energy stored in their roots to grow a new tiller in the spring, delaying spring growth and negatively impacting growth and production potential. The height of crested wheatgrass was the highest for slight to moderate use with a median height of 12.5 inches (Figure 1a). The height was highly variable for the severe use locations ranging from 2.5 to 10 inches. The severe use did have the lowest median height at 6.25 inches. The full and close use locations had similar growth with median heights of 7 and 7.5 inches, respectively. The height of smooth brome was the highest for slight to moderate use with a median height of 8.25 (Figure 1b). The severe use did have the lowest median height at 5.25 inches. The full and close use locations had similar growth with median heights of 6.25 and 7 inches, respectively. The height of Kentucky bluegrass was the highest for slight to moderate use with a median height of 9 inches (Figure 1c). The severe use did have the lowest median height at 2.5 inches. The median height for the full use was similar to the severe use, however, heights had a high variability ranging from 2 to 12 inches. The close use locations fell in the middle of the distribution with a height of 4.25 inches. The height of western wheatgrass was the highest for slight to moderate use with a median height of 6.5 inches (Figure 1d). The full and close use locations fell in the middle with median heights of 4 inches. Whereas, the severe use had the lowest median height at 3 inches.

Forage production followed a similar trend as growth (Figure 2). The slight to moderate use sites had the greatest production with a median of 2,548 pounds per acre. The full and close use sites were similar with medians of 1,275.8 and 1,250 pounds per acre, respectively. This similarity is likely due to an outlier location with close use that reported much higher production than the other sites at 5,175 pounds per acre. The severe use locations had 57% reduction in forage production when compared to slight to moderate use with a median of 1,090.8 pounds per acre.

Grazing management decisions made during drought can have long-term impacts on forage growth and production. Failure to reduce stocking rates during drought by reducing the number of animals and/or the length of the grazing period results in overuse of grasslands. Severe use of grasslands, especially in the fall, can result in tiller mortality by either removal of the growing point or physiological stress to cool-season grasses. Tiller mortality can delay growth of cool-season grasses the following growing season, as well as reduce growth and overall forage production.

The results of this program demonstrate the importance of having a drought management plan with well-defined trigger dates to reduce long-term impacts to grazing resources. Having a drought plan also enables ranchers to make timely decisions during a drought, reducing overall risk and drought related losses. If you are interested in developing a drought plan for your ranch, contact your local NDSU Extension agent.

Acknowledgments

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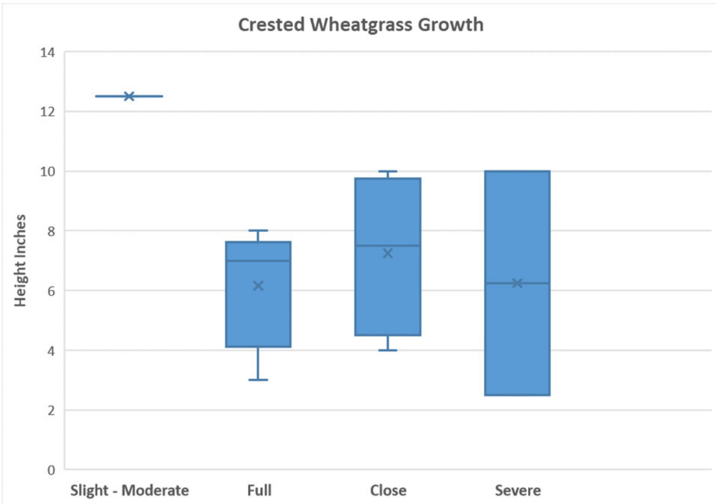
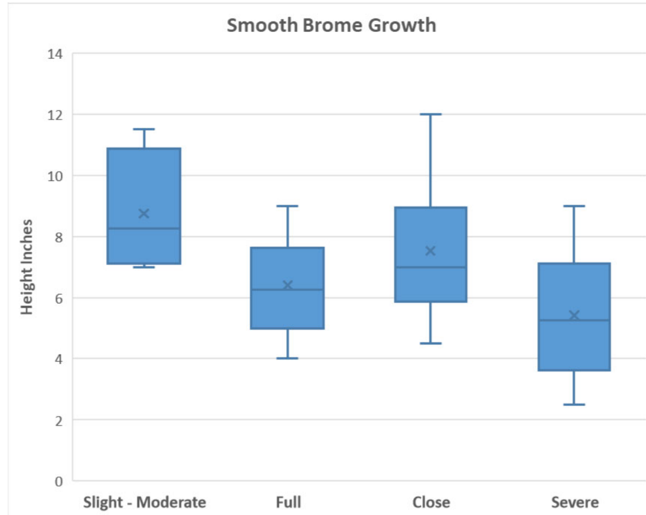
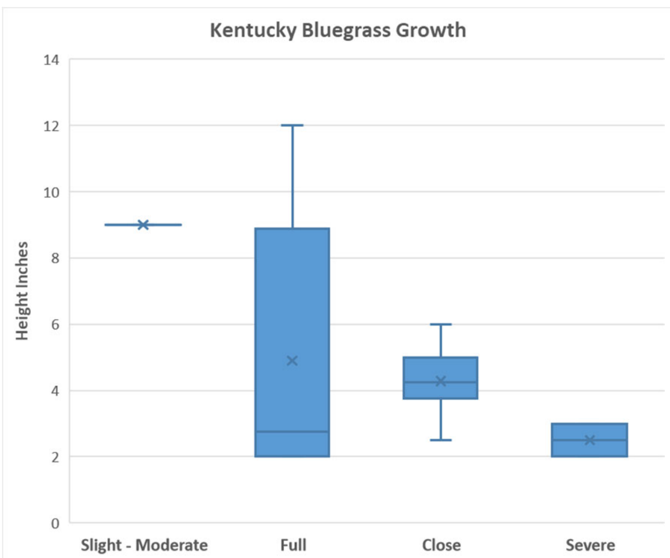


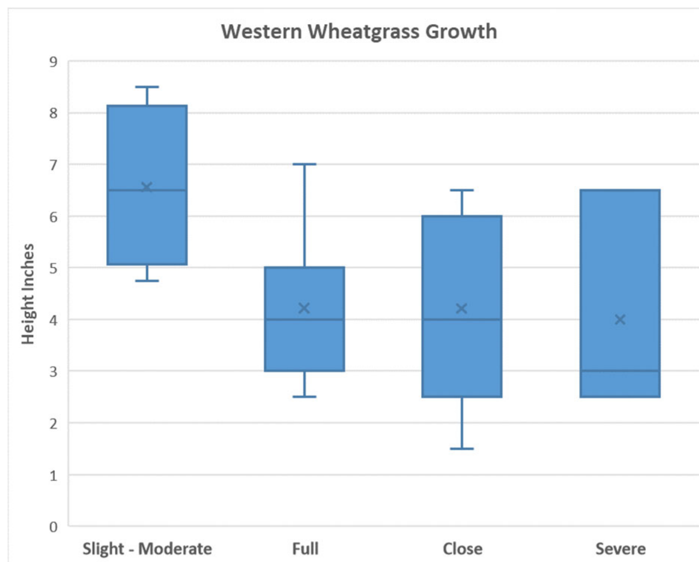
a) Crested wheatgrass



b) Smooth brome



c) Kentucky bluegrass



d) Western wheatgrass

Figure 1. Growth of a) crested wheatgrass, b) smooth brome, c) Kentucky bluegrass and d) western wheatgrass in expressed as height in inches by degree of use slight-moderate (<40%), full (40%-60%), close (60%-80%) and severe (>80%).

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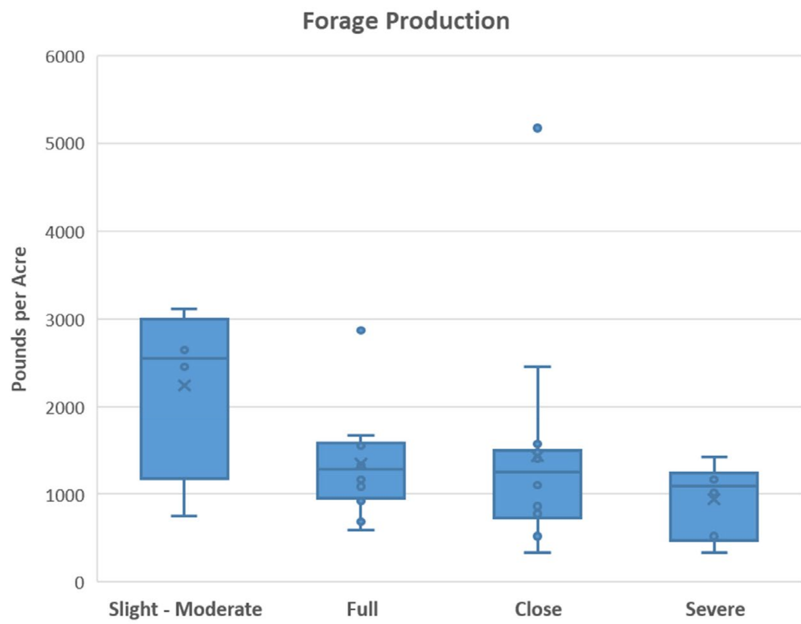

Figure 2. 2022 forage production expressed as pounds per acre by degree of use slight-moderate (<40%), full (40%-60%), close (60%-80%) and severe (>80%).

Vitamin and mineral supplementation during gestation does not influence milk yield or composition during early lactation in beef heifers

Friederike Baumgaertner[1,2], Jennifer Hurlbert[1], Kerri Bochantin[1], Ana Clara B. Menezes[1], Kevin K. Sedivec[2], James D. Kirsch[1], Sarah R. Underdahl[1], Carl R. Dahlen[1]

We conducted two experiments to 1) evaluate whether feeding a vitamin and mineral supplement to replacement heifers throughout gestation affects milk yield and composition in grazing beef heifers at a single point in time and to 2) establish a lactation curve of parlor-milked beef heifers by milking them twice daily for the first 78 days of lactation. For grazing heifers, milk yield and components were not affected by vitamin and mineral supplementation during gestation. For parlor-milked heifers, feeding a vitamin mineral supplement during gestation did not influence milk yield. However, our results show that while milk yield did not increase after day 10 of lactation, urea content in milk varied between sampling days.

Summary

We conducted two experiments to test our hypothesis that vitamin and mineral supplementation during gestation has a positive impact on milk yield and composition at a single point in time in grazing heifers and on daily milk production during early lactation in parlor-milked beef heifers. A total of 41 Angus-based heifers received either a basal ration (CON) or the basal diet plus vitamin mineral supplementation (VTM, 4 ounces per head per day) from breeding until parturition. For experiment 1, 29 heifers (12 CON and 17 VTM) were managed as one pasture group after parturition. Using a portable milking machine, heifers were milked on day 56 postpartum between 7 and 10.5 hours after calf removal. For experiment 2, 12 heifers (6 CON and 6 VTM) were acclimated to a free stall barn and milked twice daily for 78 days following parturition. We recorded milk yield twice daily and collected milk samples on days 32, 58 and 78 of lactation for component analysis. For experiment 1, milk yield and components ($P \geq 0.13$) were similar between treatments. Mean milk yield was 21.9 ± 0.75 pounds/day with 4.1 ± 0.11% fat and 2.8 ± 0.04% protein. For experiment 2, mean milk yield was 18.1 ± 0.18 pounds/day with 3.4 ± 0.14 % fat and 3.2 ± 0.03 % protein. Furthermore, milk production was not increased beyond day 10 of lactation ($P \geq 0.27$). Percent milk protein and concentrations of urea were affected by day of lactation ($P < 0.01$), where protein was increased on day 58 (3.26 ± 0.07%) compared to either days 32 and 78 (3.10 ± 0.07% and 3.16 ± 0.07%, respectively) and urea was reduced ($P < 0.01$) on day 78 compared to either days 32 or 58 (11.24 ± 0.78 vs. 18.84 ± 0.78 and 19.10 ± 0.78 mg/dL, respectively). This study demonstrates that we can successfully manage beef heifers in a dairy facility and consequently lays the platform for future work that will establish energy requirements during early lactation for primiparous beef cows.

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]Central Grasslands Research and Extension Center, NDSU

Introduction

In cow-calf operations, milk production of the dam is a major determinant of pre-weaning calf growth. Milk is the main source of nutrients available for young calves; thus, milk intake influences calf performance and health, impacting weaning weight. Because the dam's lactational performance directly impacts weaning weights, milk production could be an indicator of cow and herd profitability. However, increasing milk yield also leads to greater energy requirements , which in return is associated with increased feed costs (Mulliniks et al., 2020). Therefore, providing producers with milk production estimates can be a potential tool to balance input costs while maximizing calf crop and ranch profitability. Currently, the approaches to estimate milk yield of beef cows involve the use of prediction models and metanalysis. To the best of our knowledge, there are no studies establishing lactation curves for beef cattle based on twice-daily milking in a parlor, which raises the question of what actual recorded daily milk production values are.

Milk production is influenced by, among other factors, nutrition.

Micronutrients, such as vitamins and minerals, are essential for reproduction, lactation, energy metabolism and immune health (Harvey et al., 2021). If no additional source of mineral is provided, grazing cattle have to rely on the content provided by forages, which varies greatly between geographical regions and seasons. Furthermore, mineral status of the herd and supplementation strategies vary widely among producers. Therefore, our objectives were to evaluate the effect of mineral supplementation during gestation on milk yield and composition and to establish a lactation curve for the first third of lactation.

Experimental Design

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University. Forty-one crossbred Angus heifers were randomly assigned to either a basal diet targeting a gain of 1 pound/day (CON) or the basal diet plus a vitamin and mineral supplement (VTM; Purina Wind & Rain Storm All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per heifer per day. Briefly, for experiment 1 (CON, n = 12; VTM, n = 17) treatments were assigned at breeding via artificial insemination, whereas for experiment 2 (CON, n = 6; VTM, n = 6) the VTM supplement was initiated 70 days before artificial insemination.

Heifers were individually fed using Calan gates at the Animal Nutrition and Physiology Center or using the Insentec Feeding System at the Beef Cattle Research Complex (BCRC) in Fargo. For the Calan gate system, supplements were top dressed over the total mixed ration (TMR, whereas the supplement was mixed into the TMR for feeding in the Insentec system.

For experiment 1, heifers calved at BCRC and were transported to the Central Grasslands Research Extension Center (CGREC) 44 days after the last calf was born. Dams and calves were then managed as a single group grazing native mixed-grass prairie. On day 56 postpartum, dams were completely milked out using a portable milking machine. Briefly, dams and calves were assigned to one of four groups with three groups of seven pairs and one group with eight pairs. Beginning at midnight, calves were separated from their dams in 30-minute intervals per groups to stagger milking times and allow for continuous milking. Six hours after calf removal, calves were allowed to nurse their dams until satiety (approximately 30 minutes) to allow for similar milking status across the dams. Cow-calf pairs were then separated again and dams were milked out approximately 7 to 10.5 hours after calf removal. As part of the protocol, 1 mL of oxytocin was administered intramuscularly to each dam, the udder was prepped, and the milking machine was attached. To calculate 24-hour milk production, the measured milk yield was multiplied by 24 and divided by the average number of hours that each group was separated from their calves. Furthermore, a milk sample for analysis of composition, including somatic cell count (SCC), concentrations of urea (MUN), and percent fat, protein, lactose and solids, was collected from each dam.

For experiment 2, heifers were trained and halter broken. Immediately following calving, heifers and calves were separated and heifers were completely milked out using a portable milking machine to determine composition of colostrum. Within the first ten days of lactation, heifers were acclimated to a free stall barn at the NDSU Dairy Unit, where they were then milked twice daily for 78 days (Figure 1). Milk yield was recorded at each milking using the milk meters installed in

Figure 1. Milking beef heifers at the NDSU dairy unit.

the parlor. On days 32, 58 and 78 of lactation, milk samples were collected from each heifer for analysis of components. Milk samples were thoroughly mixed and stored at 39 degrees Fahrenheit until further analysis of components, i.e. SCC, MUN and percent fat, protein, lactose, and solids, by a DHIA laboratory.

For experiment 1, milk yield and composition were analyzed using the MIXED procedure of SAS for effect of treatment. For experiment 2, milk yield was analyzed as repeated measures in time using the MIXED procedure and composition was analyzed using the MIXED procedure to test for effects of treatment, day of lactation (DIM) and treatment × DIM interaction. In all analyses, heifer was considered the experimental unit and significance was determined at $P \leq 0.05$.

Results and Discussion

Experiment 1

On day 56 of lactation, milk yield of grazing heifers was not affected by mineral supplementation during gestation ($P = 0.57$; Table 1). Providing dairy cows in New Zealand with a trace mineral supplement from late gestation to day 230 of lactation increased milk production by 1.98 pounds/day (Griffiths et al., 2007). Similarly, Stokes et al. (2019)114, and 44 ± 26 d prepartum. Heifers were provided free-choice inorganic minerals. Heifer BW and body condition scores (BCS reported that milk production on day 71 of lactation estimated via weigh-suckle-weigh procedure was 3.46 pounds/day greater for beef heifers that were administered trace mineral injections during heifer development and gestation. Machine milking is a direct method to measure milk production, whereas weigh-suckle-weigh is an indirect approach, because it measures calf weight change as a result of suckling. Consequently, milk production may vary based on the method used.

Milk composition and SCC were not affected by mineral supplementation during gestation ($P \geq 0.13$; Table 1). Our findings agree with Griffiths et al. (2007), who observed no differences for milk composition as a result of mineral supplementation. Milk fat values reported here are greater (range from 3.94 ± 0.17 % to 4.30 ± 0.17 %; Table 1) than reported for sample collection using hand-stripping or hand milking by Baumgaertner et al. (2021; range from 0.34 ± 0.08 % to 1.03 ± 0.08 %) and Shee et al. (2016; range from 0.49 ± 0.13 % to 1.50 ± 0.13 %). These results demonstrate that sampling technique has a large influence on the proportion of milk fat in a sample and needs to be carefully considered when designing and interpreting research efforts and deciding whether results can be assumed to represent actual calf consumption.

Experiment 2

Colostrum composition ($P \geq 0.33$; Table 2) and milk composition during early lactation ($P \geq 0.16$; Table 3) were similar between CON and VTM heifers for all components. However, percent of protein and MUN were impacted by DIM ($P < 0.01$), with protein being greater on day 58 compared to days 32 and 78, and concentrations of urea being reduced on day 78 compared with days 32 and 58. Further, milk yield (Figure 2) was not affected by mineral supplementation during gestation ($P = 0.43$), but was influenced by DIM ($P < 0.01$). The average milk yield measured during early lactation was 18.1 ± 0.18 pounds/day with 3.4 ± 0.14 % fat and 3.2 ± 0.03 % protein and daily milk production did not increase beyond day 10 of lactation ($P \geq 0.27$). Similarly, Machado et al. (2013)50 mg of manganese, 25 mg of selenium, and 75 mg of copper at 230 and 260 days of gestation and 35 days postpartum, on the health, milk production and reproductive performance of lactating Holstein

Table 1. Milk yield and composition of grazing beef heifers as influenced by vitamin and mineral supplementation during gestation[1]

	Treatment[2]			
Item	CON	VTM	SEM[3]	*P*-value
Milk yield, lbs.	21.41	22.30	1.191	0.574
Fat, %	4.30	3.94	0.173	0.128
Protein, %	2.83	2.82	0.060	0.883
SCC[4], cells x 10^3/mL	31.6	36.0	14.47	0.781
MUN[5], mg/dL	11.01	10.46	0.521	0.421
Lactose, %	5.09	5.08	0.031	0.905
Other Solids, %	5.96	5.97	0.038	0.832

[1]Samples were collected at a single point in time (d 56) during lactation.
[2]Treatment: Control (CON) and vitamin mineral supplement (VTM) groups received the same basal diet targeting a gain of 1 pound/day, but VTM heifers also received a commercially available vitamin mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day.
[3]SEM = Standard error of the mean (CON, n = 12; VTM, n = 17).
[4]SCC = somatic cell count.
[5]MUN = milk urea nitrogen.

cows. A randomized field trial was conducted on three large commercial dairy farms located near Ithaca, New York, USA, with 1416 cows enrolled. All cows were housed and offered a total mixed ration consisting of approximately 55% forage and 45% concentrate on a dry matter basis of the diet, which supplied 2–6 times the NRC requirements for the supplemented elements. Dry cows and pregnant heifers were blocked by parity and randomly allocated to one of two treatments: Trace mineral

Table 2. Colostrum composition of beef heifers later milked in a parlor as influenced by vitamin mineral supplementation during gestation

	Treatment[1]			
Item	CON	VTM	SEM[2]	*P*-value
Fat, %	7.39	8.84	0.997	0.326
Protein, %	12.16	10.90	1.166	0.460
SCC[3], cells x 10^3/mL	5,160	3,457	1341.21	0.390
MUN[4], mg/dL	13.60	12.28	3.010	0.762
Lactose, %	3.11	3.25	0.191	0.601
Other solids, %	4.03	4.13	0.178	0.717

[1]Treatment: Control (CON) and vitamin mineral supplement (VTM) groups received the same basal diet targeting a gain of 1 pound/day, but VTM heifers also received a commercially available vitamin mineral supplement (Purina Wind & Rain Storm All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day.
[2]SEM = standard error of the mean (CON, n = 6; VTM, n = 6).
[3]SCC = somatic cell count.
[4]MUN = milk urea nitrogen.

Table 3. Milk composition of parlor-milked beef heifers on days 32, 58 and 78 of lactation as influenced by vitamin mineral supplementation during gestation

			Day of lactation[1]					*P*-value[2]		
Components	Trt[3]		32	58	78	Trt Avg[4]	SEM[5]	Trt	Day	Trt × Day
Fat, %	CON		3.20	3.27	3.96	3.47	0.357	0.811	0.938	0.118
	VTM		3.64	3.50	3.03	3.39				
		Day[6]	3.42	3.39	3.49					
Protein, %	CON		3.19	3.30	3.18	3.22	0.069	0.268	<0.001	0.308
	VTM		3.01	3.22	3.13	3.12				
		Day	3.10[a]	3.26[b]	3.16[a]					
SCC[7], cells × 10^3/mL	CON		126.17	153.67	141.50	140.44	69.068	0.881	0.521	0.932
	VTM		100.50	143.00	147.33	130.28				
		Day	113.33	148.33	144.42					
MUN[8], mg/dL	CON		18.27	18.93	10.18	15.79	0.781	0.156	<0.001	0.373
	VTM		19.42	19.28	12.30	17.00				
		Day	18.84[a]	19.10[a]	11.24[b]					
Lactose, %	CON		4.83	4.90	4.88	4.87	0.132	0.301	0.359	0.948
	VTM		4.96	5.00	4.98	4.98				
		Day	4.89	4.95	4.93					
Other Solids[9], %	CON		5.74	5.81	5.79	5.78	0.108	0.272	0.190	0.993
	VTM		5.85	5.91	5.88	5.88				
		Day	5.79	5.86	5.83					
Total Solids[10], %	CON		12.12	12.37	12.93	12.47	0.384	0.850	0.824	0.143
	VTM		12.52	12.63	12.05	12.40				
		Day	12.32	12.50	12.49					

[1]Day of lactation: milk samples were collected on days 32, 58 and 78 of lactation.
[2]Probability values for the effects of treatment, day of lactation, and treatment × day.
[3]Trt = treatment; CON heifers received a basal total mixed ration to gain 1 pound/day; VTM heifers received the basal diet plus a vitamin mineral supplement (4 ounces per head per day) from first time breeding until parturition.
[4]Mean component values of treatment groups across days 32, 58 and 78 of lactation.
[5]Average standard error of the mean for the treatment × day of lactation interaction (for all days CON, n = 6; VTM, n = 6).
[6]Mean component values across treatments within days of lactation.
[7]SCC = somatic cell count.
[8]MUN = milk urea nitrogen.
[9]Other solids calculated based on the formula: lactose + ash, with 0.91 as the constant for ash.
[10]Total solids calculated based on the formula: fat + protein + lactose + ash, with 0.91 as the constant for ash.
[a,b]Means within row with different superscripts differ significantly ($P \leq 0.05$).

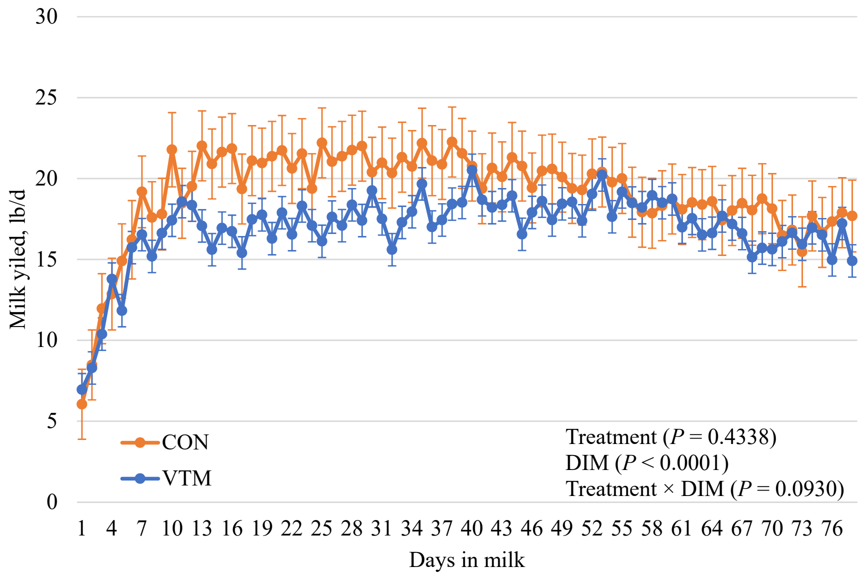

Figure 2. Milk yield of parlor-milked beef heifers during the first 78 days of lactation and the effect of vitamin and mineral supplementation during gestation [supplemented (VTM) vs. unsupplemented (CON)]. Values are least squares means with errors bars depicting the standard error.

supplemented (TMS reported no differences in milk production for cows either receiving an injectable trace mineral during late gestation and early lactation. Milk production estimates using weigh-suckle-weigh may vary depending on calf losses, i.e. feces and urine, and accuracy of scales used. To our knowledge no other experiments measured twice daily milk production in beef heifers to establish lactation curves without the use of prediction models. While we were only able to use a small set of animals for experiment 2 with inherent individual animal variation, we clearly demonstrated that it is possible to train beef heifers to a free stall dairy barn and milking in a parlor, which will allow us to record milk production throughout lactation and determine energy requirements for first parity beef females in future experiments.

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Rate of gain during early gestation in beef Heifers does not influence development, feed intake and behavior, puberty attainment, and concentrations of hormones and metabolites in female offspring

Friederike Baumgaertner[1,2], Ana Clara B. Menezes[1], Wellison J. S. Diniz[3], Jennifer L. Hurlbert[1], Kerri A. Bochantin[1], James D. Kirsch[1], Sheri T. Dorsam[1], Sarah R. Underdahl[1], Kevin K. Sedivec[2], Carl R. Dahlen[1]

The objectives of this study were to evaluate whether feeding an energy/protein supplement to replacement heifers to achieve a moderate rate of gain during early gestation affects offspring growth and development, feed intake and behavior, body size and composition, puberty attainment, and concentrations of hormones and metabolites. Our results show that while calves born to moderate gain heifers were heavier at birth, post-natal growth, performance, and metabolic indicators of offspring were not impacted by maternal nutritional treatment.

Summary

We hypothesized that a moderate rate of gain during the first 84 days of gestation would positively affect heifer offspring growth and development, feed intake and behavior, body size and composition, puberty attainment, and metabolic and hormonal profiles. Starting at breeding, we fed 45 Angus-based heifers either a basal total mix ration for gains of 0.63 pounds/day (low gain [LG], n = 23) or the basal diet plus an energy/protein supplement allowing for 1.75 pounds/day gain (moderate gain [MG], n = 20) for 84 days. For the remainder of gestation, heifer dams were managed as a single group grazing rangeland at the Central Grasslands Research Extension Center (Streeter, ND), where they calved in early March 2020. Dams and their calves grazed native mixed-grass prairie until weaning, at which point they were moved to the Beef Cattle Research Center (Fargo, ND) to record individual feed intake of a common hay-based diet. Heifer offspring were weighed at key timepoints between calving and day 84 of gestation. Blood samples were collected at calving, turnout, weaning, breeding, and at day 42 and day 84 of gestation, and were analyzed for concentrations of IGF-1, insulin, NEFA, and glucose. Additional blood samples were collected throughout development and analyzed for progesterone concentration to determine puberty attainment. Carcass characteristics and body measurements were recorded at a single point in time during the development period. Our results show that calves from MG were heavier at birth (*P* = 0.03) than calves from LG dams; however, subsequent postnatal weights, feed intake and behavior, carcass characteristics and body measurements, hormones and metabolites, and puberty attainment did not differ between female offspring from LG or MG dams (*P* > 0.12). We conclude that while early gestation maternal nutrition affected offspring birth weights, no long-term effects throughout offspring development and breeding were observed.

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]Central Grasslands Research and Extension Center, NDSU
[3]Department of Animal Sciences, Auburn University, Auburn, AL

Introduction

Nutrient availability often varies for grazing cattle because energy and protein concentration in forages often declines throughout the grazing season. Providing supplemental sources of energy and/or protein when available forage cannot meet nutrient demands during gestation can positively affect growth rates and reproductive performance and therefore improve productivity of the cow herd. While the majority of fetal growth occurs during the last trimester of gestation, during early gestation the placenta is established and vascularized to allow for optimal transfer of nutrients to the fetus, and vital fetal organs are developed (Caton et al., 2019).

During early gestation, fetal growth is vulnerable to maternal dietary nutrient supply, which may affect post-natal offspring characteristics. Previous research has demonstrated that providing mineral supplements and feeding beef heifers to different rates of gain achieved via energy/protein supplements during early gestation affected fetal growth (Menezes et al., 2022). Others reported that while early gestation nutrient restriction to 65% of the requirements did not alter birth weights (Noya et al., 2019a) immunological and physiological profiles during the next lactation in two cattle breeds. Fifty-three Parda de Montaña (PA or body weights during the development period, weaning weights were reduced in calves from restricted cows (Noya et al., 2019b)we evaluated the effects of maternal subnutrition in early pregnancy on the growth and reproductive performance of female offspring during their rearing, first gestation, and lactation. We inseminated 21 Parda and 15 Pirenaica multiparous cows and assigned them to a CONTROL (100% of nutrition requirements. However, the long-term effects of different rates of gain during early gestation on offspring performance need to be evaluated. Therefore, the objective of this study was to evaluate how feeding heifers to a moderate rate of gain during the first 84 days of gestation impacts heifer offspring growth and development, feed intake and behavior, body measurements and composition, puberty attainment, and metabolic and hormonal profiles.

Procedures

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University. One-hundred Angus-based heifers were estrus synchronized and bred to female-sexed semen from a single sire via artificial insemination. At breeding, heifers were randomly assigned to one of two treatments: 1) a basal total mixed ration (TMR; low gain [LG]) to achieve 0.63 pound/day gain or 2) the basal TMR diet plus an energy/protein supplement mixed into the ration (moderate gain [MG] to achieve 1.75 pounds/day gain). The supplement was included in the ration at a rate reflective of what we would expect to see consumed on pasture. We would expect gains similar to our LG treatment when heifers are grazing mixed grass-prairie, and gains similar to our MG treatment if supplementation was provided. After the 84-day feeding period, heifers gestating female calves were managed as a single group grazing native mixed grass prairie at the Central Grasslands REC.

Following weaning, 43 offspring (LG, n = 23; MG, n =20) were transported from the Central Grasslands REC to the Beef Cattle Research Center for the development period and trained to the Insentec Feeding System (Hokofarm B.V., Marknesse, The Netherlands). Offspring were managed as one group and had *ad libitum* access to a forage-based diet including a mineral supplement (Purina Wind & Rain Storm All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.). Individual feed intake was monitored daily using the Insentec Feeding System to determine feed intake and behavior. Individual feeding events were summarized by heifer and day for each day of the experimental period. The parameters evaluated were events (number of daily visits and meals to the feed bunk), time eating (per visit, per meal and per day), dry-matter intake (per day, per visit and per meal), and eating rate. A visit was defined as each time the Insentec system detected a heifer at a feed bunk, and a meal was defined as eating periods that might include short breaks separated by intervals no longer than seven minutesSimmental, and Shorthorn breeding were used to study the effect of metabolizable protein (MP.

Body weights were recorded at birth, pasture turnout (2-day weights), mid-summer, weaning (2-day weights), upon the arrival at Beef Cattle Research Center in Fargo, once a month during the development period, at the initiation of estrus synchronization, and day 42 of gestation. Furthermore, we evaluated body composition and morphometric measurements of offspring when they were approximately 10 months of age. Body composition was assessed via carcass ultrasonography (500 V Aloka with 3.5-MHz transducer, Wallingford, CT) for the specific measurements of rump fat, rib fat, rib-eye area and percent of intramuscular fat. Body measurements included shoulder-hip length (distance between the middle of the shoulder blades to the middle of the hip), chest circumference (circumference around the chest right behind the shoulder blades), abdominal girth (circumference around the abdominal cavity at the umbilicus behind the last rib), hip circumference (circumference right before the hips), hip width (distance between the highest points of the hip protrusions), and hip height (from the highest part of the hip bone to the floor).

We collected blood samples at calving before first suckling, pasture turnout, weaning, initiation of first estrus synchronization, day 42, and day 84 of gestation for analysis of insulin, IGF-1, glucose and NEFA. Additional blood samples were collected for assessment of puberty attainment at four timepoints throughout development with two samples per timepoint spaced ten days apart. Heifers were considered pubertal once serum P4 concentration were ≥ 1.0 ng/mL at any of the sampling points.

Offspring body weights, feed intake and behavior, concentrations of hormones and metabolites were analyzed as repeated measures in time using the MIXED procedure of SAS for effects of maternal treatment, day, and a maternal treatment × day interaction. Puberty attainment, carcass characteristics and body measurements were analyzed using the GLM procedure for effects of maternal treatment. In all analyses, offspring were considered the experimental unit and significance was determined at $P \leq 0.05$.

Results and Discussion

We previously reported that offspring from MG heifers were 4.8 pounds heavier at calving (Baumgaertner et al., 2020); however, subsequent weights recorded from calving throughout the development period revealed no differences for a treatment × day interaction ($P = 0.40$) or treatment effects ($P = 0.35$). For instance, at weaning offspring from LG and MG heifers weighed on average 596.2 ± 10.4 pounds and 595.4 ± 10.4 pounds, respectively, and around the time of breeding offspring from LG weighed 840.4 ± 15.8 pounds and offspring from MG weighed 874.0 ± 15.8 pounds.

Maternal rate of gain during early gestation did not affect dry-matter intake or feeding behavior ($P \geq 0.15$), as both LG and MG offspring had similar dry matter intake (17.2 ± 0.29 and 17.6 ± 0.29 pounds/ day for LG and MG, respectively), visited the feed bunk a similar number of times (50.5 ± 0.76 and 49.3 ± 0.76 visits/ day for LG and MG, respectively), and spent similar times eating (208.2 ± 4.14 and 209.8 ± 4.14 minutes/ day for LG and MG, respectively) throughout the development period. Furthermore, neither body composition nor morphologic measurements (Table 1) differed between offspring from LG and MG dams at approximately 10 months of age ($P \geq 0.31$ and $P \geq 0.53$, respectively). Noya et al. (2019a; 2019b) immunological and physiological profiles during the next lactation in two cattle breeds. Fifty-three Parda de Montaña (PA reported greater body measurements at 4 months of age but not at 12 months of age for offspring from mature cows fed 100% of their nutrient requirements compared to offspring from dams fed 65% of their nutrient requirements during the first 82 days of gestation.

Table 1. Impact of maternal nutritional treatment on carcass ultrasonography measurements in female offspring during the development period at approximately 10 months of age

Item	Treatment[1]		SEM[2]	*P*-value
	LG	MG		
No. of offspring	23	20		
Carcass measurement				
Rump fat, in	0.19	0.19	0.015	0.728
Rib fat[3], in	0.20	0.20	0.013	0.741
Rib-eye area[4], in^2	7.63	7.80	0.199	0.527
Intramuscular fat[5], %	4.36	4.42	0.184	0.814
Body measurements, in				
Shoulder-hip length[6]	28.85	29.38	0.375	0.310
Chest circumference[7]	64.72	64.58	0.537	0.847
Abdominal circumference[8]	76.98	78.00	0.904	0.413
Hip circumference[9]	67.89	67.93	0.740	0.974
Hip width[10]	14.35	14.48	0.191	0.629
Hip height[11]	45.26	45.30	0.231	0.902

[1]Treatment = Nutritional treatments of dams during the first 84 d of gestation: LG, basal diet; MG, basal diet plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 pounds/day for moderate gain and 0.63 pound/day for low gain heifers.
[2]SEM = Standard error of the mean (n = 43).
[3]Rib fat (measured at 12th rib).
[4]Rib-eye area (measured at 12th rib).
[5]% intramuscular fat (measured at 12th rib).
[6]Shoulder-hip length (from shoulders to hips).
[7]Chest circumference (circumference around the chest at the shoulder).
[8]Abdominal circumference (circumference behind the last rib).
[9]Hip circumference (circumference before the hips).
[10]Hip width (distance between protrusion of hip bones).
[11]Hip height (distance from the top of hip bone protrusion to the floor).

Similarly, there was no effect of maternal treatment on circulating concentrations of serum IGF-1 ($P = 0.23$), insulin ($P = 0.78$), glucose ($P = 0.12$) or NEFA ($P = 0.17$) in female offspring (Figure 1), concentrations of IGF-1, insulin, glucose, and NEFA were influenced by the main effect of day ($P < 0.01$). Concentrations of IGF-1 changed over time, with the lowest values present at calving ($P < 0.01$). Contrarily, concentrations for insulin, glucose, and NEFA were greatest at calving and decreased over time ($P < 0.01$) in female offspring, which is similar to offspring endocrine and metabolic profiles reported by López Valiente et al. (2022)caused by seasonal pasture production, often results in poor production traits in progeny. Aims. The objective of the current study was to determine whether different levels of maternal nutrient intake in beef cows during late gestation affect fetal and postnatal growth, glucose metabolism, and insulin-like growth factor 1 (IGF1.

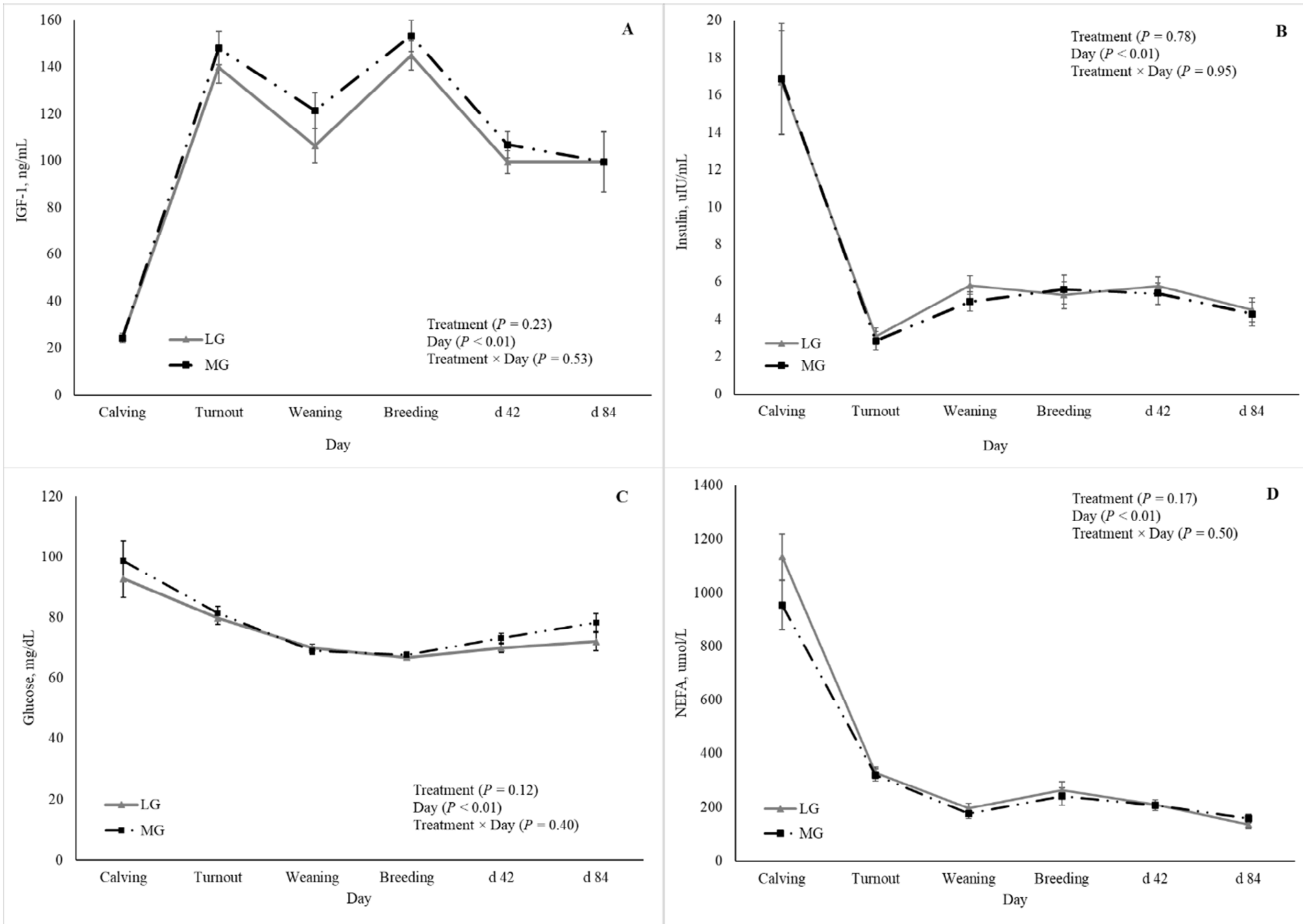

Figure 1. Impact of maternal rate of gain during the first 84 days of gestation (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) on female offspring metabolic and endocrine profiles. Panel A = IGF-1; Panel B = Insulin; Panel C = Glucose; and Panel D = NEFA.

The timing of puberty onset, i.e. start of cyclicity, was similar between heifers from LG and MG dams ($P \geq 0.39$; Figure 2). While onset of puberty in female offspring did not differ between maternal treatments, the percent of heifers that were cyclic increased over time. Just prior to the first estrus synchronization and breeding, at which point in time female offspring were between 14 to 15 months of age, more than 80% of the heifer offspring were cyclic. This is important as heifers becoming pubertal younger can go through several estrous cycles prior to breeding, and

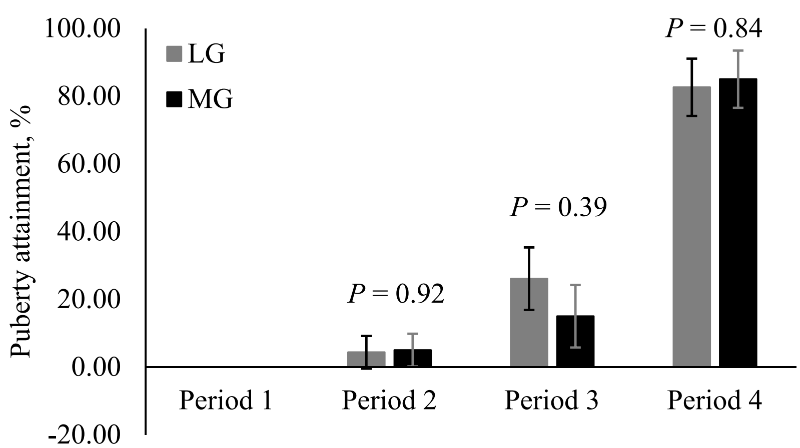

Figure 2. Impact of maternal rate of gain during the first 84 days of gestation (low gain [LG], 0.63 pound/day; moderate gain [MG], 1.75 pounds/day) on female offspring puberty attainment rate. Heifer age from period 1 to 4 was approximately 8.5 to 14.5 months.

therefore, have a greater possibility of conceiving early in the breeding season.

Overall, these results indicate areas necessary for future evaluation. This includes examining different windows of maternal supplementation, e.g. mid gestation, late gestation and gestation in its entirety. While differences based on maternal treatment were not present at the sampling timepoints described for this research effort, we need to determine whether differences may develop later in an offspring's life, e.g. after their third, fourth, etc. calf. Lastly, effects of maternal treatment during early gestation may not be present in female offspring but could show up in future generations. Therefore, future research needs to extend to grand- and great-grand offspring.

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Mature rams managed on divergent planes of nutrition exhibit altered concentrations of hormones and metabolites but not semen characteristics

Kerri A. Bochantin[1], Friederike Baumgaertner[1], Jennifer L. Hurlbert[1], James D. Kirsch[1], Sheri T. Dorsam[1], Ana Clara B. Menezes[1], Christopher S. Schauer[2], Carl R. Dahlen[1]

The objective of the current study was to characterize the effects of divergent planes of nutrition on body weight, hormone and metabolite concentrations, and semen characteristics in mature rams. Results demonstrate altered concentrations of metabolic hormones, including thyroid hormones and insulin-like growth factor, in response to divergent planes of nutrition. However, sperm motility was not impacted. Future work must evaluate whether sperm molecular characteristics and/or offspring outcomes are impacted by divergent planes of nutrition.

Summary

Twenty-four mature Rambouillet rams (initial mean body weight [BW] = 183.0 ± 6.4 lb) were randomly assigned to be managed on either a positive (POS; gain 12% of initial BW), maintenance (MAINT; maintain initial BW), or negative (NEG; lose 12% of initial BW) plane of nutrition for an 84-day period. Rams were weighed weekly and diet allocations were adjusted based on weekly weights to achieve targeted weight gain or loss. On days 0, 28, 56 and 84, body condition scores (BCS) and scrotal circumference (SC) measurements were recorded, and blood and semen samples were collected. Blood was analyzed for concentrations of triiodothyronine (T3), thyroxine (T4), insulin-like growth factor-1 (IGF-1), testosterone (T), glucose and non-esterified fatty acids (NEFA). Semen was analyzed via Computer Assisted Semen Analysis (CASA) for quantification of number of sperm in the ejaculate and sperm motility. By design, rams managed on the POS treatment gained more weight than NEG rams by day 14 of the feeding period, which was maintained for the remainder of the study ($P < 0.001$). Body condition score and SC followed similar patterns of divergence between POS and NEG rams by day 28, as indicated by a significant treatment × day interaction ($P < 0.001$). Of the hormones and metabolites analyzed, T3 and IGF-1 demonstrated a significant treatment × day interaction ($P < 0.001$). Concentrations of T3 tended to be greater in NEG rams at day 56 ($P = 0.10$) while IGF-1 increased in NEG rams at day 28 and 56, as compared to MAINT and POS rams ($P < 0.02$). Non-esterified fatty acid concentrations were greater in MAINT across all sampling time points, as compared POS and NEG rams ($P = 0.01$). While not impacted by treatment, glucose concentrations were greatest at day 0 and decreased by day 84 of the experiment ($P < 0.0001$). Semen characteristics were not impacted by dietary treatment, but rather ejaculate volume and concentration of sperm per ejaculate were greater at day 84 as compared to day 0 ($P < 0.01$). The percentage of motile, progressive motile and static sperm found within the ejaculate were unaffected by treatment or day effects ($P > 0.11$). Future efforts in this area will be focused on determining paternal contributions to offspring growth and development.

Introduction

Throughout the production year, dramatic changes in body composition and weight can occur in rams as a result of variation in nutrient availability and workload during the breeding season. Nutritional management of sires represents an important consideration for producers in an effort to optimize reproductive performance. However, variation exists between management strategies among producers, resulting in variable patterns of weight change leading up to the breeding season. The consequences of these decisions on the overall semen characteristics and hormone profiles remains relatively unexplored in livestock species.

Spermatogenesis refers to the continual process of sperm production that takes place within the seminiferous tubules of the testes. Within this microenvironment, Sertoli cells are specialized cells that are responsible for the support, protection and development of sperm. The process of sperm development is under tight hormonal regulation, including

[1]Department of Animal Science, NDSU
[2]Hettinger Research Extension Center, NDSU

testosterone, insulin-like growth factor-1 (IGF-1) and thyroid hormones (Meroni et al., 2019). Additionally, Sertoli cells utilize nutrients such as glucose, lipids and amino acids to synthesize energy for their own metabolic needs as well as for the developing sperm (Alves et al., 2013). Thus, alterations in concentrations of hormones regulating sperm development or nutrient availability may impact the subsequent sperm development. Previous research has demonstrated that undernutrition in mature rams reduces the spermatic efficiency, including decreasing number of sperm per ejaculate and increasing DNA damage within the sperm (Guan et al., 2014). However, the exact consequences of alterations in the plane of nutrition on sperm characteristics remains to be determined. The objective of this study was to evaluate the impact of divergent plane of nutrition on circulating hormone and metabolite concentrations and semen characteristics in mature rams.

Procedures

All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Twenty-four mature Rambouillet rams (BW = 183.0 ± 6.4 lb) from the Hettinger Research Extension Center (HREC; Hettinger, North Dakota) were utilized for this study. Rams were transported to the Animal Nutrition and Physiology Center (ANPC) in Fargo, North Dakota, where they were individually housed and randomly assigned to one of three treatments; a positive (gain 12% of initial BW [POS]; n = 8), a maintenance (maintain initial BW [MAINT]; n = 8), or negative (lose 12% of initial BW [NEG]; n = 8) plane of nutrition. Rams were fed for 84 days, which is the length of two spermatogenic cycles, ensuring all sperm were exposed to the dietary treatments. Rams were fed a common diet (Table 1), weighed on a weekly basis, and individual feed intake was adjusted to achieve the targeted BW. On days 0, 28, 56 and 83, body condition score (BCS) and scrotal circumference (SC) were recorded. Further, blood was collected at the same timepoints via jugular venipuncture, which was then centrifuged at 1,500 x g for 20 minutes at 4 degrees Celsius. Serum was analyzed for triiodothyronine (T3), thyroxine (T4), insulin-like growth factor-1 (IGF-1), and testosterone (T), glucose and non-esterified fatty acids (NEFA). Lastly, semen was collected via electroejaculation on days 0, 28, 56 and 84. The ejaculate volume was recorded, and the semen was subjected to analysis via Computer Assisted Semen Analysis (CASA; IVOS II, Hamilton Thorne) to objectively evaluate the concentration of sperm per mL, total number of sperm in the ejaculate, and characterize sperm motility and kinematic properties.

Data were analyzed using the MIXED procedure of SAS 9.4 (SAS Inst., Cary, NC), with individual ram serving as the experimental unit. Repeated measures were used to evaluate body weight, BCS, SC, hormones (T3, T4, T and IGF-1), metabolites (glucose and NEFA), and semen characteristics (ejaculate volume, sperm concentration and sperm motility). Significance was determined at $P \leq 0.05$ and tendency at $0.05 < P \leq 0.10$.

Table 1. Ingredients and nutrient composition of the diet delivered to rams managed on divergent planes of nutrition

Item	%
Ingredients, % DM	
Corn silage	46
Hay	31
Whole corn	8
DDGS	15
Chemical composition, % DM	
Ash	8.5
Crude protein	12.0
ADF	30.1
NDF	52.2
Fat	2.8
Ca	0.7
P	0.4

Results and Discussion

By design, POS rams had greater average daily gain compared with MAINT rams (0.22 ± 0.02 vs. 0.02 ± 0.02 lb/d), which were greater than NEG rams (-0.26 ± 0.02 lb/d; $P < 0.001$). There was a significant treatment × day interaction for BW ($P < 0.001$), with divergence between treatments observed by day 14 (Figure 1A). On this day, POS rams had greater BW compared with NEG rams ($P = 0.05$), which was maintained for the remainder of the feeding period. Rams on the POS treatment had greater daily feed intake (3.8 ± 0.1 lb/d dry matter basis (DMB)), as compared with MAINT (2.6 ± 0.1 lb/d DMB), which was greater than NEG (1.8 ± 0.1 lb/d DMB; P < 0.001). Additionally, BCS and SC were influenced by a treatment × day interaction ($P < 0.001$). Initial BCS were similar among treatments, but by day 56, NEG had reduced BCS compared with POS and MAINT ($P = 0.03$; Figure 1B), which continued for the remainder of the evaluation period. Similarly, divergence was observed in SC by day 28, with NEG having decreased SC as compared with POS and MAINT through the end of the experiment ($P < 0.001$; Figure 1C).

Concentrations of T3 and IGF-1 were influenced by treatment × day interactions ($P = 0.02$; Table 2). Concentrations of T3 in NEG tended to be greater than POS at day 28 ($P = 0.10$; Table 2). Insulin-like growth factor-1 concentrations were similar at day 0 but increased in POS as compared with MAINT and NEG at day 28 and 56 ($P = 0.02$), and by day 83, NEG was greater than POS ($P = 0.05$; Table 2). Concentrations of T4 also tended to be influenced by a treatment × day interaction ($P = 0.09$); however, no difference between treatments was observed when LSMeans separation was evaluated ($P > 0.92$). Concentrations of testosterone were not affected by treatment ($P = 0.72$), day, ($P = 0.46$) or their interaction ($P = 0.76$; Table 2). Glucose was affected by day of experiment ($P < 0.001$), with concentrations of glucose the greatest at day 0 (76.8 ± 1.9 mg/dL), as compared with day 28 (64.9 ± 1.9) and day 56 (65.4 ± 1.9), and day 84 (68.7 ± 1.9; $P < 0.02$).Concentrations of NEFA were impacted by treatment ($P = 0.001$), with MAINT rams (535.8 ± 30.3 µmol/L) tending to be greater than NEG (442.4 ± 26.8) and POS rams (403.5 ± 27.2; $P < 0.08$).

Though ejaculate volume was not influenced by a treatment × day interaction ($P = 0.55$), a day effect was present ($P < 0.001$; Table 3), with the greatest volume occurring at day 84 (2.9 ± 0.2 mL). Similarly, concentration of sperm (per mL of ejaculate) was also influenced by day ($P = 0.01$), with the lowest concentration for all treatments being observed on day 84 (1,372.9 ± 233.6 sperm/mL; Table 3). Total number of sperm in the ejaculate was not impacted by treatment or day ($P > 0.10$; Table 3). These findings are contrary to those reported by Guan et al. (2014), who observed greater semen volume and total number of sperm, but not sperm concentration, in overfed rams than maintenance or underfed rams. The CASA system allows for in-depth evaluation of sperm characteristics, including the quantification of sperm motility, which are indicative of the sperm's ability to fertilize the female ova (Kathiravan et al., 2011). There were no differences among treatments in percentage of motile sperm (expressed as a percentage of the total number

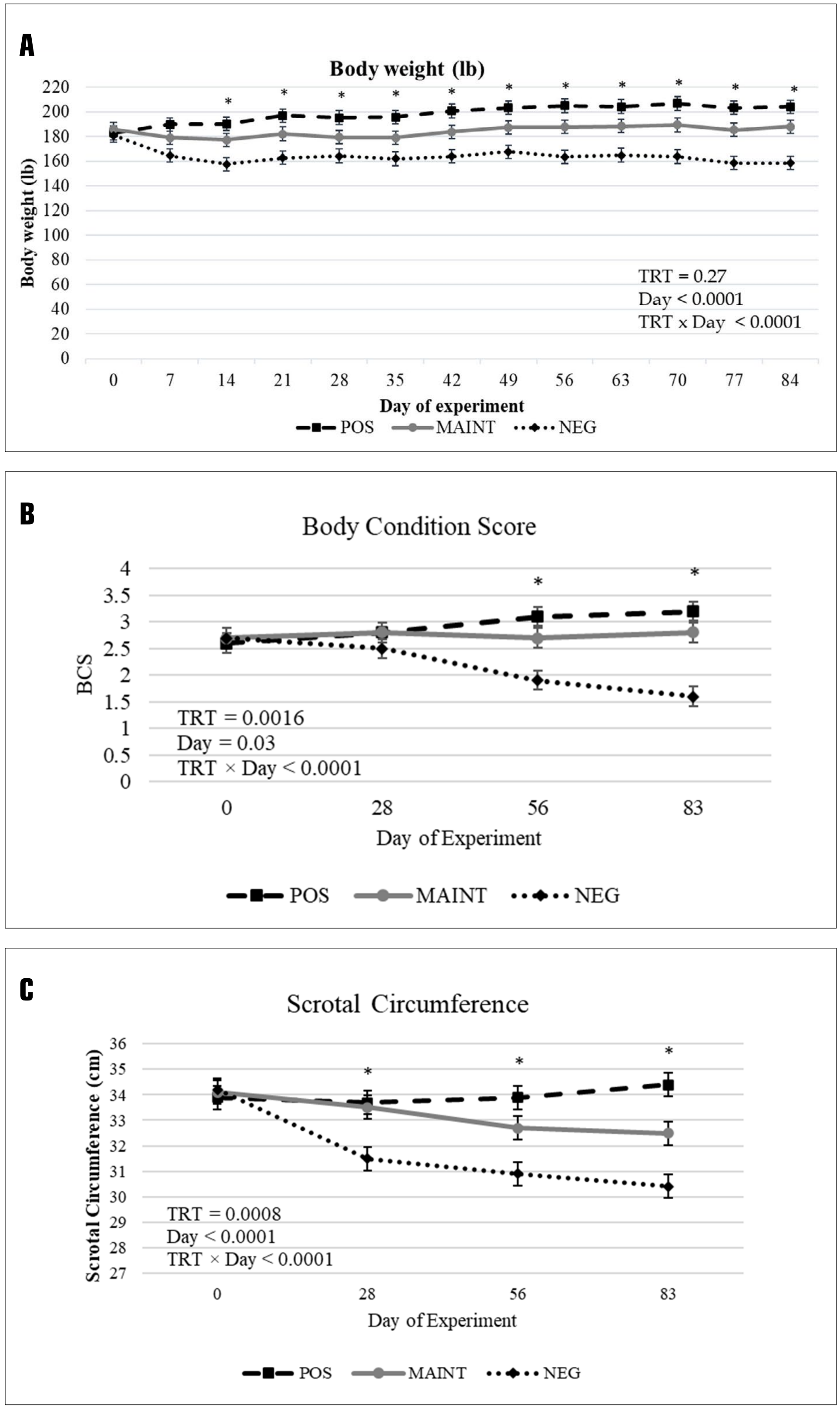

Figure 1. Body weight (A), body condition score (B) and scrotal circumference (C) for rams managed on divergent planes of nutrition. Rams were individually managed over an 84-day period to either gain (POS), maintain (MAINT), or lose (NEG) 12% of initial body weight.

of sperm; $P = 0.35$), progressively motility sperm (percentage of total sperm that are progressively moving forward; $P = 0.11$), or percentage of static sperm (limited sperm movement; P = 0.11; Table 3). Guan et al., (2014) did not observe any differences in sperm motility of over- and under-fed rams; but other characteristics not evaluated in the current study, such as sperm velocity and DNA integrity, were impaired in underfed rams.

While no differences were observed in sperm motility between treatments, prolonged exposure of the testicular microenvironment and developing sperm to various hormonal profiles and nutrient availability may be altering the genetic messages found within the sperm. Guan et al. (2017) describe alterations to the gene expression profile of the sperm in under-nutrition rams, including differences in messenger RNA and microRNA expression. There is potential for these changes in gene expression regulators within the sperm to be translated to the embryo following fertilization, and potentially contribute to altered embryo development and post-natal performance (Bakos et al., 2011). Future assessment of the long-term implications of paternal nutrition on offspring growth could provide valuable insight on improving sire management decisions.

Table 2. Effect of divergent planes of nutrition on circulating concentrations of hormones and metabolites in mature Rambouillet rams.

	Treatment[1]															
	POS				MAINT				NEG					P-values[2]		
Collection Day	0	28	56	84	0	28	56	84	0	28	56	84	SEM	TRT	Day	TRT × Day
T3, ng/dL	97.6^{b}	37.8^{a}	52.7^{a}	46.8^{a}	84.9^{a}	56.5^{a}	41.3^{a}	46.8^{a}	74.1^{a}	91.7^{b}	64.9^{a}	41.7^{a}	12.1	0.19	0.01	0.006
T4, ug/dL	9.9^{c}	7.3^{ab}	7.4^{ab}	6.9^{ab}	9.9^{c}	7.9^{b}	6.6^{ab}	6.0^{a}	9.0^{bc}	8.3^{bc}	7.3^{ab}	6.6^{ab}	0.4	0.80	< 0.001	0.09
Testosterone, ng/dL	286.6	322.4	543.4	563.9	704.0	289.7	509.1	556.4	368.4	360.4	523.9	776.7	198.9	0.72	0.46	0.79
IGF-1, ng/mL	406.8^{bc}	445.3^{c}	444.7^{c}	374.6^{b}	415.8^{bc}	335.2^{ab}	334.9^{ab}	328.5^{ab}	415.2^{bc}	338.5^{ab}	326.7^{ab}	278.0^{a}	20.2	0.001	0.001	<0.001
Glucose, mg/dL	75.3	66.0	67.3	74.6	79.4	64.5	65.5	68.3	75.7	64.4	63.3	63.3	3.4	0.40	< 0.001	0.45
NEFA, µmol/L	601.4	225.9	403.1	353.7	543.0	505.1	569.4	525.6	598.0	328.3	393.6	449.9	59.6	0.01	0.23	0.45

[1]Rams were managed to either gain 12% initial BW (POS), maintain BW (MAINT) or lose 12% initial BW (NEG) over 84 d; the hormones and metabolites evaluated included: triiodothyronine (T3), thyroxine (T4), testosterone (T), insulin-like growth factor-1 (IGF-1), glucose, and non-esterified fatty acids (NEFA).
[2]Significance was determined at $P < 0.05$ and included plane of nutrition (TRT), collection (Day) and their interaction (TRT × Day)
[abc]Means within rows lacking a common superscript differ ($P < 0.05$)

Table 3. Summary of semen characteristics of rams managed on divergent planes of nutrition over an 84-day period.

	Treatment				Collection Day					*P*-value		
Item	POS	MAINT	NEG	SEM	0	28	56	84	SEM	TRT	Day	TRT × Day
Ejaculate vol, mL	2.1	1.9	2.0	0.2	1.8^{a}	1.6^{ab}	2.4^{bc}	2.9^{c}	0.2	0.79	< 0.0001	0.55
Concentration, sperm/mL	1775.5	1825.8	1899.2	288.7	2288.5^{a}	1845.1^{ab}	1827.4^{ab}	1372.9^{b}	233.6	0.95	0.01	0.95
Total sperm	3389.6	3653.8	3361.5	624.6	2830.0	2955.7	4395.5	3691.9	559.4	0.94	0.11	0.91
Motile, %	63.7	59.2	65.7	4.4	64.1	57.7	67.5	52.3	3.5	0.57	0.11	0.78
Progressive Motile, %	47.4	50.2	41.8	5.6	48.9	42.4	48.8	45.9	4.1	0.56	0.35	0.48
Slow, %	4.9	4.7	3.1	0.8	2.9^{a}	5.1b	4.6^{ab}	4.8^{ab}	0.6	0.26	0.02	0.34
Static, %	36.3	40.8	34.3	4.4	35.9	42.3	32.5	37.7	3.5	0.57	0.11	0.78

[1]Rams were managed to either gain 12% initial BW (POS), maintain BW (MAINT) or lose 12% initial BW (NEG) over 84 d.
[2]Significance was determined at $P < 0.05$ and included plane of nutrition (TRT), collection (Day) and their interaction (TRT × Day)
[abc]Means within rows lacking a common superscript differ ($P < 0.05$)

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Effects of supplementing one-carbon metabolites to first time heifers receiving adequate or restricted feed intake during early gestation

Yssi L. Entzie[1], Layla E. King[1], Jessica G. Syring[1], Mara Hirchert[1], Joel S. Caton[1], Matthew S. Crouse[2], Carl R. Dahlen[1], Alison K. Ward[1]

Nutrition during pregnancy plays a key role in setting the developing calf up for success. Strategic nutrient supplementation may improve nutrient delivery to the fetal calf during periods of feed shortage.

Summary

Our objective was to evaluate the effect of plane of nutrition and supplementation of one-carbon metabolites (OCM) on maternal hematology, serum glucose, blood urea nitrogen (BUN), non-esterified fatty acids (NEFA), insulin-like growth factor (IGF) and insulin, as well as fetal fluid glucose concentration in cows receiving adequate or restricted feed intake during the first 63 days of gestation. Cross-bred Angus heifers were estrous synchronized using a 7-day CO-Synch + CIDR estrus synchronization protocol and artificially inseminated with female-sexed semen from a single sire. At breeding, heifers were assigned to one of four treatments in a 2 × 2 factorial arrangement, with n=8 heifers per treatment. The first factor was plane of nutrition with control (CON) feed intake adjusted to target 0.45 kg/day average daily gain, versus restricted (RES) with intake adjusted to target -0.23 kg/day gain. The second factor was OCM supplementation (+OCM; choline, methionine, folate, and vitamin B12) or no supplementation (-OCM). Blood samples were collected on day 0, 35 and 63 of gestation and fetal fluids were collected on day 63. Red blood cell count, packed cell volume and hematocrit were greater in RES than CON, indicating that red blood cell production was increased in response to feed restriction. There was no effect of treatment on serum insulin or IGF-1 concentrations. Serum glucose was greater in CON than RES (3.44 vs 3.21 ± 0.07 mM; *P* = 0.03). Additionally, serum NEFA concentrations increased and BUN concentrations decreased overtime in CON, but no change was observed in RES. This reflects the adequate versus inadequate energy and protein content of the diets. Amniotic fluid fructose concentration was greater in CON-OCM than CON+OCM and RES-OCM, with RES+OCM intermediate, and allantoic fluid glucose concentration tended to be greater for CON-OCM than CON+OCM. This suggests that OCM supplementation may increase fetal energy supply during nutrient restriction. In conclusion, supplementation with OCM could improve fetal nutrient supply during times of maternal feed restriction which is likely not a result of increased maternal hematopoiesis.

[1]Department of Animal Sciences, NDSU
[2]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE

Introduction

During gestation maternal blood volume increases to meet the needs of the growing fetus. Folate and vitamin B_{12} are hematopoietic vitamins required for DNA synthesis in developing red blood cells. We sought to determine if the effects of nutrient restriction early in pregnancy affected the components in blood and if strategic supplementation with one carbon metabolites (methionine, choline, folate and vitamin B_{12}) mitigates any detrimental effects.

Previous research has shown that maternal nutrient restriction during pregnancy alters offspring post-natal growth and body composition (Ford, 2007). We hypothesize that epigenetic modification is a mechanism driving this developmental programming. Vitamin B_{12} and folic acid play a crucial role in protein and energy metabolism, as well as regeneration of homocysteine (Hcy) to methionine (Met). Methionine transfers its methyl group in S-adenosylmethionine (SAM) which is a methyl donor that acts upon a wide range of acceptors (Finkelstein, 1990). SAM is required for DNA methylation, which is an epigenetic mechanism regulating gene expression. Methionine, choline, vitamin B_{12} and folate are all nutrients that drive the one-carbon metabolism cycle.

We hypothesize that feed restriction will reduce maternal energy supplies, as evidenced by increased serum non-esterified fatty acid (NEFA) and decreased glucose concentrations. Furthermore, we hypothesize that strategic supplementation with nutrients that drive the one-carbon metabolism cycle (and therefore provide methyl donors) will mitigate the effects of reduced nutrient availability to the fetus via epigenetic modification, resulting in higher fetal organ weights and less oxidative stress.

The long-term goal of our research is to develop nutritional strategies through targeted supplementation to mitigate the detrimental effects of developmental programming on the fetal calf during times of poor forage availability. The first step towards this goal is to determine the effects of these supplementation strategies on maternal energy homeostasis, including glucose, BUN, and NEFA, and adaptation to different planes of nutrition during pregnancy.

Experimental Procedures

All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Cross-bred Angus heifers were blocked by body weight into one of six breeding groups. They were then estrous synchronized with the 7-day CO-Synch + CIDR estrus synchronization protocol and artificially inseminated with female-sexed semen from a single sire. At breeding (day 0), heifers were assigned to one of four treatments (n = 8) in a randomized complete block and 2 × 2 factorial design. The first factor was plane of nutrition with control (CON) feed intake adjusted to target 0.60 kg/day average daily gain, versus restricted (RES) with intake adjusted to target -0.23 kg/day gain. The second factor was OCM supplementation (+OCM; rumen protected choline [0.60 g/day] and methionine [10 g/day] in a fine ground corn carrier and weekly intramuscular injections of 320 mg folate and 10 mg vitamin B12) or no supplementation (-OCM; corn carrier and saline injections).

Heifers were housed with six heifers per pen and individually fed using Calan Broadbent electronic head gates (American Calan, Northwood, NH) and allowed to acclimate for two weeks before beginning of the trial. The basal diet was composed of 45% alfalfa grass/hay mix, 31% ground corn, 15% alfalfa hay and 9% corn silage, and had 11.4% crude protein, 7.95% ADF and 31.9% NDF (all on a dry-matter basis).

Blood samples were collected on day 0, day 35 and day 63 relative to breeding. Ultrasonography was used to determine gestation status on day 35 of gestation, and sex of the fetus was evaluated on day 55 of gestation or later via visualization of the genital tubercle.

Blood samples were collected prior to feeding on days 0, 35 and 63 via jugular venipuncture using 10-mL serum monoject corvac blood collection tubes (Cardinal Health, Dublin, OH). Samples were allowed to clot for 20 minutes at room temperature, then centrifuged at 2,000 × *g* for 10 min. Serum was separated from blood constituents and stored at -112 degrees Fahrenheit. Complete blood count analysis was performed by the North Dakota State University Veterinary Diagnostics Laboratory. Serum glucose analysis was performed using the Infinity glucose hexokinase liquid stable reagent (Fisher Diagnostics, Middletown, VA). Serum urea-N was determined using the QuantiChrome urea assay kit (BioAssay Systems, Hayward, CA). Non-esterified fatty acid (NEFA) concentration in serum samples was measured using the NEFA-HR (2) colorimetric assay (FUJIFILM Medical Systems USA Inc., Lexington, MA). All kits were analyzed using a Synergy H1 Microplate Reader (BioTek, Winooski, VT). Blood serum IGF-I concentrations were determined by radioimmunoassay. Plasma insulin concentrations were determined using the Porcine Insulin RIA kit (EMD Millpore, St. Louis, MO)

On day 63, animals were harvested at the North Dakota State University Meat Lab. After animals had been euthanized and the skin removed, the reproductive tract was removed. Allantoic and amniotic fluid samples were collected using a sterile hypodermic needle and syringe. Glucose concentrations were analyzed using the Infinity Glucose Hexokinase Liquid Stable Reagent while fructose concentrations were analyzed using the EnzyChrom fructose assay kit (BioAssay Systems, Hayward, CA).

Data was analyzed using the PROC MIXED procedure and repeated measures with SAS 9.4 (SAS Inst. Inc). Least square means were generated and corrected with Tukey's procedure. A P-value ≤ 0.05 was considered significant.

Results and Discussion

Red blood cell count was greater ($P = 0.002$) in RES than CON (Table 1). Additionally, hematocrit ($P = 0.08$) and packed cell volume tended ($P = 0.09$) to be greater in RES than CON. This suggests increased hematopoiesis as a potential compensatory mechanism in response to restricted nutrition. The percentage of monocytes was lower ($P = 0.04$) in +OCM than -OCM (1.5 vs 3.0 ± 0.50%). The percentage of segmented neutrophils was greater ($P = 0.01$) in CON than RES (24.6 vs 16.8 ± 1.93%). However, monocytes and segmented neutrophils remained within the normal range for cattle (Hematology, 2021). These results indicate that supplementation with OCM did not increase hematopoiesis in early gestion in heifers receiving an adequate or restricted plane of nutrition.

Table 1. The effect of plane of nutrition (intake) and one-carbon metabolite supplementation on maternal serum glucose, blood urea nitrogen, non-esterified fatty acid insulin-like growth factor 1 (IGF-1), and insulin concentrations in pregnant heifers

	Means[2]								*P*-values			
Analyte[1]	**CON**	**RES**	**-OCM**	**+OCM**	**d0**	**d35**	**d63**	**SEM[3]**	**Intake**	**OCM**	**Day**	**Intake × day**
Glucose (mM)	3.44	3.21	3.27	3.39	3.47	3.16	3.35	0.07	0.0253	0.23	0.004	0.91
BUN (mM)	4.73	4.14	4.31	4.55	4.30	4.49	4.50	0.12	0.001	0.15	0.56	0.02
NEFA (mM/L)	476.38	501.90	516.97	461	561.98	510.78	394.66	28.87	0.4942	0.13	0.002	0.04
IGF-1 (ng/mL)	167.1	157.6	166.7	158.0	177.8	153.6	178.6	6.69	0.3085	0.36	<0.001	0.59
Insulin (µU/mL)	13.31	11.29	12.28	12.30	13.89	11.073	11.94	1.45	0.3786	0.99	0.27	0.78

[1]Blood urea nitrogen (BUN), non-esterified fatty acid (NEFA), insulin-like growth factor 1 (IGF-1).
[2]Plane of nutrition: control (CON) restricted (RES), treatment: one-carbon metabolite supplemented (+OCM), one-carbon metabolite not supplemented (-OCM), days 0, 35, and 63 of gestation.
[3]Standard error of the mean.

Table 2. The effect of plane of nutrition (intake) and one-carbon metabolite supplementation on amniotic and allantoic glucose and fructose concentrations

	Means[2]					*P*-values		
Analyte[1]	**CON**	**RES**	**-OCM**	**+OCM**	**SEM[3]**	**Intake**	**OCM**	**Intake × OCM**
Amn Glu (mM)	2.20	1.59	1.87	1.92	0.17	0.01	0.81	0.20
Ala Glu (mM)	2.09	2.02	2.17	1.94	0.24	0.85	0.49	0.09
Amn Fru (mM)	6.90	5.00	6.20	5.70	6.84	0.05	0.60	0.005
Ala Fru (mM)	8.90	8.10	9.80	7.30	9.68	0.56	0.09	0.30

[1]Amniotic glucose (Amn Glu), alantoic glucose (Ala Glu), amniotic fructose (Amn Fru), alantoic fructose (Ala Fru)
[2]Plane of nutrition: control (CON) restricted (RES), treatment: one-carbon metabolite supplemented (+OCM), one-carbon metabolite not supplemented (-OCM), days 0, 35, and 63 of gestation.
[3]Standard error of the mean.

There was no effect of treatment on serum insulin or IGF-1 concentrations. Serum glucose concentration was greater in CON than RES (3.44 vs 3.21 ± 0.07 mM; $P = 0.03$). The lower glucose concentrations observed in RES is likely due to inadequate energy intake. There was an intake × day interaction observed for serum BUN concentration (Figure 1). The BUN increased over time for CON but for RES there was no difference between day 0 and day 35 or 63. This is likely because RES heifers were on a lower plane of nutrition and consuming less total protein, resulting in less dietary amino acid deamination (in the rumen or liver). The BUN increasing over time in CON heifers may indicate an excessive level of protein in the diet. Circulating NEFA can be an indicator of mobilization of body fat reserves. The NEFA concentrations for the RES group did not change while the CON group decreased over time, indicating the CON group was not mobilizing body fat and in a positive energy balance. The difference in serum BUN, and NEFA concentrations between CON and RES demonstrates the intake treatments successfully resulted in cows being at different plains of nutrition. This data served as important validation for other phenotypical data such as fetal fluids and weights.

Amniotic fructose concentration was greater in CON-OCM than CON+OCM and RES-OCM, with RES+OCM intermediate ($P = 0.005$). This may indicate supplementing OCM to cattle experiencing a restricted plane of nutrition is beneficial by increasing fructose availability. Allantoic glucose concentration tended to be greater ($P = 0.09$) for CON-OCM than CON+OCM. This likely indicates that more glucose is being used by the fetus being supplemented, as it is not being excreted into the allantoic fluid.

This study was a crucial step to verify we have successfully established two planes of nutrition, and that fetal fluids are impacted by plane of nutrition in addition to supplementation. Therefore, we can move forward with our long-term goals of improving offspring performance through the use of strategic supplementation.

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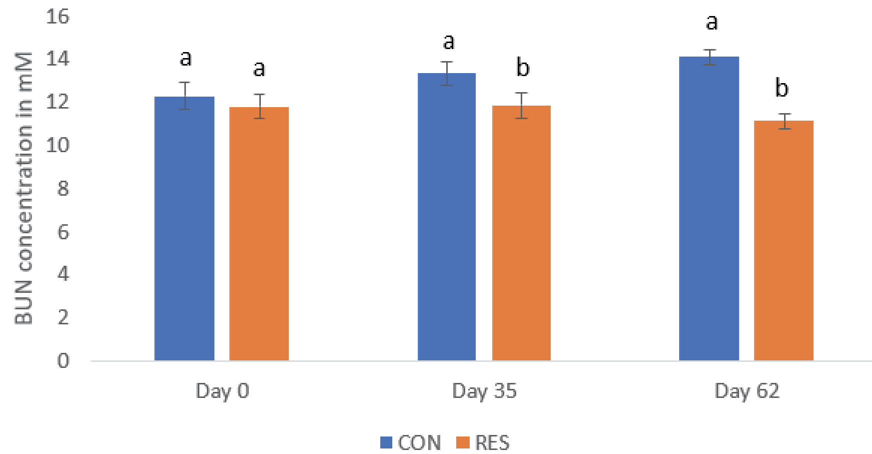

Figure 1. Histogram of the interaction between feed intake and day of gestation on blood urea nitrogen concentration in beef heifers. Day 0 is day of breeding. CON = intake to achieve 0.06 kg/d average daily gain; RES = intake to achieve -0.23 kg/d average daily gain. Error bars depict the standard error of the mean. Bars not sharing a common superscript are significantly different ($P < 0.05$). Within a day, letters indicate differences, but those letters do not represent values across days.

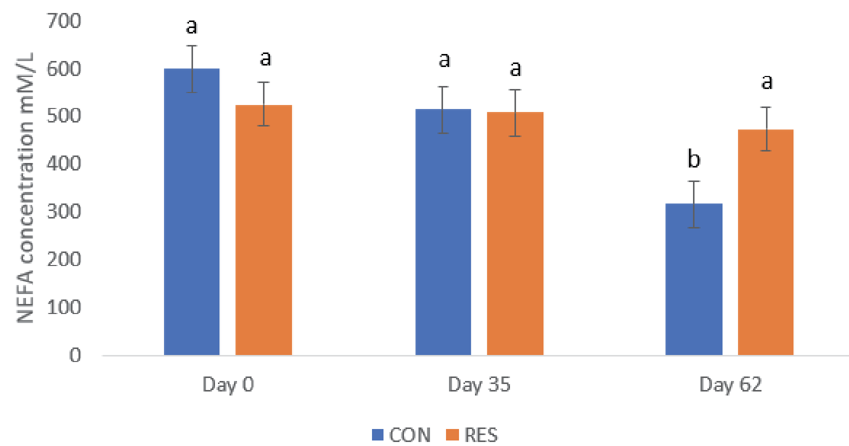

Figure 2. Histogram of the interaction between feed intake and day of gestation on non-estrified fatty acid concentration in beef heifers. Day 0 is day of breeding. CON = intake to achieve 0.06 kg/d average daily gain; RES = intake to achieve -0.23 kg/d average daily gain. Error bars depict the standard error of the mean. Bars not sharing a common superscript are significantly different ($P < 0.05$). Within a day, letters indicate differences, but those letters do not represent values across days.

Impacts of vitamin and mineral supplementation to beef heifers during gestation on performance measures of the neonatal calf, trace mineral status, and organ weights at 30 hours after birth

Jennifer L. Hurlbert[1], Friederike Baumgaertner[1], Ana Clara B. Menezes[1], Kerri A. Bochantin[1], James D. Kirsch[1], Sheri Dorsam[1], Kevin K. Sedivec[2], Samat Amat[3], Kendall C. Swanson[1], Carl R. Dahlen[1]

The objectives were to evaluate the impacts of vitamin and mineral supplementation in beef heifers throughout gestation on calf weight at birth and mineral status and organ weights of the calf at 30 hours of age. Calf body measurements, body weight and organ weights were not affected by treatment. However, concentrations of cobalt in dam serum, selenium and cobalt in calf serum, and calf liver mineral status were enhanced in cattle receiving trace mineral supplementation.

Summary

Our objectives were to evaluate the effects of feeding a vitamin and mineral (VTM) supplement to beef heifers during gestation on calf weight, body measurements, trace mineral status, and organ weight at 30 hours (h) after birth. We hypothesized that VTM supplementation during gestation improves mineral status in the neonatal calf but does not impact calf weight, body measurements, and organ weight at 30 h after birth. Fourteen Angus-based heifers (initial body weight [BW] = 603.4 ± 2.42 pounds [lbs]) were individually fed and randomly assigned to receive either a basal diet (CON; n = 7) or a basal diet plus a VTM supplement (VTM; n = 7; 4 oz•heifer^{-1}•d^{-1}, targeting gain of 1 pound/day [lb/day]) from 60 days pre-breeding through gestation.

Immediately after parturition, blood samples were collected from dams and calves, and calves were separated from their dams. Calves were fed one feeding of colostrum replacer, followed by milk replacer every 12 h and euthanized at 30 h. Body weight and measurements were recorded and organs and viscera were removed, weighed and sampled. Dam serum and neonatal serum, liver and blood were analyzed for concentrations of minerals. Data were analyzed using the GLM Procedure of SAS with individual animal as the experimental unit. Dietary treatments did not impact calf weight (0 h or 30 h), calf body measurements, or body weight of the dam at calving ($P \geq 0.32$). Further, neonatal organ weights were not influenced ($P \geq 0.21$) by maternal VTM treatment. Concentrations of selenium and cobalt in calf serum and selenium in calf liver were increased ($P \leq 0.02$) by VTM treatment; however, concentrations of copper, manganese, molybdenum and zinc in calf muscle, liver and serum were not impacted ($P \geq 0.07$) by VTM treatment. Concentrations of cobalt in serum of the dam were greater ($P = 0.001$) in VTM than CON heifers, but other minerals evaluated were unaffected ($P \geq 0.32$). In the current experiment, providing trace mineral supplementation throughout gestation did not impact calf weight at birth and calf weight and body measurements at 30 h of age. However, the implications of altered mineral status of the neonatal calves at birth, and presumably throughout their development in utero, may have additional postnatal effects on performance, health or reproduction that warrant further investigation.

[1]Center for Nutrition and Pregnancy Department of Animal Sciences, NDSU
[2]Central Grasslands Research Extension Center, NDSU
[3]Department of Microbiological Sciences, NDSU

Introduction

Trace minerals serve essential roles in cow-calf production with specific implications on reproduction, immune function and skeletal development (Davy et al., 2019; Hansen et al., 2006; Kegley et al., 2016). Trace mineral nutrition is an integral component of fetal growth and development, as the fetus relies on maternal transfer of trace elements across the placenta for development and the establishment of a postnatal mineral reserve (Hostetler et al., 2003). However, management decisions to provide beef cattle with trace minerals vary widely (Davy et al., 2019) and little is known regarding the impacts of providing a trace mineral supplement to heifers throughout gestation on the neonatal calf. Therefore, the primary goal of this study was to evaluate the hypothesis that vitamin and trace mineral (VTM) supplementation to beef heifers during gestation would improve mineral status of the neonatal calf but not influence calf birth weight, body measurements, body weight and organ weight at 30 hours (h) after birth.

Materials and Methods

All animal procedures were approved by the North Dakota State University (Fargo, ND) Institutional Animal Care and Use Committee (#A21047).

Animals, Housing, and Diet

Crossbred Angus-based heifers (n = 14; initial BW = 603.4 ± 2.42 lbs) were group-housed and individually fed via an electronic head-gate facility at the NDSU Animal Nutrition and Physiology Center (ANPC; Fargo, ND). Heifers were randomly assigned to receive either a basal diet (CON; n = 7) or the basal diet plus a vitamin and mineral supplement (VTM; n = 7). The VTM supplement was a loose product (4 ounces [oz] of Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes, Inc., Arden Hills, MN) top dressed over the basal diet (Table 1). The basal diet at ANPC included 53% grass hay, 37% corn silage, and 10% modified corn distillers grains plus solubles containing 10.63% crude protein. The diet was formulated targeting gains of 1 pound/heifer/day.

Table 1. Composition of VTM supplement1 provided to beef heifers 60 days pre-breeding until calving2; company guaranteed analysis

Item	Assurance levels	
Minerals[1]	Min	Max
Calcium, g/kg of DM	135.0	162.0
Phosphorus, g/kg of DM	75.0	-
Sodium chloride, g/kg of DM	180.0	216.0
Magnesium, g/kg of DM	10.0	-
Potassium, g/kg of DM	10.0	-
Manganese, mg/kg of DM	3,600.0	-
Cobalt, mg/kg of DM	12.0	-
Copper, mg/kg of DM	1200.0	-
Iodine, mg/kg of DM	60.0	-
Selenium, mg/kg of DM	27.0	-
Zinc, mg/kg of DM	3,600.0	-
Vitamins, IU/kg of DM		
A	661,500.0	
D	66,150.0	
E	661.5	

[1]Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN); ingredients: dicalcium phosphate, monocalcium phosphate, processed grain by-products, plant protein products, calcium carbonate, molasses products, salt, mineral oil, potassium chloride, magnesium oxide, ferric oxide, vitamin E supplement, vitamin A supplement, lignin sulfonate, cobalt carbonate, manganese sulfate, ethylenediamine dihydroiodide, zinc sulfate, copper chloride, vitamin D3 supplement, natural and artificial flavors, and sodium selenite.

[2]VTM supplement provided at a rate of 4 oz•heifer^{-1}•day^{-1}.

All heifers were subjected to a 7-day Co-Synch + CIDR estrus synchronization protocol and AI bred to female sexed semen from a single sire on d 60 of dietary treatment. Transrectal ultrasonography was used for pregnancy diagnosis at d 35 following AI, and fetal sex was determined at day 65 after AI to confirm pregnancies with female fetuses. During late-gestation, heifers were transferred to the NDSU Beef Cattle Research Complex (BCRC; Fargo, ND) where they were group-housed, individually fed via the Insentec feeding system, and continued to receive their respective dietary treatments. The basal diet at BCRC was fed for ad libitum intake with 25% corn silage, 66% alfalfa hay, 4% modified corn distillers grains plus solubles, 5% corn-based premix, and contained 17.5% crude protein. Throughout the study, heifers were weighed biweekly in the morning before feeding and individual feed deliveries were adjusted to achieve targeted BW gains.

Maternal and Neonatal Sample Collection

Heifers were allowed to calve in group pens and calves were separated from dams immediately after birth; thus, not being allowed to suckle. Within 2 h after birth, body weight was recorded and blood samples were collected via jugular venipuncture from dams and calves.

Following separation from dams, calves were fed 0.4 gallons of a commercial colostrum replacer containing a total of 150 g IgG (LifeLine Rescue High Level Colostrum Replacer, APC, Ankeny, IA) via esophageal feeder within 2 h of birth, then housed in individual pens. At 12 h and 24 h after colostrum feeding, calves were fed 0.5 gallons of a common source milk replacer (Duralife 20/20 Optimal Non-Medicated Milk Replacer, Forth Worth, TX) via esophageal feeder.

At 30 h of age, BW and body measurements including crown-rump length, shoulder-hip length, chest circumference, abdominal circumference, hip width and hip height were recorded, followed by euthanasia. At tissue collection the following organs and viscera were removed, weighed and sampled: liver (gallbladder removed), small intestine, large intestine, stomach complex, kidneys (both), spleen, heart, lungs, reproductive tract (uterus, ovaries, cervix, and vagina) and the right femur.

Sample Processing and Laboratory Analysis

Blood samples were collected using 6-mL serum vacutainer tubes (Becton Dickinson HealthCare, Franklin Lakes, NJ). Samples from the left longissimus dorsi muscle and liver were collected and placed in 6-mL tubes (Becton Dickinson HealthCare, Franklin Lakes, NJ). Serum, liver, and muscle samples were analyzed for concentrations of cobalt, copper, manganese, molybdenum, zinc and selenium via inductively coupled plasma mass spectrometry by the Veterinary Diagnostic Laboratory at Michigan State University.

Statistical Analysis

All data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with treatment as the fixed effect. Data were considered significant at $P \leq 0.05$.

Results and Discussion

Body Weights, Morphometric Characteristics, and Neonatal Tissue Weights

Dietary treatment did not impact dam body weight (CON = 1229.3 ± 35.4 lbs; VTM =1177.9 ± 35.4 lbs; $P = 0.32$) calf birth weight (CON = 72.7 ± 7.12 lbs; VTM = 75.2 ± 7.12 kg; $P \geq 0.60$), or calf BW at harvest (CON = 78.2 ± 3.75 lbs; VTM = 82.10 ± 3.48 lbs; $P = 0.47$). Similarly, calf crown-rump length, shoulder-hip length, chest circumference, abdominal circumference, hip width and hip height were not impacted ($P \geq 0.47$) by treatment. Other work by Sprinkle et al. (2006) corroborated the findings of the current study reporting no differences in calf BW at birth or cow BW after calving as a result of trace mineral supplementation.

Previous research from our group (Menezes et al., 2022) has demonstrated that maternal VTM supplementation during the first trimester of gestation resulted in greater fetal liver mass at day 83 of gestation. Thus, we were anticipating altered organ mass of neonatal calves. However, weights of organs and viscera (absolute weight and as a percentage of body weight) were not impacted ($P \geq 0.21$) by maternal dietary treatment. These findings indicate that fetal growth was likely not impacted by gestational VTM supplementation.

Mineral Concentrations in Serum, Liver, and Muscle

In the dam, concentrations of cobalt in serum were greater ($P = 0.001$) for VTM heifers compared to CON heifers (Table 2), but no

Table 2. Serum, liver, and muscle mineral concentrations of neonatal calves at harvest born to dams that were either provided with the basal diet (CON) or the basal diet plus the addition of a vitamin and trace mineral supplement (VTM) throughout gestation

Mineral concentration	Treatment		SEM	*P*-value[3]
	CON[1]	VTM[2]		
Dam serum, ng/ml				
Cobalt	0.15	0.24	0.013	0.001
Copper	1.04	1.11	0.068	0.49
Manganese	1.09	1.03	0.064	0.54
Molybdenum	20.59	19.69	1.479	0.67
Zinc	1.22	1.34	0.084	0.32
Selenium	123.14	129.71	5.647	0.43
Calf serum, ng/ml				
Cobalt	0.12	0.19	0.018	0.02
Copper	0.21	0.24	0.022	0.36
Manganese	1.00	1.02	0.020	0.34
Molybdenum	14.70	15.94	1.675	0.61
Zinc	1.92	1.47	0.174	0.09
Selenium	62.57	77.57	3.305	0.01
Calf liver, µg/g dry				
Cobalt	0.22	0.23	0.023	0.73
Copper	262.10	270.44	12.411	0.64
Manganese	10.53	10.85	0.950	0.82
Molybdenum	0.73	0.87	0.050	0.07
Zinc	343.55	244.03	58.821	0.25
Selenium	2.20	2.86	0.101	0.001
Calf muscle, µg/g dry				
Cobalt	0.07	0.06	0.004	0.15
Copper	3.92	3.48	0.186	0.12
Manganese	1.40	1.40	0.113	0.98
Molybdenum	0.07	0.06	0.005	0.21
Zinc	119.54	107.62	7.937	0.31
Selenium	0.87	0.93	0.050	0.42

[1]CON: No vitamin and mineral supplement included with the basal diet throughout gestation.
[2]VTM: Basal diet plus the addition of a vitamin mineral supplement fed at a rate of 4 oz•heifer^{-1}•day^{-1}.
[3]Significance considered at $P \leq 0.05$.

other minerals were influenced ($P \geq 0.32$) by treatment. Maternal VTM treatment contributed to greater ($P \leq 0.02$) concentrations of cobalt and selenium in serum, and greater ($P = 0.001$) concentrations of selenium in the liver of calves born to VTM dams (Table 2). However, concentrations of copper, manganese, molybdenum and zinc were not impacted ($P \geq 0.07$) in calf serum, liver or muscle. Further, concentrations of cobalt in calf liver and muscle were not influenced ($P \geq 0.15$) by treatment. The increase in calf liver selenium status could influence postnatal calf health and performance.

Implications

These results indicate that gestational vitamin and trace mineral supplementation did not impact calf size at birth. However, the implications of altered mineral status of the neonatal calves at birth, and presumably throughout gestation, may have additional postnatal effects that warrant further investigation.

Acknowledgements

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Supplementing trace minerals to beef heifers during gestation: impacts on mineral status of the dam and neonate, postnatal performance and colostrum characteristics

Jennifer L. Hurlbert[1], Friederike Baumgaertner[1], Ana Clara B. Menezes[1], Kerri A. Bochantin[1], Wellison J.S. Diniz[2], Sara R. Underdahl[1], Sheri T. Dorsam[1], James D. Kirsch[1], Kevin K. Sedivec[3], Carl R. Dahlen[1]

The objectives were to evaluate the impacts of vitamin and mineral supplementation to beef heifers during gestation on calf weight and size at birth, mineral status of the dam and calf, colostrum production, and calf performance through weaning. Though mineral status of the dam and calf and colostrum production were influenced by maternal dietary treatment during gestation, calf weight and body measurements at calving were not impacted by mineral supplementation through gestation. At pasture turnout and weaning, however, calves born to dams consuming a mineral supplement though gestation were heavier compared to their non-supplemented cohorts.

Summary

Thirty-one Angus-based heifers (body weight [BW] = 603 ± 2.4 pounds [lbs]) were estrus synchronized, bred with female-sexed semen, then were randomly assigned to either a basal diet targeting gain of 1 pound/heifer/day (CON; n = 14) or the basal diet plus a vitamin and mineral supplement (VTM; n = 17; 4 ounces [oz] per heifer/day of Purina Wind & Rain Storm All-Season 7.5 Complete, Land O' Lakes, Inc., Arden Hills, MN). Liver biopsies were obtained from dams at breeding, days 84 and 180 of gestation. At calving, liver biopsies were taken from dams and calves. Additionally, calf BW was recorded at birth, and body measurements were recorded at 24 hours after birth measurements. Colostrum samples were collected within 2 hours post-calving. In maternal liver, concentrations of selenium and copper were affected by a treatment × day interaction ($P < 0.001$), being greater ($P < 0.001$) for VTM than CON at all post-breeding timepoints and decreasing ($P \leq 0.05$) from day 84 to calving; while zinc, molybdenum, manganese, and cobalt were not ($P \geq 0.20$) affected by treatment. In calves, concentrations of liver selenium, copper, zinc, and cobalt were greater for VTM than CON ($P \leq 0.05$). Calf BW at birth and 24 hours of age and body measurements at 24 hours of age were not affected by treatment ($P = 0.45$). Furthermore, colostrum quantity and total mineral concentrations of selenium, copper, zinc, and manganese in collected colostrum were greater ($P \leq 0.04$) in VTM heifers compared with CON heifers. Additionally, calves born to VTM dams tended to be 15.4 lbs heavier ($P = 0.05$) at pasture turnout and 36.3 lbs heavier ($P = 0.07$) than their CON cohorts at weaning. These results suggest that as gestation progresses, maternal liver stores decrease to provide for the gestating calf, but calf BW and body measurements are unaffected by maternal mineral supplementation. However, performance differences at pasture turnout and weaning indicate a response to *in utero* vitamin and mineral supplementation via fetal programming during gestation.

Introduction

During gestation, the fetus relies heavily on the dam for transfer of nutrients across the placenta. Vitamins and minerals especially contribute to processes related to fetal growth and development, protein synthesis, structural integrity, lipid metabolism, and immune function and health (Harvey et al., 2021; Hidiroglou and Knipfel, 1981; Hostetler et al., 2003). Thus, maternal nutritional status during pregnancy has the potential to impact the development and health of the offspring pre- and postnatally. However, the effects of vitamin and mineral supplementation (VTM) during gestation and the long-term postnatal impacts on the offspring has not been fully elucidated. Furthermore, variation in management decisions to offer a VTM supplement to cow-calf herds is substantial. The primary goal of the current study is to evaluate the impacts of providing or not providing a VTM supplement during the entire gestation on the dam and her offspring.

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]Department of Animal Sciences, Auburn University, Auburn, AL
[3]Central Grasslands Research Extension Center, NDSU

Thus, objectives were to evaluate the effects of feeding a vitamin and mineral supplement (VTM) to heifers throughout gestation on trace mineral status of the dam and calf, calving parameters, calf morphometric characteristics and performance, and colostrum production. We hypothesized that VTM throughout gestation would enhance mineral status in the dam and offspring at birth and positively impact calf morphometric characteristics, performance, and colostrum production.

Materials and Methods

Crossbred Angus-based heifers (n = 31; initial body weight [BW] 603 ± 2.4 pounds [lbs]) were group-housed and individually fed at the NDSU Animal Nutrition and Physiology Center (Fargo, ND) via an electronic head-gate facility (American Calan; Northwood, NH). Heifers were subjected to a 7-day Co-Synch + CIDR estrus synchronization protocol and bred via artificial insemination (AI) using female-sexed semen from a single sire and were randomly assigned to either receive a basal diet (n = 14; CON) or a basal diet plus the addition of a vitamin and trace mineral supplement (n = 17; VTM). The VTM supplement used was a loose product (4 ounces [oz] of Purina Wind & Rain Storm All-Season 7.5 Complete, Land O' Lakes, Inc., Arden Hills, MN; Table 1) and was top dressed over the basal diet. The basal diet consisted of 53% grass hay, 37% corn silage, and 10% modified corn distillers grains plus solubles with a crude protein concentration of 10.6%. Feed deliveries were adjusted as needed to target gains of 1 pound/heifer/day.

Pregnancy diagnosis was conducted via transrectal ultrasonography on day 35 following AI with fetal sex determined at day 65 following AI. Heifers were confirmed pregnant with female fetuses and transported to the NDSU Beef Cattle Research Complex (Fargo, ND) where they were group-housed, individually fed (Insentec Feeding System; Hokofarm B.V., Marknesse, The Netherlands), and remained on their respective dietary treatments. Diets consisted of 59% grass hay, 30% corn silage, 6% modified corn distillers grains with solubles, and 5% ground corn premix with a crude protein concentration of 11.7%. Heifers in the VTM treatment received the loose VTM supplement incorporated into the total mixed ration. Feed deliveries were adjusted as needed to target 1 pound/heifer/day gain throughout gestation.

Liver biopsies were collected at breeding, days 84 and 180 of pregnancy, and at calving using the biopsy procedure outlined by McCarthy et al. (2019). Briefly, heifers were restrained in a squeeze chute, the biopsy site - between the 10th and 11th ribs - was clipped, followed by a 3-ml subcutaneous lidocaine injection and scrubbed with betadine and 70% ethanol. A stab incision was made at the targeted site, liver samples were collected via a Tru-Cut biopsy trochar (14 ga, Merit Medical, South Jordan, UT, USA), placed in tubes designed for trace mineral analysis (potassium ethylenediaminetetraace-tate; Becton Dickinson Co., Franklin Lakes, NJ, USA) and stored at –20 degrees Celsius until further analysis.Heifers were allowed to calve in group pens and cow-calf pairs were moved inside the calving barn for sample collections immediately after calving.

Table 1. Composition of VTM supplement[1] provided to beef heifers at breeding until calving[2]; company guaranteed analysis

Item	Assurance levels	
Minerals[1]	**Min**	**Max**
Calcium, g/kg of DM	135.0	162.0
Phosphorus, g/kg of DM	75.0	-
Sodium Chloride, g/kg of DM	180.0	216.0
Magnesium, g/kg of DM	10.0	-
Potassium, g/kg of DM	10.0	-
Manganese, mg/kg of DM	3,600.0	-
Cobalt, mg/kg of DM	12.0	-
Copper, mg/kg of DM	1200.0	-
Iodine, mg/kg of DM	60.0	-
Selenium, mg/kg of DM	27.0	-
Zinc, mg/kg of DM	3,600.0	-
Vitamins, IU/kg of DM		
A		661,500.0
D		66,150.0
E		661.5

[1]Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN); ingredients: dicalcium phosphate, monocalcium phosphate, processed grain by-products, plant protein products, calcium carbonate, molasses products, salt, mineral oil, potassium chloride, magnesium oxide, ferric oxide, vitamin E supplement, vitamin A supplement, lignin sulfonate, cobalt carbonate, manganese sulfate, ethylenediamine dihydroiodide, zinc sulfate, copper chloride, vitamin D3 supplement, natural and artificial flavors, and sodium selenite.
[2]VTM supplement provided at a rate of 4 oz•heifer^{-1}•day^{-1}.

An important aspect of the current study was to collect pre-suckling samples and measurements from the dam and neonatal calf to evaluate the influence of gestational VTM supplementation on calf size, mineral status, and colostrum characteristics. Thus, a post-calving weight was recorded for the dam and birth weight recorded for the calf within 2 hours of birth. A pre-suckling liver biopsy was also collected from the calf (McCarthy et al., 2019, adapted) and samples stored at –20 degrees Celsius until further analysis.

Colostrum production was determined on a single quarter from each heifer using a portable milking machine (InterPuls, Albinea, Italy). Heifers were administered 1 mL of oxytocin (20 IU) intramuscularly immediately prior to colostrum collection to induce colostrum letdown. Each teat was stripped three times prior to attaching the portable milk machine to only the right-front quarter. The udder was massaged during colostrum collection until colostrum flow ceased to ensure that the quarter was fully milked out. The colostrum sample (n = 26) was placed into a 1000 mL graduated cylinder, measured, and weighed using a bench top scale, and subsamples were collected for trace mineral analysis.

Following sample collections, dams and calves were rejoined and observed for nursing within 1 hour of sampling procedures. Calves were provided assistance to nurse, if needed, and pairs were allowed 24 hours to bond. At 24 hours following initial sampling, calves were weighed, and body measurements were recorded including crown-rump length, hip height, hip width and chest circumference. Following 24-hour measurements, pairs from each treatment were moved back to the group pens and all cows received a common diet including the VTM supplement. Once all heifers calved, pairs were transported to the Central Grasslands Research Extension Center (CGREC; Streeter, ND) and assigned to the general herd management of the research herd, which included the addition of a free-choice trace mineral supplement on pasture. Calves were weighed at pasture turnout and weaning to evaluate the impacts of gestational mineral supplementation on postnatal growth.

Liver and colostrum samples were sent to the Diagnostic Center for Population and Animal Health at Michigan State University and analyzed using inductively couple plasma mass spectrometry to determine the concentrations of cobalt, copper, manganese, molybdenum, selenium and zinc.

Data were analyzed as a completely randomized design with the individual animal as the experimental unit. The PROC GLM procedure in SAS (SAS Inst., Cary, NC) was used with repeated measures in time when appropriate. Significance was considered at $P \leq 0.05$.

Results and Discussion

In maternal liver, concentrations of selenium and copper were affected ($P < 0.001$) by a treatment × day interaction, being greater ($P < 0.001$) for VTM dams compared to CON dams at all post-breeding timepoints and decreasing ($P \leq 0.05$) from day 84 to calving (Figures 1 and 2). The concentrations of zinc, molybdenum, manganese and cobalt in the dam were not influenced ($P \geq 0.20$) by dietary treatment during gestation. In the calf, liver concentrations of selenium, copper, zinc and cobalt were greater ($P \leq 0.05$) in calves born to VTM dams compared with calves born to CON dams (Table 2). Liver concentrations of molybdenum and manganese in

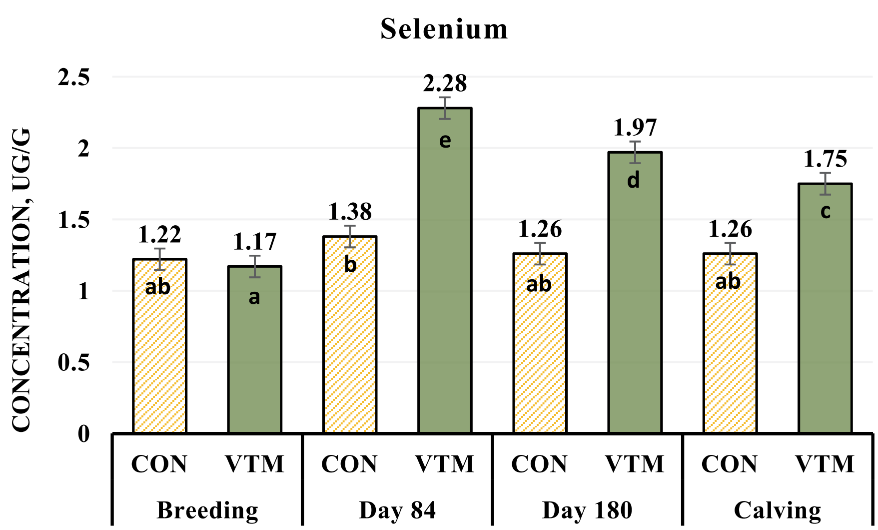

Figure 1. Selenium concentrations in the liver of beef heifers fed either a basal diet (CON) or the basal diet plus a vitamin and mineral supplement (VTM) throughout gestation. Heifers were assigned to their respective dietary treatment at breeding and continued receiving their treatments through calving. Liver biopsies were collected at breeding, days 84 and 180 of pregnancy, and at calving. A treatment × day interaction was detected ($P < 0.001$). Means lacking common letter differ ($P \leq 0.05$).

the calf were not impacted ($P \geq 0.06$) by dietary treatment of the gestating dam (Table 2). Marques et al. (2016) reported increased liver copper, cobalt and zinc concentrations in gestating cows when supplementing inorganic or organic mineral sources or no providing supplement. Liver mineral concentrations of copper, cobalt and zinc were also greater in calves born to supplemented vs. non-supplemented dams (Marques et al., 2016). These results suggest that as gestation progresses, maternal trace mineral stores are shunted to the fetus for the establishment of a postnatal mineral reserve and are reflected in the mineral status of the calf at birth.

At calving, maternal body weight was not different (CON = 1201 ± 38.0 lbs; VTM = 1266 ± 38.0 lbs; $P = 0.26$) for heifers receiving the VTM or the CON treatments throughout gestation. Intakes were controlled during gestation to reach targeted BW gains; thus, similar BW between treatment groups was not unexpected; however, Stanton et al. (2000) observed similar performance in gestating cows receiving organic or inorganic mineral sources on ad libitum intake pastures.

Colostrum weight (CON = 8.3 ± 1.24 oz; VTM = 12.6 ± 1.2 oz) and volume (CON = 8.3 ± 1.24 fluid oz; VTM = 12.4 ± 1.2 fluid oz) were greater ($P \leq 0.03$) for VTM heifers compared with CON heifers. Additionally, mineral concentrations of selenium, copper, zinc, and manganese in collected colostrum were greater ($P \leq 0.04$) for heifers consuming VTM through gestation compared with non-supplemented heifers.

Calf birth weights (CON = 70.0 ± 1.87 lbs; VTM = 70.8 ± 1.87 lbs) and 24-hour weights (CON = 73.1 ± 1.85 lbs; VTM = 73.8 ± 1.85 lbs) were not impacted ($P \geq 0.78$) by maternal VTM treatment during pregnancy. Stanton et al. (2000) also reported no differences in birth weights of calves when supplementing pregnant beef cows during late gestation with organic or inorganic trace minerals. Additionally, Marques et al. (2016) observed no differences in calf birth weight when dams were supplemented with organic minerals or not supplemented in late gestation. Calf body measurements including crown-rump length, chest circumference, hip height and hip width at 24 hours of age were similar ($P \geq 0.45$) for calves born to VTM and CON heifers.

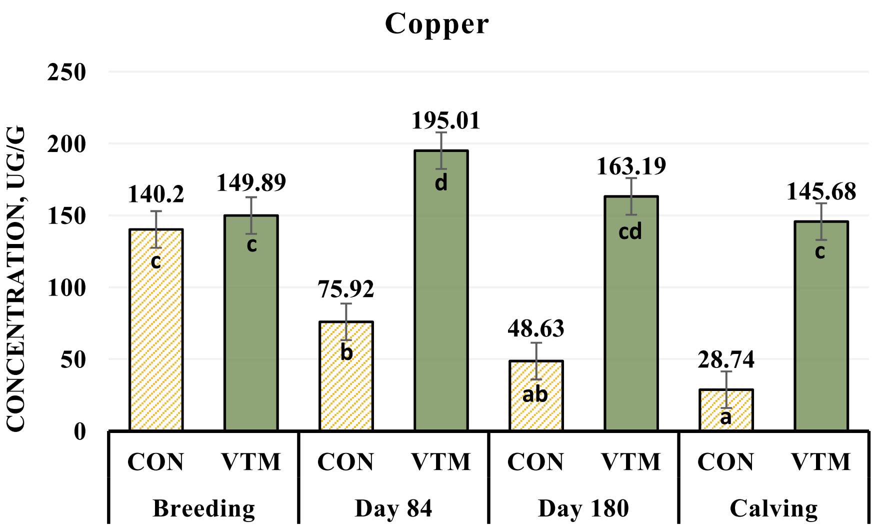

Figure 2. Concentrations of copper in the liver of beef heifers receiving a basal diet (CON) or the basal diet plus a vitamin and mineral supplement (VTM) throughout gestation. Heifers were assigned to their respective dietary treatments at breeding and continued receiving their treatments through calving. Liver biopsies were collected at breeding, days 84 and 180 of pregnancy, and at calving. A treatment × day interaction was detected ($P < 0.001$). Means lacking common letter differ ($P \leq 0.05$).

Table 2. Concentrations of trace minerals in the liver of beef calves at birth[1]

	Treatment[2]			
Item	CON	VTM	SEM	*P*-value[3]
Mineral concentration, µg/g				
Selenium	2.53	5.31	0.375	<0.001
Copper	327.63	414.16	29.667	0.05
Zinc	208.71	361.10	52.997	0.05
Molybdenum	1.06	1.27	0.077	0.06
Manganese	6.30	6.78	0.398	0.40
Cobalt	0.08	0.10	0.005	0.04

[1]Liver samples were collected via biopsy at birth prior to suckling.
[2]Treatments of gestating heifers were: 1) received the basal diet from breeding through calving (CON; n = 14); 2) received the basal diet plus the addition of a vitamin and mineral supplement (VTM; n = 17) provided at a rate of 4 oz•heifer^{-1}•day^{-1}.
[3]Significance considered at $P \leq 0.05$.

Although differences in calf size and performance were not observed at birth, evaluation of these heifer calves at pasture turnout and at weaning create an interesting discussion. Because all cow-calf pairs were fed the same diet post-calving and throughout weaning, we can evaluate the *in utero* nutritional impacts on the F1 offspring through the development period on pasture with their dams. At pasture turnout, calves from VTM heifers were 15.4 lbs heavier ($P = 0.05$) than calves from CON heifers. At weaning, calves born to VTM dams tended to be 36.3 lbs heavier ($P = 0.07$) than CON cohorts. Marques et al. (2016) also reported greater weaning weights in calves born to cows supplemented with organic trace mineral supplemented during late gestation compared to calves born to non-supplemented dams.

These results imply that impacts of trace mineral nutrition during pregnancy in the F0 generation are observed as enhanced mineral status and greater weaning weights of F1 generation calves. Further investigation into the extent of post-weaning impacts is warranted to determine physiological mechanisms behind the performance differences observed as well as the long-term impacts of gestational trace mineral supplementation on the direct offspring and across generations.

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Nutrition during early pregnancy impacts offspring ovarian characteristics

Isabella M. Jurgens[1], Friederike Baumgaertner[1], Sarah R. Underdahl[1], Jennifer L. Hurlbert[1], Kerri A. Bochantin[1], Kevin K. Sedivec[2], James D. Kirsch[1], Sheri T. Dorsam[1], Ana Clara B. Menezes[1], Wellison J.S. Diniz[3], Alison K. Ward[1], Kacie L. McCarthy[4], Joel S. Caton[1], Carl R. Dahlen[1]

The objective of this study was to determine how characteristics of offspring ovaries were affected by different maternal rates of gain (0.63 lb/d vs. 1.75 lb/d) during the first trimester of pregnancy in beef cattle. Heifer offspring from dams fed for low gain for the first 84 days of gestation had a heavier corpus luteum and a longer ovary length than offspring from moderate-gain dams. These findings suggest that feeding for a low gain during the first trimester of pregnancy produces offspring that may have higher rates of reproductive success in the future.

Summary

We hypothesized that maternal nutrition during the first 84 days of gestation would influence offspring ovarian characteristics. At breeding, 16 Angus-crossed beef heifers (body weight = 818.2 ± 8.7 pounds) were randomly assigned to one of two treatments: 1) a basal diet targeting 0.63 lb/d (low gain [LG]; n = 8) or 2) a starch-based energy/protein supplement targeting 1.75 lb/d (moderate gain [MG]; n = 8) for the first 84 days of pregnancy. After this period, they were managed as a single group through calving. Heifer calves (n = 16) remained with their dams until weaning and were managed as a single group through breeding. Before breeding, antral follicles were counted and classified via transrectal ultrasonography. On the 84th day of gestation, heifers were slaughtered, ovaries were removed from the reproductive tract, then weighed, and visible antral follicles were counted. Though no differences ($P \geq 0.48$) were observed in the number of visible antral follicles, the corpus luteum (CL) was heavier ($P = 0.03$) and the average ovarian length was greater ($P = 0.05$) in offspring from LG dams compared with those from MG dams. The number of microscopic follicles was not influenced by treatment. Heavier CLs have a positive correlation with the amount of progesterone released, which is essential for pregnancy maintenance. Longer lengths of the ovaries suggest more area for follicles to develop, which is indicative of future reproductive success. These findings demonstrate that maternal nutrition during early pregnancy impacts offspring ovarian development and can be useful for producers when making early gestation feeding decisions.

[1]Animal Sciences, Center for Nutrition and Pregnancy, NDSU
[2]Central Grasslands Research and Extension Center, NDSU
[3]Animal Science, Auburn University, Auburn, AL
[4]Animal Science, University of Nebraska, Lincoln, NE

Introduction

Reproductive success is a fundamental aspect of any livestock operation. Understanding how to positively influence reproductive outcomes can help ensure the longevity and overall profitability of a herd. During early pregnancy, offspring are directly exposed to nutrients consumed by their mother, and the development of their own reproductive tract is underway. During the first trimester of gestation, the entire ovarian reserve is established, although follicle activation does not take place until around day 90 of gestation (Yang and Fortune, 2008). In a bovine model, it has been observed that nutrient restriction during early gestation results in lower ovarian reserves in offspring (Mossa et al., 2013). There is sufficient evidence to support the concept that nutrition throughout gestation has lasting effects on offspring; however, there is more to be understood about how additional supplementation during the first trimester affects offspring ovarian characteristics.

Procedures

All experimental procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Sixteen Angus-crossed beef heifers (Body Weight = 818.2 ± 8.7 pounds) were estrus synchronized and bred via artificial insemination to a common sire using female-sexed semen. At breeding, heifers were randomly assigned to one of two treatments: 1) a basal diet targeting 0.63 lb/d (low gain [LG]; n = 8) or 2) a starch-based energy/protein supplement targeting 1.75 lb/d (moderate gain [MG]; n = 8) (Table 1). Heifers received their treatments until day 84 of gestation, after which time they were managed as a single group through calving. Heifer calves (F1) remained with their dams until weaning, then were managed as a single group through breeding. Prior to breeding, antral follicle count was determined via transrectal ultrasonography (PBAF), and follicles were classified as small (< 5 mm), medium (5 to 10 mm) or large (> 10 mm). Heifers were estrus-synchronized and AI bred to a common sire using female-sexed semen. On day 84 of gestation, F1 heifers were slaughtered, and ovaries were removed from the reproductive tract and weighed. Visible antral follicles (macroscopic follicles visible on the exterior of the ovary) were counted and classified as small (1-5mm), medium (5-10mm) and large (>10mm; SFC). The side of the corpus luteum (CL) was recorded and subsequently was excised from the ovary and weighed. Ovarian follicular fluid was removed from both ovaries, ovarian lengths and heights were measured using a digital caliper, and ovarian weight was recorded (Table 2). A cross-section out of the center of the non-CL ovary (1.5mm) was taken and placed in neutral-buffered formalin. Cross-sections from the ovary were post-fixed and embedded in paraffin. For each ovary, the tissue was then serially sectioned into three 5µm sections with a minimum of 10 sections between to avoid potentially counting follicles more than once. Sections of each ovary were then stained with Hematoxylin and Eosin for histological evaluation. Once slides were stained, they were digitally scanned using MoticEasyScan Pro. Microscopic primordial, primary, secondary and antral follicles were classified and counted according to established criteria (Figure 1; Cushman et al., 1999). Internal follicles were counted and classified manually for histological follicle count (HFC; Table 2).

Table 1. Chemical composition of diets offered to beef heifers from breeding to day 84 of gestation

	Treatment	
Chemical Composition	Basal Diet[1]	Protein and energy supplement[2]
Ash, % DM	11.5	2.4
Crude protein, % DM	9.9	17.5
Dry matter, %	53.0	87.7
Ether extract, %DM	1.5	9.1
Neutral detergent fiber, % DM	65.9	19.4
Nonfiber carbohydrates, % DM	11.1	51.6

[1]Basal diet was made up of corn silage (37%), prairie hay (53%) and dried distillers grains plus soluble (10%)
[2]Protein and energy was fed to achieve moderate rates of gain (1.75 lb./d) and was a blend of ground corn, DDGS, wheat midds, fish oil and urea.

Table 2. External ovarian characteristics of maternal ovaries on day 84 of gestation

	Treatments			
Item	LG[1]	MG[2]	SEM	*P*-value
Ovary characteristics				
Length, mm	28.6	26.5	0.69	0.05
Height, mm	16.0	15.3	0.67	0.49
Weight, g	2.71	2.47	0.226	0.46
Corpus luteum characteristics				
Diameter, mm	18.5	18.3	0.73	0.82
Weight, g	4.19	3.64	0.164	0.03
Surface follicles				
Small (<5mm), no.	16.3	19.9	3.87	0.52
Medium (5 to 10mm), no.	2.38	2.88	0.430	0.43
Large (>10mm), no.	1.50	1.50	0.230	1.00
Total follicles, no.	20.1	24.3	3.72	0.45

[1]LG: Heifers fed a basal diet targeting 0.63 lb./d
[2]MG: Heifers fed basal diet plus a protein/energy supplement targeting gain of 1.75 lb./d.

Data were analyzed using the GLM procedure of SAS, with heifer as the experimental unit. Data were deemed significant at $P \leq 0.05$. In this study we also aimed to determine the correlation between different methods of predicting the number of morphologically healthy follicles within the ovary using the CORR procedure of SAS. Thus, correlations between PBAF, SFC and HFC were analyzed.

Results and Discussion

There has been limited research in beef heifers on the effects of providing supplementation during early gestation on offspring reproductive performance. Much of the research has been focused on late gestation, as this is the period with greater fetal growth. However, early gestation is a critical period for fetal development, where most of the visceral organs are developed, including the reproductive tract. F1 heifers from LG dams had heavier CL ($P = 0.03$) and longer ovaries ($P = 0.05$) than F1 heifers from MG dams. This may indicate that there is not a significant need to increase supplementation during early gestation to influence offspring ovarian characteristics. There is evidence, however, that low levels of maternal nutrition during the first trimester of gestation can negatively affect fetal growth and birth weight (Micke et al., 2009), so nutrition during this time should not be overlooked. A study that utilized two different feeding programs for young heifers found that heifers fed for slower development during puberty had more primordial follicles than heifers fed for rapid development (Freetly et al., 2014). There was no evidence in the current study to support that there were any differences in microscopic or macroscopic (antral) follicle counts of offspring from dams on different planes of nutrition.

There was a significant correlation between histological follicle count and surface follicle count ($P = 0.002$), and between pre-breeding antral follicle count and surface follicle count ($P = 0.02$). Conversely, no correlation between pre-breeding antral follicle count and histological follicle count was identified ($P = 0.10$; Table 4). These results are consistent with a study conducted with cattle to determine if antral follicle count was a reliable predictor of healthy internal oocytes and follicles (Ireland et al., 2008). By utilizing this information, professionals in the industry can make a reasonable prediction of reproductive ability via transrectal ultrasound.

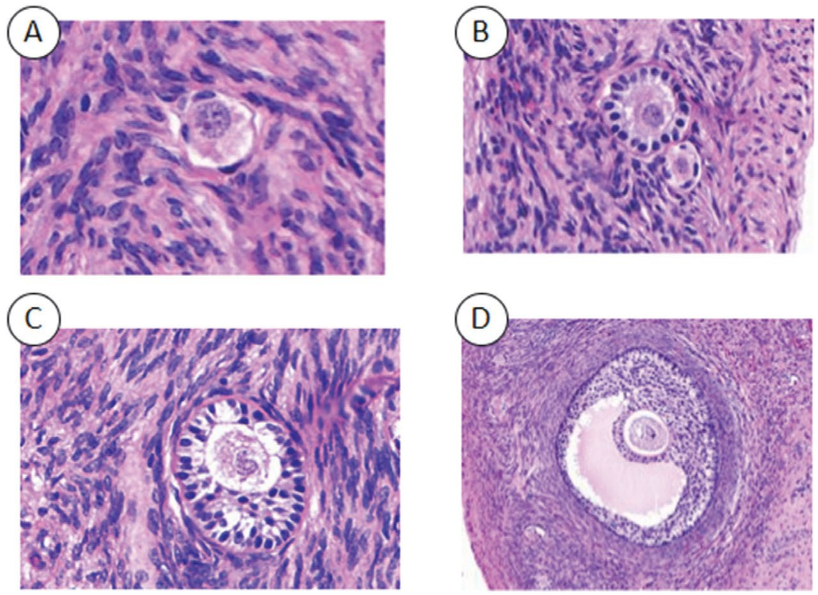

Figure 1. Motic digital scans of ovarian follicles: histological classifications. A) A primordial follicle, a flat single layer of granulosa cells. B) Primary follicle, a single layer of cuboidal granulosa cells. C) Secondary follicle, more than a single layer of cuboidal granulosa cells. D) Antral follicle, many layers of cuboidal granulosa cells that possess intra-follicular fluid.

Table 3. Internal follicle counts from histological sections on maternal ovaries on day 84 of gestation

	Treatments			
Follicles Per Section	LG[1]	MG[2]	SEM	*P*-value
Primordial	14.8	29.1	7.32	0.18
Primary	49.8	72.7	16.3	0.32
Secondary	4.90	6.10	2.220	0.70
Antral	0.130	0.190	0.0660	0.48
Total follicles	69.6	108.1	24.70	0.28

[1]LG: Heifers fed a basal diet targeting 0.63 lb./d

[2]MG: Heifers fed basal diet plus a protein/energy supplement targeting gain of 1.75 lb./d.

Table 4. Correlations between surface follicle count (SFC), histological follicle count (HFC) and pre-breeding antral follicle count (PBAF) via ultrasound

Comparison	Correlation coefficient	Number of observations	*P*-value
SFC vs. HFC	0.73	15	0.002
SFC vs. PBAF	0.60	16	0.01
HFC vs PBAF	0.44	15	0.10

In conclusion, these findings suggest that feeding for low gain during the first trimester of pregnancy impacts offspring ovarian characteristics. The impact of these findings on future reproductive success is unknown and future investigation is warranted.

Acknowledgements

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Vitamin and mineral supplementation during gestation does not affect neonatal ovarian follicular reserve

Isabella M. Jurgens[1], Jennifer L. Hurlbert[1], Friederike Baumgaertner[1], Ana Clara B. Menezes[1], Kerri A. Bochantin[1], James D. Kirsch[1], Sheri T. Dorsam[1], Kevin K. Sedivec[2], Kendall C. Swanson[1], Carl R. Dahlen[1]

The aim of this study was to determine how maternal vitamin and mineral supplementation during gestation would affect neonatal ovarian follicular reserve in beef cattle. Heifers were fed either a basal diet (CON; n=7) or a vitamin and mineral supplement in addition to the basal diet (VTM; n=7) from 60 days pre-breeding to parturition. Maternal dietary treatment had no effect on neonatal ovarian reserve at 30 hours of age (P ≥ 0.13). Additional investigation in this area may be beneficial in determining maternal nutritional impact on offspring reproductive development and establishment of the ovarian reserve.

Summary

Neonatal vitamin and mineral concentrations are correlated with maternal nutrient intake during gestation, and vitamins and minerals play an important role in many processes necessary for fetal development. The objective of this project was to evaluate the impact of maternal vitamin and mineral supplementation on neonatal ovarian characteristics. Fourteen Angus-based heifers (body weight [BW] = 603.4 ± 2.43 pounds [lbs]) were randomly assigned to a control treatment group that received a basal diet fed at a rate of 1 lb/heifer/day (CON; n = 7) or a treatment group that received the basal diet with the addition of a vitamin and mineral supplement at a rate of 4 oz/heifer/day (VTM; n = 7). Heifers were subjected to their respective treatments from 60 days before breeding, throughout gestation and through calving. Calves were euthanized thirty hours after birth, and the reproductive tract was subsequently removed. Upon removal, ovaries were weighed and vertical and horizontal measurements were taken. The right ovary was halved then placed in neutral-buffered formalin to preserve the tissue until processing. The samples were then serially sectioned into three 5-micron sections with ten sections between to avoid counting follicles more than once. The sections were placed on slides and stained with Hematoxylin and Eosin for histological evaluation. Using MoticEasyScan Pro, each slide was digitally scanned and total number of ovarian follicles (microscopic structures within the ovary that encases an egg) were recorded and classified depending on stage of maturity as primordial, primary, secondary or antral. Data were analyzed using the Mixed procedure of SAS with heifer as the experimental unit. There was no difference in ovarian size or in number of primordial, primary, secondary or antral follicles between treatments (*P* ≥ 0.13). Additional investigation in this area may be beneficial in determining maternal nutritional impact on measures of offspring reproductive development at further post-natal time points.

Introduction

Maternal nutrition during gestation is integral to the growth and development of offspring. Understanding the implications of how supplementation may improve offspring performance is of great interest to producers. It has long been understood that trace minerals are integral to many essential and fundamental physiological processes (Hidiroglou and Knipfel, 1981). Forage alone may not be sufficient to meet nutrient requirements due to the significant variability in forage trace mineral content and changes throughout the growing season.

Previous research indicated that nutrient restriction during gestation negatively affects follicular development in cattle offspring (Evans et al., 2012). There has been limited research on how feeding the dam additional nutrients before and during gestation affects offspring ovarian reserve, which is established *in utero*. After birth, follicles will be perpetually lost throughout an animal's reproductive lifespan, and over time as the follicular reserve depletes, reproductive ability decreases (Iwata, 2016). With the human population steadily increasing, demand for beef products is increasing, making efficiency more important than ever. Reproductive success is essential to any cow-calf operation and helps to ensure that producers are financially sustainable and are

[1]Animal Sciences, Center for Nutrition and Pregnancy, NDSU
[2]Central Grasslands Research and Extension Center, NDSU

operating at the highest level of efficiency. Ensuring that producers are aware of how gestational nutrition may influence reproductive ability will help producers with management decisions regarding nutrition of gestating females.

Procedures

All experimental procedures were approved by the North Dakota State University (Fargo, ND) Institutional Animal Care and Use Committee.

Fourteen angus-crossed beef heifers (body weight [BW] = 603.4 ± 2.43 lbs) were group-housed and individually-fed at the NDSU Animal Nutrition and Physiology Center (ANPC; Fargo, ND). Heifers were randomly assigned to either 1) a basal diet (CON; n=7) or 2) a basal diet with additional vitamin and trace mineral supplementation (VTM; n=7). The VTM supplement top-dressed on the basal diet was a loose product (Purina Wind and Rain Storm All-Season 7.5 Complete, Land O' Lakes, Inc., Arden Hills, MN) fed at a rate of 4 ounces (oz) per heifer per day. The basal diet consisted of 53% grass hay, 37% corn silage, and 10% modified corn distillers grains with solubles. Crude protein in the basal diet was 10.6% and the diet was formulated for a target gain of 1 pound/heifer/day.

Heifers were synchronized for estrus using a 7-day Co-Synch + CIDR protocol and bred via AI with female-sexed semen from a single sire on day 60 of treatment with treatments continuing until parturition. At birth, calves were separated from their dams immediately and transferred to individual pens. Calves were fed with a common source colostrum within 2 hours of birth and fed milk replacer every 12 hours thereafter. Calves were euthanized 30 hours after birth, and the right ovary was subsequently excised from the reproductive tract. Other organs and tissues were removed, weighed and sampled (See Hurlbert et al., 2022). Ovary height and width were measured using a digital caliper. Ovaries were placed in neutral-buffered formalin to preserve the tissue until processing. Samples were halved and embedded in paraffin. Slides were cut into three 5-micron sections with a minimum of 10 sections between to avoid potentially counting follicles multiple times. Slides were stained with Hematoxylin and Eosin and digitally scanned using the MoticEasyScan Pro digital imaging software for histological evaluation. The follicles were counted and classified manually by criteria established in Cushman et al. (1999; Figure 1).

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS. Covariate structures were selected based on the lowest AIC and BIC values. For primordial follicles, primary follicles and total follicles, the unstructured covariate structure was used. For secondary and antral follicles, the Toeplitz covariate structure was used. Data were deemed significant if $P \leq 0.05$.

Results and Discussion

There is limited research pertaining to how additional vitamin and mineral supplementation during gestation impacts the offspring ovarian reserve. There is evidence, however, that vitamins and minerals play an important role in the development of the ovarian reserve, so it would be reasonable to infer that additional supplementation

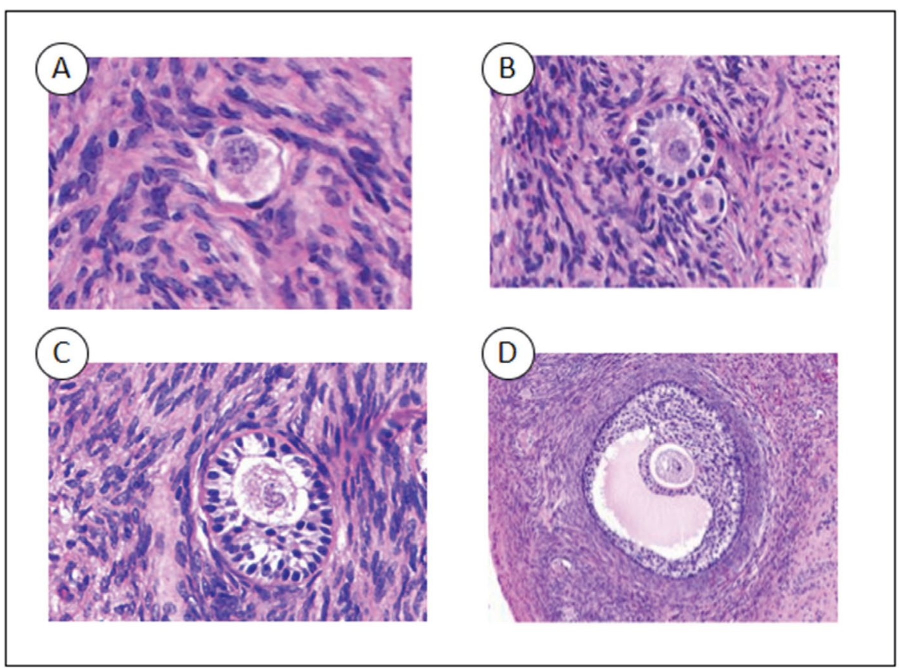

Figure 1. Motic digital scans of ovarian follicles in a mature ovary: histological classifications. A) A primordial follicle, a flat single layer of granulosa cells. B) Primary follicle, a single layer of cuboidal granulosa cells. primordial follicle. C) Secondary follicle, more than a single layer of cuboidal granulosa cells. D) Antral follicle, many layers of cuboidal granulosa cells that possess intra-follicular fluid.

would have positive effects on offspring reproductive development in utero (Harvey et al., 2021). It is well supported that nutrient deficiencies during gestation result in a lower ovarian reserve in offspring (Mossa et al., 2013). Data from this study shows that the number of primordial, primary, secondary and antral follicles, as well as the total number of follicles did not differ ($P \geq 0.13$) between calves born to VTM supplemented dams and calves born to CON dams. These results are corroborated by a study conducted on beef heifers at two different rates of gain during gestation without restriction to model a production scenario, where no differences in offspring ovarian reserve were observed between heifers (Jurgens et al., 2022). In conclusion, this study shows that supplementing replacement heifers with a vitamin and mineral supplement throughout gestation does not affect offspring ovarian reserve at 30 hours of age. Further investigation is required to gain a more thorough understanding of the effects of vitamin and mineral supplementation during gestation on offspring reproductive development.

Acknowledgements

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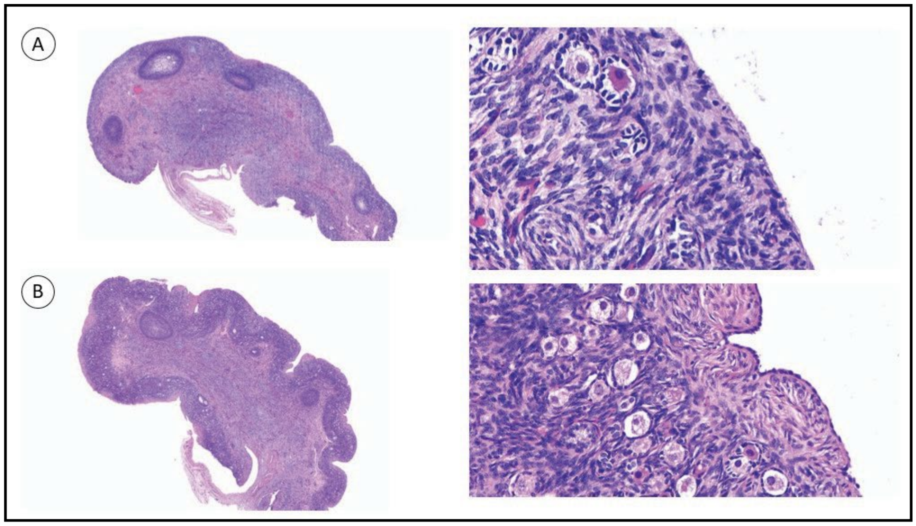

Figure 2. Example of an ovary with a low follicle count compared to an ovary with a high follicle count. Ovary A) example of an ovary with a low follicle count; 1X magnification of ovary with a section of cortex at 20X magnification. Ovary B) example of an ovary with a high follicle count; 1X magnification of ovary with a section of cortex at 20X magnification.

Table 1. Composition of the vitamin and mineral supplement2 provided to replacement beef heifers throughout gestation (Purina Wind and Rain Storm All Season 7.5 Complete Mineral, company guaranteed analysis).

Item	Assurance levels		
Minerals[1]	Min	Max	
Calcium, g/kg of DM	135.0	162.0	
Phosphorus, g/kg of DM	75.0	-	
Sodium Chloride, g/kg of DM	180.0	216.0	
Magnesium, g/kg of DM	10.0	-	
Potassium, g/kg of DM	10.0	-	
Manganese, mg/kg of DM	3,600.0	-	
Cobalt, mg/kg of DM	12.0	-	
Copper, mg/kg of DM	1200.0	-	
Iodine, mg/kg of DM	60.0	-	
Selenium, mg/kg of DM	27.0	-	
Zinc, mg/kg of DM	3,600.0	-	
Vitamins, IU/kg of DM			
A			661,500.0
D			66,150.0
E			661.5

[1]Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN); ingredients: dicalcium phosphate, monocalcium phosphate, processed grain by-products, plant protein products, calcium carbonate, molasses products, salt, mineral oil, potassium chloride, magnesium oxide, ferric oxide, vitamin E supplement, vitamin A supplement, lignin sulfonate, cobalt carbonate, manganese sulfate, ethylenediamine dihydroiodide, zinc sulfate, copper chloride, vitamin D3 supplement, natural and artificial flavors, and sodium selenite.
[2]Vitamin and mineral supplement provided at a rate of 4 oz•heifer^{-1}•day^{-1}.

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Table 2. Internal follicle counts (average count per section) of neonates from heifers fed either a basal diet (CON) or the basal diet plus a vitamin and mineral supplement (VTM) during gestation.

	Treatment			
Follicle Type	CON[1]	VTM[2]	SEM	P-value[3]
Primordial	97.5	75.6	23.17	0.55
Primary	64.5	62.5	11.90	0.91
Secondary	12.9	8.7	1.6	0.13
Antral	0.646	0.684	0.3095	0.94
Total	208	205	24.3	0.94

[1]CON: The basal diet; 53% grass hay, 37% corn silage, and 10% modified corn distillers grains with solubles. The total crude protein in the basal diet was 10.63%. The diet was formulated for a target gain of 1 pound/heifer/day.

[2]VTM: The basal diet as described above, top-dressed with Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN); ingredients: dicalcium phosphate, monocalcium phosphate, processed grain by-products, plant protein products, calcium carbonate, molasses products, salt, mineral oil, potassium chloride, magnesium oxide, ferric oxide, vitamin E supplement, vitamin A supplement, lignin sulfonate, cobalt carbonate, manganese sulfate, ethylenediamine dihydroiodide, zinc sulfate, copper chloride, vitamin D3 supplement, natural and artificial flavors, and sodium selenite.

Supplementation of one-carbon metabolites to beef heifers during early gestation effects on fetal liver and muscle mitochondrial oxygen consumption rate ratios at day 63 of gestation

Layla E. King[1], Jessica Syring[1], Yssi Entzie[1], Mara Hirchert[1], Matthew S. Crouse[2], Joel S. Caton[1], Carl R. Dahlen[1], Alison K. Ward[1]

In ruminant production systems, inadequate maternal nutrition during gestation is a common stressor cattle undergo, since many systems are designed for cattle to receive the majority of nutrients from grazing. This study investigated the effects of supplementation of one-carbon metabolites (OCM) on fetal growth and development in feed-restricted heifers. Supplementation of OCM did not influence fetal cellular respiration of fetal liver and muscle tissue.

Summary

The objective of this experiment was to investigate the effects of one-carbon metabolite supplementation during early gestation on beef cattle fetal liver and muscle cellular respiration. The experiment utilized 72 angus-crossbred heifers that were housed at the Animal Nutrition Physiology Center at North Dakota State University from June 2021 until October 2021. The experimental design has treatments arranged as a 2 × 2 factorial with two levels of feed intake (planes of nutrition) and two levels of strategic OCM supplementation. The heifers were assigned to one of four nutritional treatments: control intake without OCM supplementation (CON - OCM), CON with OCM supplementation (CON + OCM), restricted intake without OCM supplementation (RES - OCM), or RES with OCM supplementation (RES + OCM). At d 63 of gestation fetal liver and muscle tissues were collected and oxygen consumption rate (OCR) was measured. Respiratory control ratio (RCR) was determined using state 3 and 4 oxygen consumption rate values from mitochondrial respiration assays. No treatment, gain, or interaction effects were observed for RCR in liver and muscle tissue. Similarly, when RCR values were normalized to a control, no treatment, gain or interaction effects were seen. Results show that more assays in later phases of the project are necessary to determine effects of OCM supplementation on mitochondrial oxygen consumption rates. All *P*-values were above 0.05.

Introduction

Developmental programming is the concept that maternal or parental stressors affect fetal development and can program the increased risk of postnatal pathologies (Barker et al., 2004). Since the majority of fetal growth occurs during the last two months of gestation, the effect of maternal nutrition during early gestation may seem negligible (Robinson et al., 1977; Funston et al., 2010). However, prenatal growth trajectory responds to maternal nutrient intake from the early stages of embryonic life. For example, maternal nutrient restriction during the first 50 days of gestation in beef heifers can alter transcript abundance of genes that influence tissue metabolism, accretion, and function in fetal liver, muscle and cerebrum (Crouse et al., 2019). Additionally, evidence suggests that in the early stages of fetal development, poor nutrition can influence placental growth, cell differentiation and organ development. Furthermore, perturbed maternal nutrition during critical time windows during gestation may negatively affect fetal growth and development through epigenetic modifications such as changing patterns of DNA methylation and histone modification, impacting endocrine control, and ultimately leading to impaired growth and metabolism of the conceptus. Thus, inadequate nutrient delivery in diets may negatively affect fetal development impacting beef production by reducing the offspring's feed efficiency and average daily gain.

Lastly, feed costs are the largest economic burden for beef cattle producers and are usually designed for the parent cow more than the future market bound offspring. Therefore, it would be beneficial for producers to target nutrients designed for both parent and conceptus in order to improve the offspring's genetic potential and productivity. Based off this information, the objective was

[1]Department of Animal Sciences, NDSU
[2]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE.

to investigate if OCM supplementation improved cellular respiration of fetal tissues which would aid in postnatal efficiency.

Materials and Methods

Animal handling and care procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. The experimental design has treatments arranged as a 2 × 2 factorial with two levels of feed intake (planes of nutrition) and two levels of strategic OCM supplementation. Heifers were bred 16 to 22 hours after detected estrus with female-sexed semen from a single sire. At breeding (day 0), heifers were assigned to one of four nutritional treatments: control intake without OCM supplementation (CON - OCM), CON with OCM supplementation (CON + OCM), restricted intake without OCM supplementation (RES - OCM), or RES with OCM supplementation (RES + OCM). The CON plane of nutrition targeted an average daily gain of 0.45 kg/day. The RES plane of nutrition targeted -0.23 kg/day. The OCM supplement consisted of rumen-protected choline (60 g/d) and methionine (10 g/d) in a fine-ground corn carrier fed daily, and weekly injections of folate (320 mg) and vitamin B_{12} (10 mg). The -OCM heifers received the corn carrier and weekly saline injections.

Heifers were managed on their respective treatment until slaughter and fetal tissue collection on d 63 (+/- 2) of gestation. Immediately following collection, fetal liver and muscle were placed in a buffer and underwent mitochondrial respiration assays using a Seahorse XFe96 Analyzer (Agilent). Data were analyzed using the MIXED procedures of SAS and significance was set at $P < 0.05$.

The basal diet consisted of corn silage, ground corn and an alfalfa/grass hay mix (Table 1). Heifers were fed by an individual Calan gate system and average daily gain was adjusted weekly. Restricted intake targeted and average daily gain of -0.23 kg/day and achieved that average. Control intake targeted 0.45 kg/d and achieved an actual average daily gain of 0.60 kg/d.

Table 1. Diet Composition

Ingredient	% Dry Matter	% Crude Protein	% of Diet
Ground corn	89.77	8.34	31
Corn Silage	45.48	6.88	9
Alfalfa	89.89	21.90	15
Alfalfa/grass mix	91.10	14.74	45

Results

There were no effects of treatment, gain or the treatment by gain interaction for RCR in liver or muscle (Table 2). After RCR values were normalized using a control baseline, there was still no effects of treatment, gain or the treatment by gain interaction in liver and muscle (Table 3).

Discussion

In this study, OCM supplementation provided during early gestation up until day 63 of gestation was investigated for effects on fetal liver and muscle mitochondrial oxygen consumption rates during maternal nutrient restriction. Oxygen consumption rate is a key energy metabolism pathway that measures how much oxygen the mitochondria are consuming within the respective tissue being analyzed. The Seahorse XFe96 Analyzer used in this study quantifies many aspects of cellular metabolism and immune metabolism. State 3 respiration is the

Table 2. The effect of maternal plane of nutrition and supplementation with one-carbon metabolites (methionine, choline, folate, vitamin B_{12}) from day 0 to 63 of gestation on fetal liver and muscle respiratory control ratios

	Organ Respiratory Control Ratios[1]					*P*-value[3]		
	CON-OCM	CON+OCM	RES-OCM	RES+OCM	SEM[2]	Gain	Trt	Gain×Trt
Liver RCR	5.82	5.15	5.56	5.48	0.22	0.94	0.44	0.54
Muscle RCR	4.10	3.55	3.68	3.76	0.29	0.86	0.71	0.62

[1]CON-OCM = Control (0.45 kg/d) without one-carbon metabolite supplementation; CON+OCM = Control (0.45 kg/d) with one-carbon metabolite supplementation; RES-OCM = Restricted (-0.23 kg/d) without supplementation; RES+OCM = Restricted (-0.23 kg/d) with supplementation.

[2]Standard error of the mean.

[3]Gain = Main effect of feed intake levels; Trt = Main effect of one-carbon metabolite supplementation; Gain×Trt = Main effect of feed intake levels interaction with one-carbon metabolite supplementation.

Table 3. The effect of maternal plane of nutrition and supplementation with one-carbon metabolites (methionine, choline, folate, vitamin B_{12}) from day 0 to 63 of gestation on fetal liver and muscle normalized respiratory control ratios

	Organ Normalized Respiratory Control Ratios[1]					*P*-value[3]		
	CON-OCM	CON+OCM	RES-OCM	RES+OCM	SEM[2]	Gain	Trt	Gain×Trt
Liver NRCR	1.00	0.88	0.95	0.94	0.039	0.945	0.44	0.54
Muscle NRCR	1.00	0.86	0.89	0.91	0.073	0.87	0.71	0.62

[1]CON-OCM = Control (0.45 kg/d) without one-carbon metabolite supplementation; CON+OCM = Control (0. 45kg/d) with one-carbon metabolite supplementation; RES-OCM = Restricted (-0.23 kg/d) without supplementation; RES+OCM = Restricted (-0.23 kg/d) with supplementation.

[2]Standard error of the mean.

[3]Gain = Main effect of feed intake levels; Trt = Main effect of one-carbon metabolite supplementation; Gain×Trt = Main effect of feed intake levels interaction with one-carbon metabolite supplementation.

measurement of max respiration by the mitochondria. State 4 respiration is a measure of both mitochondrial and non-mitochondrial respiration. These two states are used to determine the respiratory control ratio which is an indicator of cellular function through respiration.

There were no significant treatment, gain or interaction effects on cellular respiration observed. However, further research is needed to determine if timing of nutrient restriction or OCM supplementation influences cellular respiration measures.

The results shown from this study indicate that supplementation of OCM did not influence mitochondrial respiration of fetal liver and muscle. Impaired development of these organs can reduce offspring efficiency and production performance, which can be costly to beef producers. Further research on other measures of cellular function with OCM supplementation is in progress.

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Effect of supplementation with vitamins and minerals and/or rate of gain on placental vascular development of Angus heifers

Bethania J. Dávila[1], Carl R. Dahlen[1], Jennifer L. Hurlbert[1], Friederike Baumgaertner[1], Kerri A. Bochantin[1], Ana Clara B. Menezes[1], Wellison J.S Diniz[1], Sara R. Underdahl[1], James D. Kirsch[1], Kevin K. Sedivec[1], Pawel P. Borowicz[1], Sebastián Cánovas[2], Lawrence P. Reynolds[1]

The objective of this study was to evaluate the effect of supplementation with vitamins and minerals and/or rate of gain during two different stages of pregnancy (day 83 of gestation and parturition) on the vascular development of the fetal part of the placenta of Angus heifers. Our results showed greater vascularity in the vitamin-mineral supplemented group at parturition, a beneficial effect on placental vascular development, therefore potentially enhancing placental function.

Summary

The objective of this study was to evaluate the effect of supplementation with vitamins and minerals (VTM; 113 g•heifer^{-1}•d^{-1} to provide macro and trace minerals and vitamins A, D, and E to meet 110% of the requirements suggested by the NASEM Nutrient Requirements of Beef Cattle publication) and/or rate of gain (RG; low gain [LG], 0.28 kg/d, vs. moderate gain [MG], 0.79 kg/d) during two different stages of pregnancy (day 83 of gestation and parturition) on the vascular development of the fetal part of the placenta (termed cotyledon; COT) of Angus heifers. We hypothesized that dietary VTM supplementation and/or RG would improve fetoplacental vascular development, thereby potentially enhancing placental function. Two experiments were conducted. In experiment 1, 34 heifers were randomly assigned to VTM/NoVTM supplementation at least 71 days before artificial insemination (AI). At breeding, the diet and VTM supplementation were maintained, and heifers were randomly assigned to LG or MG dietary supplementation, resulting in the following treatment combinations: NoVTM-LG (Control; n=8), NoVTM-MG (n=8), VTM-LG (n=9), and VTM-MG (n=9). Dietary supplementation was maintained until day 83 when heifers were ovariohysterectomized and placentas were collected. In experiment 2, 72 heifers were randomly assigned to VTM supplementation (n=36) or control (CON; n=36) treatments at breeding and continuing until parturition when COT from a subset of 28 heifers was collected. The placentas (Exp. 1) and COT (Exp. 2) were evaluated by immunohistochemistry using rabbit anti-CD34 and anti-CD31 antibodies as markers for blood vessels (to quantify vascularity along with DAPI for background nuclear staining. In the day-83 group, BS1 lectin was used as a marker of fetal placental (COT) tissue. Three images per animal were captured and the percentage/number of blood vessels within each placental tissue area was evaluated using image analysis (Advanced Imaging and Microscopy [AIM] Core Laboratory, NDSU). The data were analyzed using the GLM procedure of SAS. Results indicated that on day 83 COT vascularity was not affected by VTM (P-value = 0.50), RG (*P*-value = 0.55), or their interaction (*P*-value = 0.67), whereas at parturition there was a tendency for COT vascularity to be greater in VTM than CON (*P*-value = 0.07) heifers.

Introduction

The placenta is the first organ to be formed in mammals, and very early in pregnancy establishes a uteroplacental vascular interface by which the circulatory systems of the mother and the embryo transport respiratory gases, nutrients, and wastes across the placental membranes, supplying the bioenergetic needs for successful development of the embryo/fetus. Therefore, early pregnancy is critical for fetal development, as the establishment of a functional fetoplacental vascular bed in cattle takes place during the first 50 days of gestation, which determines subsequent placental function. Inadequate vascular placental development is a principal factor involved in fetal growth restriction and subsequent low birth weight (Reynolds et al., 2010).

During pregnancy, maternal nutritional needs increase, and

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]University of Murcia, Spain

poor maternal nutrition is one of the major drivers of developmental programming in offspring, the process in which altered development affects the structure of the body's organs and the function of its systems during pregnancy and postnatally (Barker and Thornburg, 2013). It has been suggested that VTM and/or RG supplementation affects hormonal regulatory pathways, and the sex steroids progesterone and estrogen are the main regulators of the synthesis and release of angiogenic factors by placental cells (Borowicz et al., 2007). These observations led us to hypothesize that supplementation with VTM and/or RG will influence fetoplacental vascular development and function, and therefore ensure proper fetal development and the delivery of healthy offspring.

Experimental Procedures

Two different experiments were conducted. In experiment 1, 34 Angus heifers were randomly assigned to one of the following treatment groups 71 days before the AI: VTM (heifers received the basal total mixed ration [TMR] with the addition of 113 g of Wind and Rain Storm, Land O' Lakes, Inc., mineral and vitamin supplementation per day – Table 1) or NoVTM (heifers receiving the basal TMR) and maintained until breeding. At breeding, RG dietary treatments were assigned (LG, 0.28 kg/d, vs. MG, 0.79 kg/d), resulting in the following treatment combinations: NoVTM-LG (Control; n = 8), NoVTM-MG (n = 8); VTM-LG (n = 9) and VTM-MG (n = 9). Heifers were fed individually, and diets were delivered once daily until the experimental endpoint of day 83 ± 0.27 of gestation when heifers were ovariohysterectomized and the largest placental unit (placentome) closest to the fetus was collected (Menezes et al., 2021).

In experiment 2, 72 Angus heifers were randomly assigned to one of the two following groups at breeding: supplementation with VTM (n=36, heifers receiving the basal TMR with the addition of 113 g of Wind and Rain Storm, Land O' Lakes, Inc., mineral and vitamin supplementation – Table 1) or NoVTM (n=36, heifers receiving the basal total mixed ration). Supplementation continued until parturition when 28 placental samples were collected from 12 heifers from the NoVTM group and 16 heifers from the VTM group (Hurlbert et al., 2022).

Cross-sections of placentomes from experiment 1 and COT from experiment 2 were fixed in formalin, embedded in paraffin, and stained using immunofluorescence for image analysis. For immunofluorescent staining in both experiments, rabbit anti-CD34 and rabbit anti-CD31 were used as markers of blood vessels for analysis of vascularity, and DAPI was used for background nuclear staining (Figures 1 and 2). In addition, for experiment 1, fluorescein griffonia simplifolia lectin I (BS1 lectin) was used as a marker of fetal tissue (Figure 1). Three images per animal were taken and the areas of interest were carefully outlined and analyzed for the percentage and number of blood vessels within the tissue area using the image analysis

Table 1. Nutrient composition of total mixed ration and supplements provided to beef heifers during the first trimester of gestation.

Composition	TMR[1]	NoVTM[2]	VTM[3]	RG[4]
Dry matter, %	53.0	86.6	89.6	87.7
Ash, % DM	11.5	5.3	25.1	2.4
Crude protein, % DM	9.9	15.6	14.8	17.5
Neutral detergent fiber, % DM	65.9	41.9	27.6	19.4
Ether extract, % DM	1.5	-	-	9.1
Non-fiber carbohydrates, % DM	11.1	37.2	32.5	51.6
Mineral Content				
Calcium, g/kg DM	5.74	2.47	50.62	0.30
Phosphorus, g/kg DM	2.05	8.94	22.82	4.59
Sodium, g/kg DM	0.26	0.12	19.44	0.24
Magnesium, g/kg DM	2.83	4.47	5.20	1.96
Potassium, g/kg DM	15.81	14.22	13.15	6.05
Sulfur, g/kg DM	2.25	2.41	4.84	2.57
Manganese, mg/kg DM	121.2	103.9	953.4	26.0
Cobalt, mg/kg DM	0.36	0.14	3.38	0.05
Copper, mg/kg DM	4.8	13.7	285.8	3.6
Selenium, mg/kg DM	0.3	0.4	7.0	0.3
Zinc, mg/kg DM	28.4	130.2	1051.8	35.0

Taken from Menezes A.C, et al 2021

[1]Total Mixed Ration (proportion of ingredients) prairie grass hay (55%), corn silage (38%) and dried distillers grains plus solubles (7%); this group served as the Control group.

[2]NoVTM: No vitamin-mineral supplement was a pelleted carrier product fed at 0.99 lb/heifer/day with no added vitamin and mineral supplement.

[3]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day and consisting of 113 grams (g) of a vitamin and mineral supplement (Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, MN) and 337 g of a carrier.

[4]Starch-based protein/energy: An energy/protein supplement formulated with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil, and urea; targeting a rate of gain of 1.74 lb/d for moderate gain and 0.62 lb/d for low-gain heifers.

software Image-Pro Premiere. The values for the percentage/number of blood vessels within each placental tissue area were analyzed using the GLM procedure of SAS.

Results and Discussion

In experiment 1, COT vascularity was not affected by VTM (P = 0.50), RG (P = 0.54), or their interaction (P = 0.66), while in experiment 2 there is a tendency (P=0.07) for COT vascularity to be greater in VTM than CON (Table 2).

Placental angiogenesis requires the proliferation, migration and differentiation of endothelial cells within the preexisting trophoblastic microvessels to become new placental blood vessels (Chen and Zheng 2014). Previous studies have shown that fetal COT appears to be relatively poorly vascularized until midgestation, when it undergoes a dramatic cellular proliferation and tissue remodeling resulting in greater vascularization (Borowicz et al. 2007). Therefore, it was expected to find greater COT vascularity in the parturition study compared with d 83 study (Table 3). Previous studies (Diniz et al., 2021) demonstrated that VTM supplementation led to differential gene expression in COT by day 83 of gestation in heifers, but the impact on gene expression of angiogenic factors is still unknown. Even though our results suggest that the dietary VTM supplementation from breeding until parturition has a beneficial effect on placental vascular development, potentially enhancing placental function, future studies are needed to evaluate the influence of VTM supplementation on angiogenic factor expression and steroid hormones and their relationship with the increase in placental vascularization, the main developmental process responsible of fetal growth and healthy offspring.

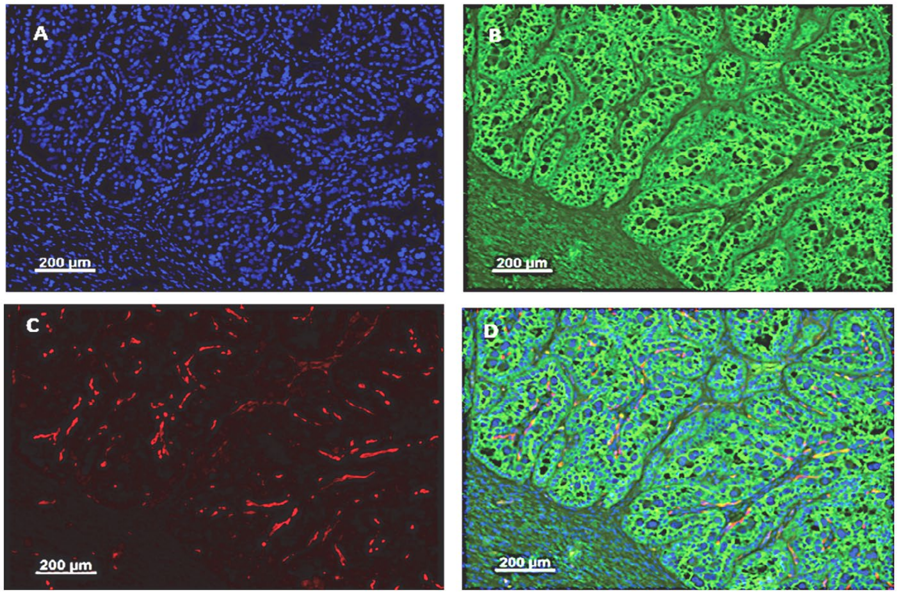

Figure 1. Experiment 1 immunostaining (200X magnification). A) Background nuclear staining with DAPI; B) fetal membranes stained with BS1 lectin; C) blood vessels stained with CD31 + CD34; D) DAPI + BS1 (green) + CD31 & CD34 (red).

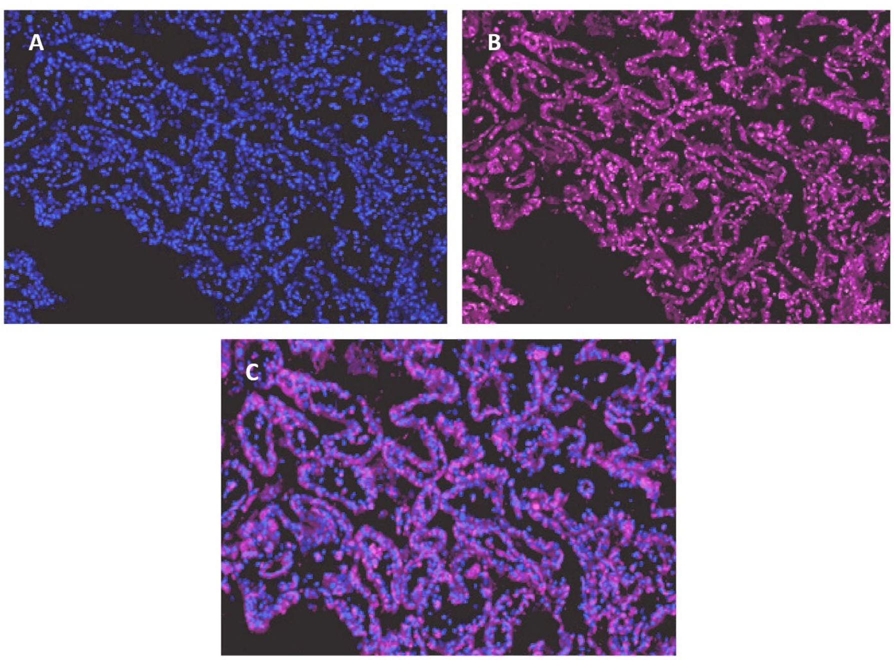

Figure 2. Experiment 2 immunostaining (200X). A) Background nuclear staining with DAPI; B) blood vessels stained with CD31 and CD34 antibodies; C) DAPI + CD31 & CD34.

Table 2. Experiment 1 and 2 vascularity area of VTM/ NoVTM, LG/MG and their interaction.

Treatment	Vascularity Area (%)	Standard Error	N	
Experiment 1				
NoVTM	2.66	0.19	16	
VTM	2.45	0.19	18	
				***P* = 0.50**
LG	2.49	0.19	17	
MG	2.65	0.19	17	
				***P* = 0.54**
NoVTM-LG	2.52	0.27	8	
NoVTM-MG	2.80	0.27	8	
VTM-LG	2.46	0.27	9	
VTM-MG	2.50	0.27	9	
				***P* = 0.66**
Experiment 2				
CON	8.65	1.39	12	
VTM	12.09	1.20	16	
				***P* = 0.07**

Table 3. Cotyledonary vascularity (percentage of tissue area represented by CD34 staining) in experiment 1 vs experiment 2.

Study group	Vascularity Area (%)	Standard Error	n	
Day 83	2.58	0.56	34	
Parturition	10.62	0.62	28	
				***P* < 0.001**

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The impacts of maternal nutrition during the first 50 days of gestation: Folate and B_{12} concentrations in maternal serum and fetal fluids

Jessica G. Syring[1], Tammi L. Neville[1], Matthew S. Crouse[2], Alison K. Ward[1], Carl R. Dahlen[1], Lawrence P. Reynolds[1], Pawel P. Borowicz[1], Kyle J. McLean[3], Bryan W. Neville[2], Joel S. Caton[1]

Maternal nutrition during gestation has an important impact on the development of the fetus. In this study, restricted maternal nutrition increased the concentrations of two B-vitamins in fetal fluid. This finding contributes to our ultimate goal of gaining insight into the impact of restricted maternal nutrition on key factors in fetal developmental programming.

Summary

Proper maternal nutrition throughout gestation is important for fetal programming and development (Wu et al., 2004). Restricted maternal nutrition, such as during long periods of drought and poor forage quality, can have impacts on the proper development of the calf. Major fetal organ systems are present by day 50 of gestation (Winters et al., 1942; Dahlen et al., 2021), and thus nutrition during early gestation is important for proper organ development. A key pathway regulating fetal development is one carbon metabolism, and it plays a major role in proper gene expression. Some of the intermediates in this pathway, known as one carbon metabolites (OCM), include the vitamins B_{12}, folate, and choline along with the amino acid methionine. This study examined the concentrations of two OCM, B_{12} and folate, present in maternal serum, fetal allantoic fluid (ALF), and fetal amniotic fluid (AMF) in heifers fed either a control or a restricted diet. Forty-three angus-cross heifers were artificially inseminated with female-sexed semen and placed on one of two diets. The control diet (CON) was formulated to meet 100% of NRC requirements for beef heifers, while the restricted diet (RES) was fed to 60% of CON. Vitamin B_{12} and folate were both found to be greater ($P = 0.04$ and $P = 0.03$, respectively) in the ALF of RES heifers when compared to the concentrations in the ALF of CON heifers. There was also a treatment × fluid interaction ($P = 0.04$) for B_{12} concentrations, and a fluid effect ($P < 0.001$) on folate concentrations. Thus, these findings indicate that a moderate nutrient restriction of the dam during early gestation increases concentration of B_{12} and folate in ALF.

Introduction

Throughout gestation, maternal nutrition plays an important role in the growth and development of the fetus (Wu et al., 2004). Early gestation is a critical window for growth and the forming of major organ systems (Winters et al., 1942; Dahlen et al., 2021). In fact, previous research in beef cattle have found reduced fetal tissue weights when the dams were fed a restricted diet from days 30 to 125 of gestation (Long et al., 2009). Thus, it is important that dams are receiving sufficient nutrition during early gestation for proper fetal organ development.

The process of developmental programming involves how the maternal environment during pregnancy can have both short- and long-term effects on the offspring (Caton et al., 2020; Reynolds et al., 2022). One way development can be programmed is through "epigenetic modifications." These modifications function by essentially turning genes off or on and changing how they are expressed. One type of epigenetic modification includes DNA methylation, where methyl groups are added "on top of" certain parts of a DNA strand, without changing the actual DNA sequence. The chemical pathway involved in DNA methylation is one carbon metabolism. The nutrients involved in one carbon metabolism are called one carbon metabolites (OCM) and include folate, B_{12}, methionine and choline. Previous studies from our team found restricted maternal nutrition altered the concentration of methionine, as well as other amino acids (Crouse et al., 2019).

We hypothesized that a moderate restriction of the maternal diet during early gestation will affect the concentrations of B_{12} and folate in maternal serum, fetal allantoic fluid (ALF) and fetal amniotic fluid (AMF). Thus, the objective of this study was to determine the effects

[1]Center for Nutrition and Pregnancy, NDSU
[2]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE
[3]Department of Animal Science, University of Tennessee, Knoxville, TN

of maternal diet on B_{12} and folate concentrations in both the dam and fetus.

Materials and Methods

Treatments were started on day 0 of gestation (i.e. day of insemination). The treatments consisted of either a control (CON) or restricted (RES) diet. Control heifers were fed to gain 1 pound per day and meet 100% of requirements. Restricted heifers were fed 60% of CON to maintain body weight. The total mixed ration included grass hay, corn silage, alfalfa haylage, grain and mineral mix, and dried distillers grains with solubles to meet protein requirements.

Samples were collected on day 16, 34, or 50 of gestation, where heifers were ovariohysterectomized. Maternal serum samples were collected for each collection day (n = 42), however ALF (n = 29) and AMF (n = 11) samples were only collected on days 34 and 50. Serum was collected from the jugular vein, allowed to clot, centrifuged and then separated from the blood. Allantoic and amniotic samples were collected from the chorioallantois and amnion, respectively, and snap frozen. All samples were then stored at -20°C until they were sent to IDEXX BioAnalytics (N. Grafton, MA) for B_{12} and folate analysis.

The GLM procedure of SAS (SAS Inst. Inc.) was used for data analysis. For the B_{12} and folate concentration analysis, two models were used. The first model included treatment, day of gestation, and the treatments × day of gestation interaction. The second model included treatment, fluid type, and their interaction. For both models, heifer served as the experimental unit. A P-value < 0.05 was considered significant for all statistical analyses.

Results and Discussion

There was no treatment × day of gestation interaction ($P > 0.05$) found, so only the main effects of day of gestation and treatment will be discussed (Table 1). The concentrations of B_{12} and folate were not changed ($P > 0.05$) by treatment or day of gestation in maternal serum or AMF. However, in ALF, both B_{12} and folate concentrations were increased ($P = 0.04$ and $P = 0.03$, respectively) in RES. Additionally, folate concentrations in ALF were greater ($P = 0.003$) on day 34 of gestation compared to day 50. Vitamin B_{12} concentrations were greatest in restricted ALF, intermediate in CON ALF, and lowest in CON and RES serum and CON and RES AMF ($P = 0.04$; Table 2). Folate concentrations were greatest in ALF, followed by serum, and finally AMF ($P < 0.001$). The different responses among fluids may not be surprising as these three fluids each have different functions. The role of serum is related to nutrient transport throughout the body, the role of ALF is in collecting waste products from the fetus, and role of AMF is protecting the fetus. In a previously published study, it was found that restricting maternal nutrition also altered amino acid concentrations in fetal fluids (Crouse et al., 2019). This indicates that restricting the nutrition of the dam can have an impact on the concentrations of nutrients in fetal fluids, possibly by altering metabolic pathways in the dam.

This study helps confirm that restricting maternal nutrition during early gestation can alter concentrations of B12 and folate in the fetus. What kind of impacts this has on fetal development, and whether or not these impacts have any negative effects on the offspring is yet to be explored, but is a logical next step. These findings are also a component of solving the puzzle of improving offspring outcomes through strategic supplementation when poor nutrition occurs during early gestation.

Table 1. Main effects of treatment and day of gestation on vitamin B_{12} and folate concentrations in maternal serum, allantoic fluid, and amniotic fluid from day 16 to 50 of gestation[1]

		Means[3]						*P*-values		
Matrix[2]	Nutrient	CON	R ES	d16	d34	d50	SEM[4]	Trt	Day	Trt x Day
Serum	B_{12}, ng/L	193.3	184.0	196.0	195.3	175.6	33.50	0.67	0.66	0.65
	Folate, µg/L	6.9	7.3	7.5	6.7	--	0.65	0.47	0.18	0.83
ALF	B_{12}, ng/L	298.9	423.0	--	353.4	368.6	61.10	0.04	0.79	0.09
	Folate, µg/L	8.9	12.2	--	13.7	7.4	1.62	0.03	0.003	0.07
AMF	B_{12}, ng/L	110.4	126.6	--	--	--	14.60	0.43	--	--
	Folate, µg/L	1.7	1.4	--	--	--	0.16	0.10	--	--

[1]Day of gestation (Day) = days after insemination.
[2]ALF = allantoic fluid; AMF = amniotic fluid.
[3]Treatment (Trt): Control (CON), restricted (RES); day of gestation: d0, d34, d50.
[4]Greatest SEM for the treatment × day interaction.

Table 2. Concentrations of vitamin B_{12} and folate in maternal serum, allantoic fluid and amniotic fluid across days 16, 34 and 50 of gestation as influenced by treatment

		Fluid[1]					*P*-values		
Nutrient	Item[2]	Serum	ALF	AMF	Treatment Mean[3]	SEM[4]	Treatment	Fluid	Treatment × Fluid
B_{12}, ng/L	CON	192.6[a]	303.3[b]	110.4[a]	202.1	46.80	0.11	<0.001	0.04
	RES	183.9[a]	428.3[c]	126.6[a]	246.3				
	Fluid[5]	188.2	365.8	118.5					
Folate, µg/L	CON	6.9	8.8	1.7	5.8	1.63	0.18	<0.001	0.10
	RES	7.3	12.8	1.4	7.1				
	Fluid	7.1[d]	10.8[e]	1.6f					

[1]ALF = allantoic fluid; AMF = amniotic fluid.

[2]CON = heifers fed a diet that met 100 percent of NRC requirements to gain 0.45 kg daily; RES = heifers restricted to 60 percent of the CON diet.

[3]Mean B_{12} and folate concentrations of treatment groups across fluids.

[4]Greatest SEM for the treatment × fluid interaction (Allantoic CON n = 13, Amniotic CON n = 5, Serum CON n = 17, Allantoic RES n = 16, Amniotic RES n = 6, and Serum RES n = 23) for B_{12}; average SEM for the day × treatment interaction (Allantoic CON n = 13, Amniotic CON n = 5, Serum CON n = 12, Allantoic RES n = 16, Amniotic RES n = 6, and Serum RES n = 16) for folate.

[5]Mean vitamin B_{12} or folate concentration across treatments within fluid.

[a-c]Means without a common superscript differ ($P < 0.05$) for treatment × fluid.

[d-f]Means within a row without a common superscript differ ($P < 0.05$) for main effect of fluid.

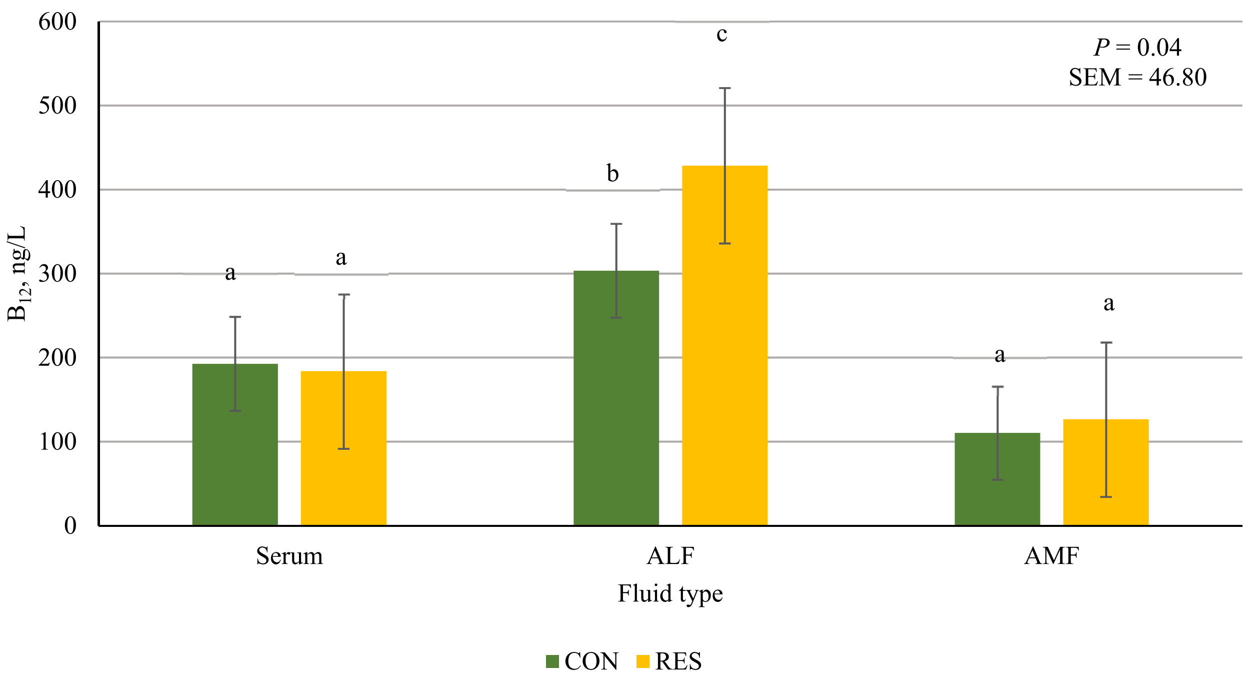

Figure 1. Concentration of B_{12} in maternal serum, allantoic fluid (ALF), and amniotic fluid (AMF) across days of gestation as influenced by maternal nutrition.

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The impact of hempseed cake supplementation on beef quality

Kiersten Gundersen[1], Kendall Swanson[1], Carl Dahlen[1], Thomas Winders[1], Eric Serum[2], David Smith[2], Bryan Neville[3], Eric P. Berg[1]

This study observed the results on carcass characteristics and meat quality characteristics after orally exposing commercial beef heifers to hempseed cake. The results indicated that hempseed cake did not influence the carcass characteristics or meat quality characteristics.

Summary

The objective of this study was to evaluate the impact of hempseed cake supplementation in a late finishing ration on carcass characteristics and meat quality attributes of meat obtained from commercial crossbred heifers. We hypothesized that harvest and meat quality characteristics will not be impacted in a positive or negative manner from the inclusion of hempseed cake within a ration fed to commercial heifers. Crossbred commercial finishing heifers (N = 32) were randomly assigned to two treatment groups; CON (control) and HEMP (hempseed cake) and utilized to evaluate harvest characteristics and meat quality attributes. Heifers were also randomly assigned to one of four withdrawal periods (day 0, 1, 4, or 8) from the feeding of hempseed cake. There were no differences observed for harvest and meat quality characteristics with hemp supplementation. Therefore, hempseed cake does not seem to influence beef quality in a positive or negative manner.

[1]Animal Science, NDSU
[2]United States Department of Agriculture, ETSARC, AMACRU, Fargo, ND
[3]United States Department of Agriculture, Clay Center, NE

Introduction

Hemp has been known to have medicinal and industrial uses for humans and livestock. Through the cultivation and processing of hemp byproducts such as fiber, food products, medicine, oilseed, and cannabinoids (cannabidiol (CBD) and (-)-Δ9-tetrahydrocannabinaol (THC; Oseyko et al., 2019) are produced.

Furthermore, hemp byproducts have the potential to serve as an alternative protein and fiber source for feed rations utilized by ruminants. The rich concentration of protein can make it an acceptable replacement for soybeans and/or barley (Oseyko et al., 2019).

Wide-spread incorporation of hemp coproducts have been hindered, due to government restrictions on feeding these products. With the rising cost of feed ingredients, producers and feedlot managers are searching for alternative feed ingredients that will not reduce feedlot efficiency. The objective of this study was to evaluate the impact of hempseed cake supplementation in a late finishing ration on carcass characteristics and meat quality characteristics of meat obtained from commercial crossbred heifers.

Experimental Procedures

Crossbred heifers 22 to 24 months of age (N = 32) were randomly assigned to one of two treatment groups, CON or HEMP, and adapted to a corn-based finishing diets over the first 21 days of the experiment. Treatments contained either 20% dried corn distillers grain with solubles or 20% hempseed cake (dry matter basis). The composition of the final phase of feed is presented in Table 1. Heifers were also randomly assigned to one of four withdrawal periods (day 0, 1, 4, or 8) from the feeding of hempseed cake. The length of withdrawal from hemp inclusion corresponded with the harvest day. Four CON and four HEMP heifers were harvested on each harvest day.

Carcass data included live weight (LW), hot carcass weight (HCW), dressing percentage (DP), 12th rib ribeye area (REA), 12th rib fat depth, kidney, pelvic, and heart fat (KPH expressed as a percentage of HCW), USDA yield grade (YG), USDA quality grade (QG), marbling score (MS), and bone maturity (BM). The DP was calculated using the following equation: (HCW / live weight) x 100 (American Meat Science Association, 2016). All of the following data were collected from the left side of each carcass; REA, fat depth, yield grade, marbling score, bone maturity, and quality grade recorded 24 hours post-harvest after chilling in the cooler at 35.6° Fahrenehit. The yield grade was calculated in accordance with the equation reported by the American Meat Science Association (AMSA, 2016) whereby:

$$\text{Yield Grade} = 2.50 + (2.50 \times \text{adjusted fat thickness; inches}) + (0.20 \times \text{percent KPH}) + (0.0038 \times \text{HCW; pounds}) - (0.32 \times \text{REA; square inches})$$

Marbling score was converted to a numeric score for statistical analysis whereby a USDA marbling score of devoid = 0 to 100, practically devoid = 100 to 199, traces = 200 to 299, slight = 300 to 399, small = 400 to 499, modest = 500 to 599, moderate = 600 to 699, slightly abundant = 700 to 799, moderately abundant = 800 to 899, and abundant = 900 to 999.

Two boneless steaks were obtained from the *Longissimus dorsi* on the right side of each carcass from the 11th to 13th thoracic rib. Steaks were individually vacuum packaged using a Cryovac machine (Sealed Air, Charlotte, NC) and frozen at 26° Fahrenheit until analysis. The first steak was evaluated for drip loss (overall moisture loss). Drip loss (DL) was collected by obtaining 7 to 18 grams of meat from each steak and suspending the samples of meat in a bag for 24 hours at 39.2° Fahrenheit. The samples were re-weighed after 24 hours in the cooler and the drip loss was calculated using the following equation: [(initial weight – final weight) / initial weight] x 100 (AMSA, 2016).

The second steak was utilized for purge loss (PL), pH, color (CIE L*, a*, and b*), cook loss (CL), and Warner-Bratzler shear force (WBSF; American Meat Science Association, 2016). Purge loss was determined by weighing the vacuum packaged steak and then removing the steak from the packaging and re-weighing the steak. The purge loss was calculated using the following equation: [(in-bag weight – out-bag weight) / in-bag weight] x 100 (AMSA, 2016). All color measurements were collected on steaks allowed to "bloom" for a 30-minute period at room temperature (66.2° Fahrenheit) prior to obtaining the CIE (Commission Internationale de l'Eclairage) L*, a*, and b* color space where L* = lightness/darkness, positive a* = red color space (negative a* = green color space), and positive b* = yellow color space (negative b* = blue color space). Color measurements were obtained using a Konica Minolta CR-400 Chroma Meter (Minolta Co., Ltd., Ramsey, NJ.) calibrated to a white tile at Y = 083.4, x = 0.3182, and y = 0.3251. The pH values were collected by a Hanna Instruments Portable pH/Temperature Meter HI 99163 (Hanna Instruments, Woonsocket, RI.). The second steaks were cooked on George Forman™ clamshell grills (Spectrum Brands, Beachwood, OH.) to an internal

Table 1. Composition of the fifth phase diet for CON vs. HEMP treatments

Ingredient, % of diet DM	Treatments: Control	Treatments: Hemp
Corn grain	55	55
DDGS	20	0
Hempseed cake	0	20
Corn silage	20	20
Supplement	5	5
Fine ground corn	1.82	1.82
Limestone	2	2
Salt	0.1	0.1
Urea	1	1
Vitamin premix[1]	0.01	0.01
Trace mineral premix[2]	0.05	0.05
Rumensin-90[3]	0.02	0.02

[1]Contained 48,510 kIU/kg vitamin A and 4,630 kIU/kg vitamin D

[2]Contained 3.62% calcium (Ca), 2.56% copper (Cu), 16% zinc (Zn), 6.5% iron (Fe), 4% manganese (Mn), 1,050 mg/kg iodine (I) and 250 mg/kg cobalt (Co).

[3]Formulated to supply monensin (Rumensin-90, Elanco Animal Health, Greenfield, IN) at 40 mg/kg.

*Trt represents treatment; Control (CON) = 20% corn silage, 55% corn grain, 20% DDGS, Hempseed cake (HEMP) = CON diet with replacement of 20% DDGS with 20% hempseed cake.

Table 2. Quantifications of cannabinoids in HEMP ration.

Cannabinoid	Cannabinoid Concentration in Hempseed Cake
Cannabichromene	Not detected ppm
Cannabidiol	5 ppm
Cannabidiolic Acid	16 ppm
Cannabidivarin	Not detected ppm
Cannabinol	Not detected ppm
Tetrahydrocannabinolic acid	Not detected ppm
Δ8-THC (Delta-8-tetrahydrocannabinol)	Not detected ppm
Δ9-THC (Delta-9-tetrahydrocannabinol)	Not detected ppm
Cannabigerol	Not detected ppm

temperature of 149° Fahrenheit and re-weighed after reaching 66.2° Fahrenheit (room temperature). The cook loss was calculated using the following equation: [(raw weight – cooked weight) / raw weight] x 100. Warner-Bratzler shear force was conducted according to AMSA (2016) and 6 cores (1.27cm in diameter) were extracted from each steak after reaching an internal temperature of 73.4° Fahrenheit. Each core was then placed in the middle of a V-notched (60-degree°- angle) cutting blade. After the blade cut through the steak core sample, a number was displayed that indicated the kilograms of force needed to cut through the core.

Data collected from harvest and meat quality characteristics were analyzed using the MIXED procedures of SAS (SAS 9.4, SAS Institute Inc., Cary, NC) setting the fixed effects of treatment and slaughter day for all analyses. Significance levels were set at $P \leq 0.05$. Least-square means was separated using the PDIFF statement in SAS 9.4. Data were also analyzed for the interaction between treatment group and slaughter day.

Results and Discussion

No differences were observed across treatment or treatment x withdrawal day for any harvest criteria (Table 3). The similarities in harvest characteristics between the two treatment groups suggests that feeding hempseed cake had neither positive or negative effects on the economically important harvest parameters.

To our knowledge, this is the first study to implement the supplementation of hempseed cake in finishing rations for commercial beef heifers to evaluate the impacts of supplementation on beef quality.

Table 3. Interactions of treatment groups and withdrawal days for harvest characteristics between CON and HEMP treatments

		Withdrawal Days				*P* Values	
Carcass Data[1]	Trt	0	1	4	8	Trt	Trt x Withdrawal Day
LW (kg)	CON	716 ± 28.92	687 ± 28.92	685 ± 28.92	692 ± 28.92	0.42	0.81
	HEMP	665 ± 28.92	673 ± 28.92	686 ± 28.92	689 ± 28.92		
HCW (kg)	CON	432 ± 18.45	408 ± 18.45	421 ± 18.45	418 ± 18.45	0.47	0.77
	HEMP	399 ± 18.45	400 ± 18.45	420 ± 18.45	420 ± 18.45		
DP (%)	CON	60.50 ± 0.69	59.40 ± 0.69	61.39 ± 0.69	60.43 ± 0.69	0.94	0.91
	HEMP	60.08 ± 0.69	59.44 ± 0.69	61.34 ± 0.69	60.99 ± 0.69		
REA (cm^2)	CON	99.68 ± 0.66	96.64 ± 0.66	96.64 ± 0.66	93.09 ± 0.66	0.34	0.16
	HEMP	86.64 ± 0.66	97.61 ± 0.66	90.52 ± 0.66	99.23 ± 0.66		
FD (cm)	CON	1.78 ± 0.09	1.60 ± 0.09	1.78 ± 0.09	1.80 ± 0.09	0.61	0.66
	HEMP	1.57 ± 0.10	1.55 ± 0.09	2.01 ± 0.09	1.49 ± 0.09		
YG	CON	3.4 ± 0.32	3.15 ± 0.32	3.45 ± 0.32	3.63 ± 0.32	0.87	0.40
	HEMP	3.5 ± 0.37	3.0 ± 0.37	3.95 ± 0.32	3.03 ± 0.32		
QG	CON	2.0 ± 0.09	2.0 ± 0.09	2.0 ± 0.09	2.0 ± 0.09	0.33	0.41
	HEMP	1.75 ± 0.09	2.0 ± 0.09	2.0 ± 0.09	2.0 ± 0.09		
MS	CON	3.90 ± 0.46	3.73 ± 0.46	4.1 ± 0.46	3.3 ± 0.46	0.55	0.29
	HEMP	3.05 ± 0.46	4.00 ± 0.46	4.55 ± 0.46	4.23 ± 0.46		
BM	CON	1.68 ± 0.28	1.0 ± 0.28	1.30 ± 0.28	1.60 ± 0.28	0.45	0.53
	HEMP	1.0 ± 0.28	1.0 ± 0.32	1.33 ± 0.28	1.63 ± 0.28		

*Trt represents treatment; Control (CON) = 20% corn silage, 55% corn grain, 20% DDGS, Hempseed cake (HEMP) = CON diet with replacement of 20% DDGS with 20% hempseed cake.

[1]Carcass Data abbreviations: LW = live weight; HCW = pre-rigor (hot) carcass weight; FD = subcutaneous fat depth measured adjacent the 10th rib; YG = USDA yield grade; QG = USDA quality grade; whereby Prime = 1.0 – 1.99, Choice = 2.0 – 2.99; MS = marbling score; whereby devoid = 0-100, practically devoid = 100-199, traces = 200-299, slight = 300-399, small = 400-499, modest = 500-599, moderate = 600-699, slightly abundant = 700-799, moderately abundant = 800-899, and abundant = 900-999; BM = bone maturity; whereby 1.0 – 1.99 = A0 to A99 maturity.

USDA Quality Grade; Prime = 1.0 – 1.99, Choice = 2.0 – 2.99

No differences were reported for purge loss and drip loss. However, there were significant differences indicated for pH and cook loss, based upon the interaction of treatment and withdrawal day. The most noticeable difference for pH was on day 0. The day 0 CON had a significantly lower pH than HEMP. Also, the cook loss was lower for CON on days 0, 1, and 8. Finally, there was noticeably lower tenderness values for the CON group throughout all withdrawal periods [Table 4]. These differences cannot be easily rationalized from a physiological perspective. That said, the differences found in pH, cook loss, and shear force could be mainly driven by the random association of slaughter day and completely unrelated to the dietary treatment. Additional research is necessary to verify the cause of differences in the meat quality characteristics between heifers fed the control diet fed and the hempseed cake diet.

Acknowledgments

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Table 4. LSMEANS (± standard error) for meat quality characteristics obtained from CON vs. HEMP treatments

Quality Traits[2]	Trt	Withdrawal Days 0	1	4	8	*P* Value Trt	Trt x Withdrawal Day
pH	CON	5.41 ± 0.02 a	5.52 ± 0.02 b	5.53 ± 0.02 b	5.53 ± 0.02 b	0.20	0.03
	HEMP	5.49 ± 0.02 b	5.52 ± 0.02 b	5.52 ± 0.02 b	5.52 ± 0.02 b		
PL (%)	CON	6.47 ± 0.80	6.81 ± 0.80	4.94 ± 0.80	4.83 ± 0.80	0.69	0.33
	HEMP	4.94 ± 0.80	7.13 ± 0.80	5.74 ± 0.80	6.15 ± 0.80		
DL (%)	CON	6.07 ± 2.33	5.54 ± 2.33	4.17 ± 2.33	0 ± 2.33	0.61	0.30
	HEMP	3.47 ± 2.33	1.79 ± 2.33	2.50 ± 2.33	4.58 ± 2.33		
CL (%)	CON	16.11 ± 2.09 a	13.30 ± 2.09 a	19.37 ± 2.09 ac	14.34 ± 2.09 a	0.09	0.02
	HEMP	16.96 ± 2.09 a	21.07 ± 2.09 b	14.34 ± 2.09 a	20.97 ± 2.09 bc		
WBSF Avg. (N)	CON	2.36 ± 0.21	1.72 ± 0.21	2.71 ± 0.21	2.32 ± 0.21	0.009	0.56
	HEMP	2.78 ± 0.21	2.14 ± 0.21	2.82 ± 0.21	3.04 ± 0.21		

*Trt represents treatment; Control (CON) = 20% corn silage, 55% corn grain, 20% DDGS, Hempseed cake (HEMP) = CON diet with replacement of 20% DDGS with 20% hempseed cake.

[1]Values within the same row with different letter indicate significance at ($P<0.05$).

[2]Quality Trait abbreviations: PL = purge loss; DL = drip loss; CL = cook loss; and WBSF Avg. = Warner Bratzler Shear Force average.


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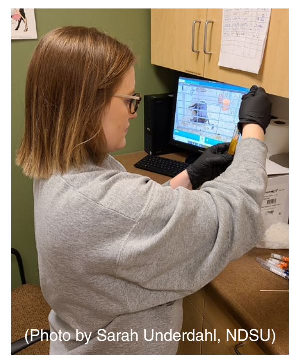
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