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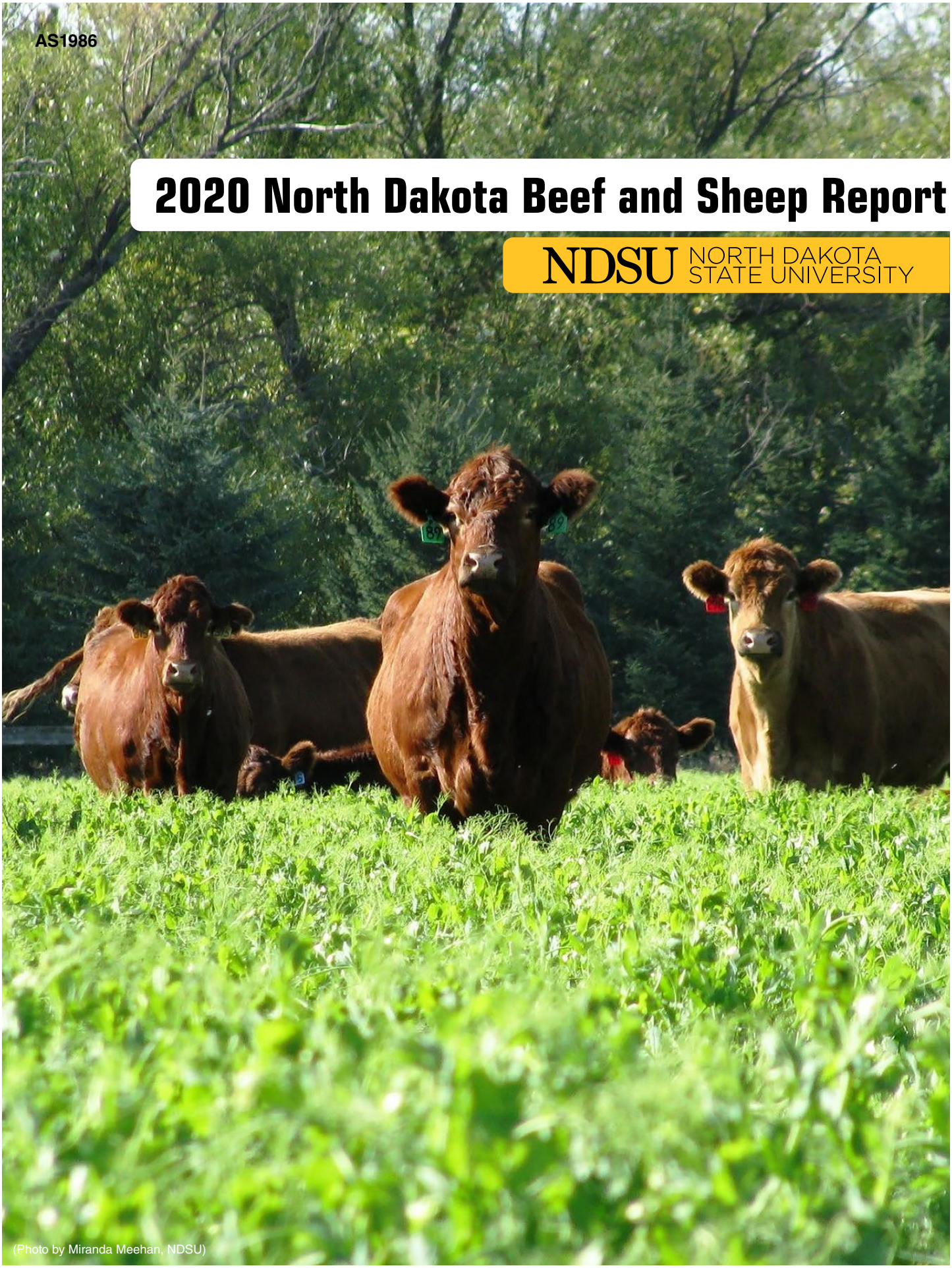
2020 North Dakota Beef and Sheep Report

NDSU NORTH DAKOTA STATE UNIVERSITY



(Photo by Miranda Meehan, NDSU)

2020 North Dakota Beef and Sheep Report

This is the ninth year that I have been the coordinator and editor of the North Dakota Beef Report (the last three years as the North Dakota Beef and Sheep Report), and I still enjoy this activity because it is an important means to report our research findings to producers and industry personnel across North Dakota and beyond. It also allows me to reflect and think about the quality and breadth of beef cattle and sheep research in North Dakota.

The beef and sheep programs at the North Dakota Agricultural Experiment Station's Main Station in Fargo and the Research Extension Centers across North Dakota are dedicated to serving the producers and stakeholders in North Dakota by developing new knowledge and technology to improve the management, efficiency and production of high-quality beef cattle and sheep. This report includes a broad range of research that provides producers and stakeholders with one document that contains reports of beef- and sheep-related research conducted at NDSU each year.

For this year's report, I am excited that we 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 again thank Ellen Crawford and Deb Tanner for their great assistance in editing and formatting the reports so that we can produce a great statewide report. Also, thanks to the contributors to the report and to the staff and students who help with the research, teaching and Extension activities on beef cattle and sheep.

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

I assure you that although the past few years have been challenging and unpredictable in many ways, both in agriculture as a whole and at the university, we are doing our best to provide relevant research results and Extension programming to support the beef cattle and sheep industries in North Dakota in the near and long term.

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 beef cattle and sheep research in North Dakota.

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

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Quality of livestock water sources in North Dakota

Miranda A. Meehan[1] and Thomas Scherer[2]

Providing adequate water to livestock is critical for animal health and production. The goal of this Extension program is to improve the quality of livestock water and reduce losses of livestock due to toxic water conditions. To date, 158 samples have been screened. These samples display high variability in the total dissolved solids (TDS) concentration, reinforcing the importance of monitoring the quality of water sources. Surface water sources have greater potential to have an elevated TDS concentration in comparison with groundwater.

Summary

Extension agents are monitoring the quality of water sources utilized by livestock. To date, TDS have been screened for 158 samples from 127 locations in 20 counties. Samples were classified based on county, sampling date and water source. Water samples were collected and screened for TDS concentrations monthly using an electric conductivity meter. Samples screened displayed high variability in the TDS concentration, ranging from 120 to 23,050 parts per million (ppm). The majority of the samples screened (84%) were classified as acceptable for livestock consumption (TDS concentration below 3,000 ppm). Surface water sources had a greater potential to have an elevated TDS concentration, with 22% of samples exceeding 3,000 ppm, in comparison with only 2% of groundwater samples. The variation in the results to date reinforces the importance of monitoring the quality of water sources throughout the grazing season to ensure that livestock performance and health are not negatively impacted by water quality.

Introduction

Providing adequate water to livestock is critical for animal health and production. Good-quality water can increase feed intake and weight gain of cattle. The quality of water accessible to livestock is directly tied to the amount of forage they consume. Gains can be improved by as much as 0.24 pound per day in yearlings and 0.33 pound per day in calves receiving good-quality water (Willms et al. 2002).

Providing good-quality water also can improve herd health. Livestock with primary water sources of ponds and dugouts have a greater risk of contracting illnesses such as giardia, leptospirosis and cyanobacterial poisoning, compared with livestock drinking from a trough.

All natural water contains salts, which are dissolved minerals or solids. The concentration of the TDS is measured in ppm. Water quality varies depending on the source.

Groundwater tends to be of higher quality than surface water; however, some aquifers in North Dakota have naturally high levels of potentially toxic salts, such as sulfate, due to geology. Weather also can influence water quality. When runoff is low in the spring or during a drought, the salts in surface water become more concentrated as water levels decline and can reach levels that are toxic.

The goal of this Extension program is to improve the quality of livestock water and reduce losses of livestock due to toxic water conditions. This will be accomplished by monitoring and reporting the level of TDS in livestock sources across North Dakota throughout the grazing season. Monitoring data will demonstrate the variability in water quality as it relates to location, source, time of year and between years.

Experimental Procedures

In the summer of 2020, NDSU Extension initiated a pilot program to monitor the quality of water sources utilized by livestock. To date, TDS have been measured at 127 locations in 20 counties. Sites sampled included 98 surface water sources and 29 groundwater sources.

Samples will be collected monthly during the grazing season May through October in 2020 and 2021. Extension agents were critical to the success of this effort, with 23 agents volunteering to aid in sample collection.

Water samples were collected monthly and screened for TDS using an electric conductivity meter. Samples were classified based on county, sample date and water source. If TDS concentrations were elevated (greater than 4,500 ppm)

[1]Department of Animal Sciences, NDSU
[2]Department of Agricultural and Biosystems Engineering, NDSU

at the time of screening, laboratory analysis was recommended. In addition to screening for TDS, a visual assessment was conducted for the presence of cyanobacteria blooms.

Results and Discussion

To date, 158 samples have been screened. They displayed high variability in the TDS concentrations, ranging from 120 to 23,050 ppm (Table 1). The majority of the samples screened (133, 84%) were classified as acceptable for livestock consumptions with TDS concentrations below 3,000 ppm.

At TDS concentrations between 3,000 and 5,000, feed conversion and intake can decline, resulting in reduced livestock performance (Meehan et al. 2015). The TDS concentrations of 19 samples were between 3,000 and 5,000 ppm.

TDS concentrations between 5,000 and 7,000 ppm were observed for one sample. Concentrations at that level can result in a laxative effect (Meehan et al. 2015).

Three samples had concentrations between 7,000 and 10,000 ppm. Pregnant or lactating ruminants should not consume water with TDS between 7,000 and 10,000 ppm (Meehan et al. 2015).

Three samples exceeded 10,000 ppm. When TDS concentration exceeds 10,000 ppm, brain damage or death can occur (Meehan et al. 2015). Of the samples collected, 11 exceeded 4,500 ppm and were recommended to be sent to a laboratory for additional analyses.

Variability was observed between and within groundwater and surface water sources. Overall, groundwater had less variability and was of higher quality than surface water sources (Figure 1). The average TDS level of groundwater sources was 1,128 ppm.

The majority (98%) of groundwater samples screened were acceptable for livestock consumption, whereas surface water varied in quality, ranging from 120 to 23,050 ppm, with an average of 2,133 ppm. The TDS level was considered acceptable for 78% of surface water samples.

To understand the variation in water quality during the grazing season, samples were divided by month and continue to be monitored monthly. The TDS of groundwater increased in variability from May to June; however, the average TDS was similar between months (Table 2, Figure 2).

A similar trend was observed for the surface water samples (Table 2, Figure 3). The increased variation is due to the high TDS concentrations of surface water sources sampled in areas of the state impacted by drought. In addition to the impacts of drought, variation in geology and temperature across the state all likely contributed to the differences observed.

Water quality screening and analysis of livestock sources allows ranchers to ensure water quality is not impacting livestock performance and/or health. It also can aid in making management decisions such as when livestock should be removed from a pasture or when an alternative water source should be used or developed. A water development can help ensure that livestock have access to good-quality water throughout the grazing season.

Results of the project will help us understand and demonstrate the variability in water quality and factors that may influence this variability, including location, source, time of year and between years.

Table 1. Total dissolved levels of samples screened.

Total Dissolved Solids (TDS) in ppm	Groundwater	Surface Water
< 3,000	47	86
3,000 – 5,000	1	18
5,000 – 7,000		1
7,000 – 10,000		3
> 10,000		3

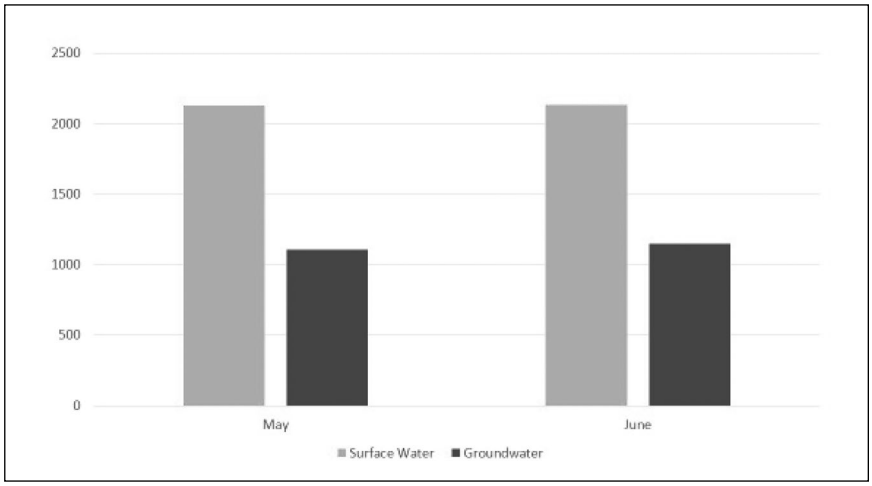

Figure 1. Average total dissolved solids (TDS) of water sources by month.

Table 2. Mean and standard deviation for total dissolved concentrations of samples screened by month and water source.

Month	Groundwater	Surface Water
May	1,106.5 ± 571.7 (n = 22)	2,128.6 ± 2,489.3 (n = 35)
June	1,147 ± 662.32 (n = 26)	2,134.9 ± 3,012.1 (n = 75)

*n denotes the number of samples screened

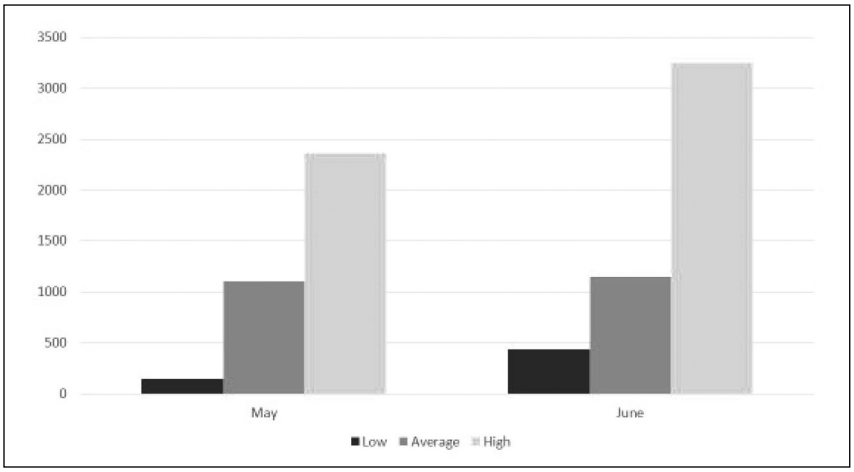

Figure 2. Variation in total dissolved solids (TDS) of groundwater by month.

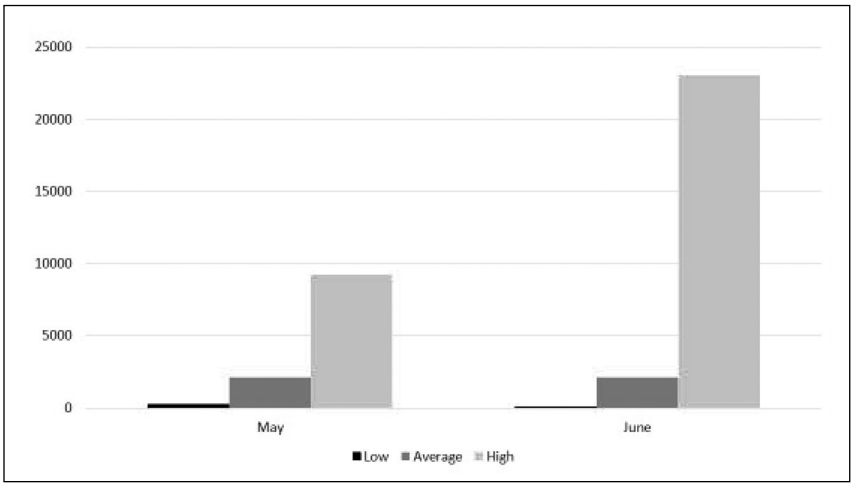

Figure 3. Variation in total dissolved solids (TDS) of surface water by month.

The variation in the results to date reinforces the importance of monitoring the quality of water sources throughout the grazing season to ensure livestock performance and health are not negatively impacted by water quality.

Contact your local NDSU Extension agent if you are concerned about water quality in your pastures. The agent can conduct a screening using a TDS meter and/or assist with sample collection and submission for laboratory analyses.

Acknowledgments

Thank you to the following NDSU Extension personal for their assistance in monitoring water quality: Hannah Nordby, Lindy Berg, Paige Brummund, Shelby Hewson, Ashley Ueckert, Katelyn Hain, Craig Askim, Emily Trzpuc, Rachel Wald, Renae Gress, Tessa Osterbauer, Max Robison, Rick Schmidt, Chandy Howard, Yolanda Schmidt, Dan Floske, Julianne Racine, Devan Leo, Kelly Leo, Jill Lagein, Calla Jarboe, Melissa Seykora, Brian Zimprich, Aspen Lenning, Karl Hoppe and Mary Keena.

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Predicted nutrient supply of Kentucky bluegrass relative to requirements for cow-calf pairs throughout the grazing season in central North Dakota

Kendall Swanson[1], David Toledo[2], Miranda Meehan[1], Carl Dahlen[1] and Rachael Christensen[2]

The objective of this study was to examine the nutritional quality of Kentucky bluegrass relative to nutrient requirements of cow-calf pairs during the grazing season for two grazing seasons in central North Dakota. Results indicated that Kentucky bluegrass pastures may not meet metabolizable energy and protein requirements throughout the grazing season, forage quality generally decreases during the grazing season and that early grazing in a drought year results in a greater decrease in forage quality during the grazing season than during nondrought years.

Summary

Kentucky bluegrass forage samples were collected during the 2017 and 2018 grazing seasons from pastures at the U.S. Department of Agriculture's Northern Great Plains Research Laboratory near Mandan, N.D. Kentucky bluegrass samples were collected from plots that were or were not mowed before the grazing season to represent pastures that had grazed early in the grazing season or not. Metabolizable energy (ME) and (MP) supply was estimated from crude protein concentrations and ruminal in vitro dry matter digestibility analyses. Environmental conditions and dietary characteristics for each month of the grazing season were entered into the NASEM model to predict ME and MP requirements and supply for a typical cow-calf pair in central North Dakota. The predicted supply of ME and MP generally decreased as the grazing season progressed. The predicted requirements for ME and MP were greater than supply for all months except for mowed pastures in May of 2017. The supply of ME and MP decreased to a greater extent as the grazing season progressed in mowed pastures in 2017, which was a drought year, than in 2018. This indicates that early grazing of Kentucky bluegrass in a drought year results in a greater decrease in forage quality as the grazing season progresses. Strategies to overcome potential deficiencies in pastures predominately containing Kentucky bluegrass should be considered.

[1]Department of Animal Sciences, NDSU
[2]Northern Great Plains Research Laboratory, U.S. Department of Agriculture-Agricultural Research Service, Mandan N.D.

Introduction

Kentucky bluegrass (*Poa pratensis* L.) is a cool-season, mat-forming, rhizomatous, grazing-tolerant, perennial midstature grass that is present, even dominant, in many of the grasslands of the northern Great Plains (Toledo et al., 2014). The exact origin or mechanisms of invasion of this grass are largely unknown, but historical records suggest that in the northern Great Plains, it was present in trace quantities in the late 1800s and through the 1900s until around the 1990s, when it became more widespread throughout the region and is still prevalent.

Reductions in grassland diversity not only have ecological consequences but also have consequences for livestock production. Despite Kentucky bluegrass being productive and palatable, it is also a C3 (cool season) species. The northern Great Plains provide optimum growing conditions for cool-season grasses for most of the growing season, but the region also has large, often unpredictable, weather variability.

Forage quality may be affected in pastures consisting primarily of Kentucky bluegrass because of a lack of diversity of forages that can maintain sufficient forage quality for cattle throughout the growing season. However, changes in nutritional quality of Kentucky bluegrass have not been quantified for this region. Therefore, the objective of this study was to examine the nutritional quality of Kentucky bluegrass relative to nutrient requirements of cow-calf pairs for two grazing seasons in central North Dakota.

Experimental Procedures

Kentucky bluegrass forage samples were collected in 2017 and 2018 approximately every three weeks from May (June in 2018) through September between 10 a.m. and 2 p.m. from pastures at the USDA Northern Great Plains Research Laboratory near Mandan, N.D. Kentucky bluegrass samples were collected from plots that were or were not mowed before the

grazing season from quadrats (approximately 20 by 20 inches) placed inside grazing exclusion cages (approximately 11.5 by 6 feet).

Bluegrass samples were dried at 140 F until dry and ground to pass a 2-millimeter screen using a Wiley mill. Samples were analyzed for crude protein using near infrared reflectance spectroscopy and for in vitro ruminal true dry matter digestibility (IVTDMD) using the ANKOM DAISY II system.

Briefly, samples were weighed in filter bags in replicate for each pasture and timepoint and were subjected to anaerobic incubation at 102 F in ruminal fluid, which was collected from two dry, nonpregnant beef cows fed a grass hay-based diet at maintenance. Ruminal fluid from each cow was filtered through four layers of cheesecloth, equally mixed and combined with preheated McDougall's buffer at a ratio of one part rumen contents to four parts buffer.

Samples were incubated for 48 hours and rinsed, dried, weighed and subjected to neutral detergent fiber analysis to remove residual microbial particles. Digestible energy (DE) concentrations were estimated using the regression equation from dry matter digestibility developed by Rittenhouse and Streeter (Rittenhouse et al., 1971) for native range.

What should be pointed out is that this prediction is from total tract digestibility and, therefore, may result in under-predicting DE. Concentrations of total digestible nutrients (TDN), metabolizable energy (ME), net energy for maintenance (NE_m) and NE for gain (NE_g) were calculated using equations described by NASEM (2016).

Ruminally undegradable protein (RDP, %) was estimated as: 100 – %IVDMD. Nutrient and energy concentrations for forage samples were estimated on the 15th of each month in each year by using weighted averages from samples collected on actual collection dates. Weighted averages for CP, RDP, TDN, ME, NEm and NEg for the 15th of each month then were entered into the NASEM model for predicting nutrient supply and requirements (NASEM, 2016).

To establish the stage of production representative of northern Great Plains herds, we used data generated from the NDSU PregCard survey system (Dahlen and Stoltenow, 2015). Data generated during a four-year period from 2,695 females revealed a mean bull turnout date of June 6. Assuming a 282-day gestation, calves conceived on the first day of the breeding season would be born on March 15.

Based on data from Rodgers et al. (2012), we anticipate calving to peak 25 days into the calving season in a natural service breeding scenario and, therefore, we estimated that the average calving date was April 9. Days since calving and days pregnant used in the NASEM model were calculated based on the predicted calving date of April 9.

Cows were assumed to be Simmental × Angus, 4 years of age, with 1,400 pounds of body weight and a body condition score of 5. Cows were assumed not to be limited in forage availability, and the NASEM model was used to predict average monthly dry-matter intake. Average monthly and previous monthly temperature and relative humidity, and average monthly minimum night temperature and wind speed in each year were obtained from the National Weather Service by querying for the weather station at the Northern Great Plains Research Laboratory, and were entered into the NASEM model for environmental conditions.

Results and Discussion

The predicted supply of ME and MP generally decreased as the grazing season progressed. The predicted requirements for ME and MP were greater than supply for all months except for mowed pastures in May of 2017 (Figure 1). The severity of the deficiency may not be as great as indicated in the graphs because of the approach used to predict ME concentrations in the forage from IVDMD.

In addition, although clipping is a good proxy for estimating forage intake and quality, cows may selectively graze forages, resulting in greater MP and ME intake in consumed compared with clipped forages (Undi et al., 2020). The mowed pastures are more representative of pastures where grazing would begin early in the grazing season, whereas unmowed pastures are more representative of pastures where grazing would begin at differing times of the grazing season.

The supply of ME and MP decreased to a greater extent as the grazing season progressed in mowed pastures in 2017, which was a drought year, than in 2018. This indicates that early grazing of Kentucky bluegrass in a drought year results in a greater decrease in forage quality as the grazing season progresses.

Additionally, the predicted requirement for and deficiency in MP supply was greatest in June for 2017 and remained through the end of the grazing season. As June is the most common time for bull turnout (Dahlen and Stoltenow, 2015), the potential exists for inadequate nutrition throughout the entire first trimester, which could compromise pregnancy rate and other production parameters, fetal development and long-term productivity (Caton et al., 2019).

Strategies to overcome potential deficiencies in pastures predominately containing Kentucky bluegrass should be considered. Approaches to increase species diversity should be explored to help

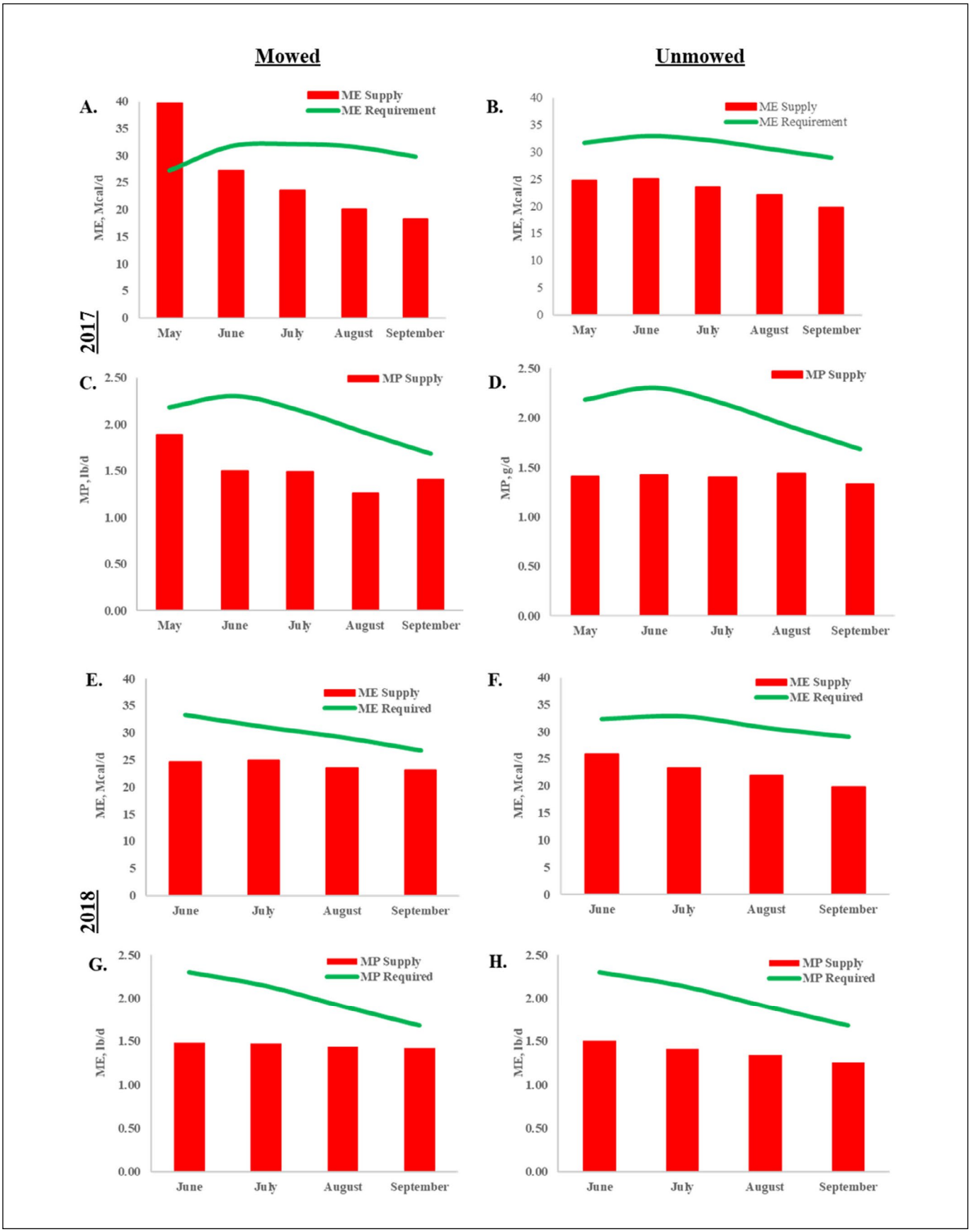

Figure 1. Metabolizable energy (ME; A, B, E, F) and metabolizable protein (MP; B, C, G, H) supply (bars) and predicted requirements (line) for cow-calf pairs from mowed (A, C, E, G) and unmowed (B, D, F, H) pastures in 2017 (A, B, C, D) and 2018 (E, F, G, H).

maintain forage quality throughout the grazing season, especially during drought years.

Alternatively, supplementation strategies should be planned in advance of turnout and implemented when necessary. We plan to continue to develop prediction models to improve the accuracy of prediction of ME and MP, as well as examine different production scenarios, such as changing the calving season for cows or for use in heifer development or backgrounding programs.

Acknowledgments

This work was supported by funds from the Conservation Effects Assessment Project jointly funded by the USDA Natural Resources Conservation Service (NRCS) and the Agricultural Research Service (ARS).

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Discovering value in North Dakota calves: Dakota Feeder Calf Show feedout project XVIII, 2019-2020

Karl Hoppe[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 profitability between consignments from the top five herds and the bottom five herds was $99.56 per head for the 2019-2020 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. 19, 2019. After a 213-day feeding period with 2.56% death loss, cattle averaged 1,344.7 pounds (shrunk harvest weight). Feed required per pound of gain was 6.4 (dry-matter basis). Overall pen average daily gain was 3.35 pounds. Feed cost per pound of gain was $0.464 and total cost per pound of gain was $0.728. Profit ranged from $165.95 per head for pen-of-three cattle with superior growth and carcass traits to $41.52 per head (no death loss). Substantial variability in the feeding and carcass value of spring-born calves continues to be discovered through participation in the feedout project.

Introduction

Cow-calf producers need to remain competitive with other livestock and poultry producers in the meat industry. By determining calf value in a feedout program, cow-calf producers can identify superior genetics under common feedlot management. 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. Because North Dakota has low-cost feeds and a favorable climate, low cost per pound of gain can be accomplished (Hoppe et al., 1997).

Combining the low cost of gains with the identification of superior cattle, this ongoing feedlot project provides cattle producers with an understanding of cattle feeding and cattle selection in North Dakota. The objective of the Dakota Feeder Calf Show feedout project is to provide data to North Dakota cattle producers to examine the actual value of their spring-born beef steer calves, provide comparisons among herds, and benchmark feeding and carcass performance.

Experimental 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. 19, 2019, at the Turtle Lake Weighing Station, Turtle Lake, N.D., 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 117, of which 100 competed in the pen-of-three contest.

The calves then were shipped to the Carrington Research Extension Center, Carrington, N.D., 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.

The cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were reimplanted with Synovex-choice.

An open house was held on Feb. 7, 2020, at the Carrington Research Extension Center Livestock Unit, where the owners reviewed the calves and discussed marketing conditions.

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

The cattle were harvested on May 20, 2020 (114 head). The cattle were sold to the Greater Omaha Packing Co., Omaha, Neb., on a flat bid carcass basis, with no premiums and discounts based on carcass quality. Carcass data was not collected after harvest due to packing plant restraints resulting from the COVID 19 pandemic.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 596.2 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on Oct. 19, 2019. After an average 213-day feeding period, cattle averaged 1,344.7 pounds (at plant, shrunk weight). Death loss was 2.56% (three head) during the feeding period.

Average daily feed intake per head was 32.7 pounds on an as-fed basis and 21.6 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 9.7 on an as-fed basis and 6.4 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.464. The overall yardage cost per pound of gain was $0.102. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.728.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.008990915* initial calf weight, pounds) + 151.2910293) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

The top-profit pen-of-three calves with superior genetics returned $165.95 per head, while the bottom pen-of-three calves returned $41.52 per head. The average of the five top-scoring pens of steers averaged $152.66 per head, while the average of the bottom five scoring pens of steers averaged $53.10 per head.

Exceptional average daily gains, weight per day of age and harvest weights can be found in calves produced from North Dakota beef herds. Feedout projects provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

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Effects of supplemental dietary leucine fed to lambs on pancreatic and intestinal starch digesting enzymes

Jessica Reiners[1], Travis Hoffman[1], Steven E. Anderson[1] and Kendall Swanson[1]

The objective of this study was to determine the effects of supplemental leucine during the neonatal period on starch digestive enzymes in finished lambs. Leucine supplementation during the neonatal period decreased maltase and isomaltase activity in the small intestine in finished lambs. Supplemental leucine during the neonatal period can alter digestive enzyme activity of finished lambs, which may result in decreased digestibility of starch-based feeds such as feed grains.

Summary

Neonatal twin- or triplet-born ram lambs (n = 19) from the NDSU Sheep Unit were used to determine the effects of neonatal supplemental leucine (Leu) added to milk replacer on pancreatic and intestinal digestive enzyme activity of finished lambs. Lambs were sorted to one of two treatments. Lambs were fed milk replacer for ad libitum intake with or without supplemental Leu. Water, chopped alfalfa hay and creep feed were provided for ad libitum intake once lambs were 2 weeks old. Lambs were weaned after 42 days and fed to a finished weight. Lambs were slaughtered at the NDSU Meat Lab, and samples of the pancreas and small intestine were collected. Supplementation of Leu during the neonatal period did not affect pancreatic α-amylase or trypsin activities in finished lambs. Activity of glucoamylase in the small intestine was not affected by treatment. Isomaltase activity tended to decrease ($P < 0.06$) in Leu-supplemented lambs and maltase activity decreased in Leu-supplemented lambs ($P < 0.01$). These data show that early supplementation of Leu has long-term effects on intestinal enzyme activity.

Introduction

In finishing lambs and cattle, starch is provided in diets as a major energy source for meat production, but higher levels of inclusion can lead to ruminal acidosis and decreased performance. Starch that avoids degradation in the rumen is digested in the small intestine, and this shift in site of starch digestion could decrease the incidence of metabolic disorders.

In addition, starch digestion is 42% more efficient in the small intestine than in the rumen (Huntington et al., 2006), and shifting starch degradation away from the rumen to the small intestine will capture greater energy without increasing risks of adverse metabolic effects. However, the small intestine is limited in its ability to degrade the available starch (Harmon, 2009), which can lead to feed waste. We hypothesize that nutrition during the neonatal period could influence the production of digestive enzymes later in life.

The pancreas is responsible for the secretion of α-amylase, which initiates starch digestion in the small intestine. Yu et al. (2014) showed that duodenal infusion of Leu increased pancreatic α-amylase secretion in goats.

However, Cao et al. (2019) reported that supplemental Leu fed to milk-fed calves had limited effects on α-amylase secretion. Data on the effects of dietary leucine on intestinal carbohydrase enzyme activity in lambs are limited and little is known about potential programming effects later in life.

The objective of this study is to determine the effects of supplemental Leu fed to neonatal lambs on pancreatic and small-intestinal digestive enzyme activity in finished lambs.

Experimental Procedures

All procedures involving the use of animals were approved by the North Dakota State University Institutional Animal Care and Use Committee. Nineteen neonatal fall-born twin or triplet Dorset-cross ram lambs (11.2 ± 0.33 pounds) were used in an experiment to determine long-term effects of neonatal supplementation of Leu in milk replacer.

Lambs remained with ewes for 12 hours post-birth to ensure adequate colostrum intake and then were removed from ewes and sorted to either a control milk replacer (Shepherd's Choice, Premier1 Supplies, Washington, Iowa; **CON**, n = 10; Table 1) or milk replacer with Leu added at 2.9% dry matter (DM) (**LEU**, n = 9). Lambs were trained to consume milk from a LAC-TEK Stainless 61450 (Biotic Industries Inc., Bell Buckle, Tenn.) milk dispenser that would allow for ad

[1]Department of Animal Sciences, NDSU

libitum milk intake. Both machines were calibrated to deliver the same amount of milk replacer and heated water.

Lambs were assigned randomly to the treatments and stratified by birth weight. Lambs were allowed access to milk for 42 days. Creep feed and chopped hay were provided for ad libitum intake when lambs reached 14 days of age (Table 1).

On day 42, lambs were removed from milk-feeding pens, comingled with lambs from both treatments, and provided ad libitum access to creep feed and chopped alfalfa hay. After all lambs were weaned, they were moved to the NDSU Animal Nutrition and Physiology Center and group housed.

Lambs were moved to individual pens when they reached approximately 50 pounds to monitor daily feed intake. Creep feed and chopped alfalfa hay were provided at 5% of body weight (BW) and lambs then were transitioned to a finishing diet during 14 days. The finishing diet (Table 1) consisted of 90% pellet and 10% chopped alfalfa hay.

Lambs were slaughtered at the NDSU Meat Laboratory on two days. The five heaviest lambs from each treatment were selected for slaughter after 67 days on feed, and all remaining lambs were slaughtered on the second day after 95 days on feed.

Samples of the pancreas and a section of the jejunum in the small intestine were collected for digestive enzyme analysis. Data were analyzed using the GLM procedure of SAS. Significance was declared at $P \leq 0.05$ and a tendency at $0.05 < P \leq 0.10$.

Results and Discussion

Activities of pancreatic α-amylase and trypsin (enzymes responsible for initial starch and protein digestion in the small intestine) were not affected by treatment (Table 2). Glucoamylase, isomaltase and maltase are produced in the small intestine and are responsible for the final steps of starch digestion.

Glucoamylase activity was not affected by Leu supplementation. Isomaltase activity tended to decrease in Leu-supplemented lambs when expressed as U/g intestine ($P = 0.06$). Supplemental Leu during the neonatal period decreased maltase activity when expressed as U/g intestine ($P < 0.01$).

These results showed an approximate 40% decrease in intestinal maltase activity of Leu-supplemented lambs when compared with control lambs. Fahey and Berger (1988)

Table 1. Dietary composition and nutrient concentrations of milk replacer (MR), milk replacer supplemented with Leu (MRL) and feeds provided to lambs after weaning (DM basis).

Ingredient	MR	MRL	Creep Pellet[1]	Creep Hay	Finishing Pellet[2]	Finishing Hay
Milk replacer	100	97.1	-	-	-	-
Leu	0	2.9	-	-	-	-
	Nutrient Composition					
Ash	6.15	5.98	6.87	8.80	4.31	9.33
Fat	16.0	15.5	3.38	0.77	3.18	0.815
Crude protein	24.4	26.6	21.8	14.0	18.2	16.7
Neutral detergent fiber	-	-	13.5	57.7	11.1	52.4
Acid detergent fiber	-	-	7.70	40.3	3.27	37.9
Ca	0.990	0.962	0.767	1.04	0.686	1.08
P	0.728	0.707	0.434	0.295	0.330	0.284
AA, % of DM						
Glu	3.95	3.84	-	-	-	-
Leu	2.41	5.25	-	-	-	-
Asp	2.36	2.29	-	-	-	-
Lys	2.21	2.15	-	-	-	-
Thr	1.68	1.63	-	-	-	-
Pro	1.67	1.62	-	-	-	-
Val	1.58	1.54	-	-	-	-
Ile	1.53	1.49	-	-	-	-
Ser	1.25	1.21	-	-	-	-
Ala	1.14	1.11	-	-	-	-
Phe	0.977	0.949	-	-	-	-
Tyr	0.850	0.826	-	-	-	-
Arg	0.850	0.826	-	-	-	-
Met	0.648	0.630	-	-	-	-
Gly	0.573	0.557	-	-	-	-
His	0.563	0.547	-	-	-	-
Cys	0.467	0.454	-	-	-	-
Trp	0.446	0.433	-	-	-	-

[1]Creep pellet consisted of (DM basis) corn (46.6%), soybean meal (30%), beet pulp (19%), limestone (1.5%), urea (0.10%) and trace mineral salt supplement (2.8%).

[2]Finishing pellet consisted of (DM basis) corn (86.1%), soybean meal (9.6%), urea (1.65%), limestone (1.1%) and trace mineral salt supplement (1.58%).

Table 2. Pancreatic and intestinal enzyme activity of lambs fed milk replacer with or without leucine during the first six weeks of life.

	Treatment			
Item	**Con**	**Leu**	**SEM**	***P*-value**
Pancreas				
Amylase				
kU/pancreas	419	355	55.5	0.42
U/kg BW	7849	6203	958	0.24
Trypsin				
U/pancreas	44.7	44.9	8.37	0.99
U/kg BW	0.866	0.801	0.1762	0.80
Small intestine				
Glucoamylase				
U/g intestine	1.11	0.945	0.1812	0.52
Isomaltase				
U/g intestine	2.90	2.03	0.303	0.06
Maltase				
U/g intestine	4.84	2.37	0.583	<0.01

reported that intestinal maltase activity may be the most limiting enzyme for post-ruminal starch digestion in sheep. Neonatal supplementation of Leu may lead to decreased starch digestion later in life.

In conclusion, Leu supplementation during the neonatal period did not influence pancreatic digestive amylase or trypsin activity. However, supplemental Leu decreased small-intestinal maltase activity, an enzyme potentially limiting post-ruminal starch digestibility, in finished lambs. Further research is needed to determine the effects of neonatal nutrition on digestive efficiency later in life in ruminants.

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Dietary fructose supplementation influences small intestinal gene expression, enzyme activity and visceral organ mass in neonatal calves

Ronald J. Trotta[1], Alison K. Ward[1] and Kendall C. Swanson[1]

The objective of this experiment was to evaluate dietary fructose supplementation on visceral organ mass and aspects of small intestinal carbohydrate digestion and nutrient transport in neonatal calves. Results from this study demonstrate that dietary fructose influences nutrient utilization, visceral organ mass, and digestive enzyme mRNA expression and activity.

Summary

The objective of this experiment was to determine the influence of fructose on visceral organ mass, carbohydrase activities and mRNA expression of genes involved in small-intestinal carbohydrate assimilation in neonatal calves. Ten calves were fed equal amounts of milk replacer twice daily at 2% of body weight (BW) and assigned to dietary treatment groups: 1) milk replacer (control; n = 6) or 2) milk replacer + 2.2 grams (g) fructose/kilogram (kg) of BW (fructose; n = 4). Calves were fed dietary treatments for 28 days and then were slaughtered and visceral weights were recorded. Post-ruminal carbohydrase activities were assayed. Quantitative, real-time polymerase chain reaction (PCR) was conducted for small-intestinal mRNA expression of nutrient transporters (*GLUT5, SGLT1, GLUT2*), carbohydrases (*LCT, MGAM, SI*) and *KHK*. Small-intestinal data were analyzed using MIXED procedures in SAS for effects of site (duodenum, proximal jejunum, distal jejunum, ileum), treatment and the site × treatment interaction. Dietary fructose increased the mass of the small intestine and liver and tended to increase kidney mass. Pancreatic α-amylase and small-intestinal isomaltase and maltase activities were not influenced by dietary fructose. Sucrase activity was undetected in the small intestine. We observed a tendency for fructose to decrease lactase activity in the proximal portions of the small intestine. We also saw a tendency for dietary fructose to increase glucoamylase activity in the duodenum, distal jejunum and ileum. Fructose increased small intestinal glucoamylase activity per gram intestine by 30% and increased *MGAM* mRNA expression by 6.8-fold. Dietary fructose did not influence mRNA expression of *GLUT5, SGLT1, GLUT2* or *KHK*. In calves fed fructose, small-intestinal *LCT* mRNA expression increased by 3.1-fold. Sucrase-isomaltase mRNA expression in the small intestine decreased by 5.1-fold with dietary fructose. Dietary fructose supply influences nutrient utilization, visceral organ mass, and carbohydrase mRNA expression and activity in neonatal calves.

[1] Department of Animal Sciences, NDSU

Introduction

The digestive tract of neonatal ruminants allows for flow of digesta to the abomasum and, subsequently, the small intestine without pregastric fermentation. Carbohydrate utilization in pre-ruminant calves has been studied extensively and it is well established that young calves readily utilize glucose, galactose and lactose but not sucrose, maltose or starch.

Fructose is a monosaccharide that is transported in the small intestine by the facilitated glucose transporter 5 (GLUT5). Dietary carbohydrates, such as glucose and potentially fructose, can be utilized in ruminants as a substrate to increase intramuscular fat or milk fat synthesis in beef or dairy cattle, respectively. Volpi-Lagreca and Duckett (2016) speculated that an intestinal supply of fructose may result in increased intramuscular fat deposition in beef cattle.

The small intestine produces enzymes (maltase, isomaltase, glucoamylase and sucrase) responsible for the final steps of post-ruminal starch digestion. A limited amount of information is available on the function of these enzymes in response to nutritional adaptation in ruminants.

The small intestine is the primary site of fructose absorption and little is known about dietary fructose supplementation in cattle. Understanding the mechanisms of how fructose influences small-intestinal carbohydrate digestion and absorption could lead to the development of nutritional approaches to increase marbling or milk fat synthesis in beef and dairy cattle, respectively.

Procedures

Twelve Holstein steer calves (less than 7 days of age; BW = 89.3 ± 4.0 pounds) were sourced from a local dairy and housed and fed in individual pens in a temperature-controlled environment at the North Dakota State University Animal Nutrition and Physiology Center. Calves were fed milk replacer at 2% of BW daily on a dry-matter (DM) basis in equal amounts at 7:30 a.m. and 7:30 p.m. during a seven-day adaptation period and throughout the 28-day feeding period.

Calves were assigned randomly to dietary treatment groups: 1) milk replacer (control) or 2) milk replacer + 2.2 g fructose/kg of BW (fructose). The amount of fructose fed was 9.9% of total dry matter intake (DMI) in fructose calves, which is similar to dietary sugar inclusion levels used in previous studies with lactating dairy cows and dairy calves. Calves were not fed starter at any point before or during the experiment.

At the conclusion of the 28-day feeding period, calves were slaughtered via captive bolt stunning and exsanguination and gastrointestinal tracts were removed and weighed, and digestive organs were separated for individual weights and subsample collection. Small-intestinal subsamples were flash-frozen in liquid nitrogen and assayed for mRNA expression [ketohexokinase (*KHK*); glucose transporter 2 (*GLUT2*); glucose transporter 5 (*GLUT5*); sodium-dependent glucose cotransporter-1 (*SGLT1*); lactase (*LCT*); sucrase-isomaltase (*SI*); maltase-glucoamylase (*MGAM*)]; and activity (glucoamylase, isomaltase, lactase, maltase, sucrase). Data were analyzed using the MIXED procedure of SAS.

Results and Discussion

Small-intestinal mass was greater ($P = 0.04$; Table 1) in fructose calves and reticuloruminal mass tended to be greater ($P = 0.08$) in control calves in the current study, suggesting a differential increase in small-intestinal mass relative to reticulorumen potentially because of the increased supply of post-ruminal fructose. Also, dietary fructose supplementation increased liver mass as a proportion of BW ($P = 0.04$) and tended to increase kidney mass ($P = 0.10$). These data may suggest that dietary fructose supplementation could have specific effects on the function of the small intestine, liver and kidney of calves.

Dietary fructose supplementation increased small-intestinal glucoamylase concentration by 30% ($P = 0.01$; Table 2) and *MGAM* mRNA expression by 6.8-fold ($P < 0.001$). Approximately 80% of the apparent maltase activity is derived from SI and the remaining 20% from MGAM in nonruminants.

Differential regulation of *MGAM* (increase) and *SI* (decrease) mRNA expression with dietary fructose supplementation may explain why we found no change in maltase activity yet an increase in glucoamylase activity. Koch et al. (2019) found that the level of milk replacer intake did not influence mRNA expression of *LCT, MGAM*, or *SI* in calves. Their

Table 1. Effects of dietary fructose supplementation on visceral organ mass.

	Treatment			
Item	Control	Fructose[1]	SEM[2]	*P*-value
Gastrointestinal tract				
kg	6.41	6.71	0.413	0.60
g/kg of BW	113	122	9.89	0.30
Reticulorumen				
g	310	263	17.7	0.08
g/kg of BW	5.50	4.82	0.434	0.28
Omasum				
g	76.0	65.2	9.82	0.44
g/kg of BW	1.34	1.16	0.175	0.47
Abomasum				
g	263	251	14.9	0.57
g/kg of BW	4.59	4.58	0.337	0.98
Small intestine				
kg	1.24	1.27	0.00935	0.04
g/kg of BW	22.1	23.3	0.638	0.20
Large intestine				
g	401	418	25.1	0.63
g/kg of BW	7.13	7.60	0.577	0.56
Liver				
kg	1.36	1.55	0.0769	0.11
g/kg of BW	23.9	27.9	1.17	0.04
Kidney				
g	247	283	16.6	0.14
g/kg of BW	4.33	5.13	0.322	0.10
Longissimus muscle				
g	49.0	53.9	3.55	0.34
g/kg of BW	0.860	0.975	0.0565	0.17

[1]Fructose was provided in the diet at 2.2 g/kg of BW.
[2]Standard error of the mean (Fructose, n = 4).

findings demonstrate that the level of DM or energy intake does not influence small-intestinal carbohydrase mRNA expression in calves, which may suggest that changes in small intestinal carbohydrase mRNA expression with dietary fructose supplementation occurred independent of DM or energy intake in the current study.

Several authors have failed to detect sucrase activity in the small intestine of cattle or sheep. Moreover, abomasal infusion of sucrose does not induce sucrase activity in lambs. Similar to previous reports, sucrase activity was not detected in the small intestine in the current study.

This demonstrates that dietary fructose supplementation does not induce sucrase activity in neonatal calves. In the current study, dietary fructose supplementation decreased *SI* mRNA expression in the small intestine. Results from the current study might suggest that fructose presence in the small intestine could selectively decrease *SI* mRNA expression through a negative feedback mechanism via product inhibition.

To our knowledge, no studies have evaluated the effects of dietary fructose on the regulation of *GLUT5*, the fructose transporter mRNA expression in the ruminant small intestine. In contrast to our hypothesis, dietary fructose supplementation did not influence *GLUT5* mRNA expression in the small intestine of neonatal calves fed milk replacer.

Previous research in steers demonstrated that *GLUT5* does not respond to ruminal or abomasal infusions of 3.1 g/kg of BW of starch hydrolysate (Liao et al., 2010). Calves in the current study were fed milk replacer with no solid feed.

Thus, results from the current study suggest that *GLUT5* expression is not influenced solely by luminal fructose supply in calves during the neonatal phase. However, it remains unknown if *GLUT5* can be nutritionally regulated by luminal fructose in weaned or mature cattle.

Sodium-dependent glucose cotransporter-1 is the transporter for glucose absorption in ruminants. However, several studies with post-ruminal carbohydrate infusions in cattle have found little or no change in sodium-dependent glucose uptake activity, *SGLT1* mRNA expression or *SGLT1* protein abundance. Similarly, we observed no effects of dietary fructose supplementation on *SGLT1* or *GLUT2* mRNA expression in the small intestine in the current study, further suggesting that carbohydrate transporters in the small intestine of cattle are not sensitive to luminal carbohydrate flow.

In summary, dietary fructose influenced visceral organ mass, and mRNA expression and activity of small intestinal carbohydrases, but not nutrient transporters. Additional research is needed to quantify fructose transport and metabolism in ruminants and determine whether increasing the post-ruminal supply of fructose has potential production benefits.

Table 2. Effects of small-intestinal site and dietary fructose supplementation on relative mRNA expression of genes and activity of enzymes in the small intestine.[1]

		Treatment			*P*-value		
Item	Fold Change	Control	Fructose[2]	SEM[3]	Site	Trt	Site × Trt
Gene							
KHK	↓1.03	1.15	1.12	0.237	0.21	0.93	0.44
GLUT5	↑1.14	0.655	0.744	0.144	<0.001	0.64	0.66
SGLT1	↓1.21	1.00	0.828	0.122	<0.001	0.28	0.69
GLUT2	↑1.21	0.869	1.05	0.142	<0.001	0.34	0.94
LCT	↑3.10	0.701	2.17	0.329	0.003	0.002	0.22
SI	↓5.07	1.36	0.268	0.281	0.20	0.006	0.69
MGAM	↑6.80	1.94	13.2	2.36	0.86	<0.001	0.91
Enzyme, U/g intestine							
Glucoamylase	-	0.480	0.624	0.0566	0.23	0.05	0.07
Isomaltase	-	0.486	0.497	0.0265	0.04	0.74	0.13
Lactase	-	5.86	4.62	0.707	<0.001	0.19	0.10
Maltase	-	0.967	1.01	0.0405	0.03	0.42	0.26

[1]*Glyceraldehyde-3-phosphate dehydrogenase* was used as the reference gene.
[2]Fructose was provided in the diet at 2.2 g/kg of BW.
[3]Standard error of the mean (Fructose, n = 4).

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Post-ruminal supply of protein increases activity of digestive enzymes involved in small-intestinal corn starch digestion in cattle

Ronald J. Trotta[1], Leonardo G. Sitorski[1], Subash Acharya[2,3], Derek W. Brake[2,3] and Kendall C. Swanson[1]

The objective of this experiment was to evaluate the effects of duodenal infusions of starch with casein or glutamic acid on post-ruminal carbohydrase activities in cattle. Results from this study suggest that small-intestinal starch digestion may be improved in cattle with increased small-intestinal flow of protein through increases in pancreatic and small-intestinal digestive enzyme activities.

Summary

Small-intestinal starch digestion in ruminants potentially is limited by inadequate production of carbohydrases. Previous research has demonstrated that small-intestinal starch digestion can be improved by post-ruminal supply of casein or glutamic acid. However, the mechanisms by which casein and glutamic acid increase starch digestion are not well understood. The objective of this experiment was to evaluate the effects of duodenal infusions of starch with casein or glutamic acid on post-ruminal carbohydrase activities in cattle. Twenty-two steers (395 ± 9.3 pounds body weight [BW]) were fitted surgically with duodenal and ileal cannulas and limit-fed a soybean hull-based diet containing small amounts of starch. Raw cornstarch (3.6 ± 0.2 pounds/day) was infused into the duodenum alone (control) or with 4.2 ± 0.25 ounces of glutamic acid/day or 15.1 ± 0.68 ounces casein/day. Treatments were infused continuously for 58 days and then steers were slaughtered for tissue collection. Activities of pancreatic (α-amylase) and intestinal (maltase, isomaltase, glucoamylase, sucrase) carbohydrases were determined. Data were analyzed as a randomized complete block (replicate group) design using the GLM procedure of SAS to determine effects of infusion treatment. Duodenal casein infusion increased ($P < 0.05$) pancreatic α-amylase activity by 290%. Duodenal glutamic acid infusion increased ($P < 0.03$) duodenal maltase activity by 233%. Duodenal casein infusion increased jejunal maltase ($P = 0.02$) and glucoamylase ($P = 0.03$) activity per gram protein by 62.9% and 97.4%, respectively. Duodenal casein infusion tended to increase ($P = 0.10$) isomaltase activity per g jejunum by 38.5% in the jejunum. Sucrase activity was not detected in any segment of the small intestine. These results suggest that small-intestinal starch digestion may be improved in cattle with increased small-intestinal flow of casein through increases in post-ruminal carbohydrase activities.

[1]Department of Animal Sciences, NDSU
[2]Department of Animal Science, South Dakota State University
[3]Division of Animal Sciences, University of Missouri

Introduction

In North American finishing cattle and dairy cattle production systems, grain-based diets containing moderate to large proportions of starch typically are fed to increase the net energy concentrations of the diet, allowing for more efficient growth and improved product quality. When grain-based diets are fed, up to 40% of dietary starch intake can escape ruminal fermentation and flow to the small intestine for potential enzymatic digestion. Host digestion in the small intestine allows for absorption of glucose and provides more energy to the host than short-chain fatty acids produced from fermentation of carbohydrates by the ruminal microbes.

Thus, small-intestinal starch digestion in cattle is energetically more efficient than ruminal fermentation of starch. However, the extent of small-intestinal starch digestion is potentially limited by inadequate production of post-ruminal digestive enzymes.

The pancreas and small intestine have important roles in post-ruminal nutrient digestion and a limited amount of information is available on their function in response to nutritional adaptation in ruminants. Understanding the mechanisms by which post-ruminal protein or amino acid flow modulate increases in small-intestinal starch digestion potentially could result in the development of nutritional approaches to improve nutrient utilization and the energetic efficiency of animal production.

The objective of this experiment was to evaluate the effects of duo-

denal infusions of starch with casein or glutamic acid on post-ruminal carbohydrase activities in cattle.

Experimental Procedures

Twenty-two steers (395 ± 9.3 pounds BW), predominantly of British and Continental-influenced breeds, were surgically fitted with duodenal and ileal cannulas. Steers were limit-fed 7.65 ± 0.72 pounds of a soybean hull-based diet that supplied 1.3 × net energy for maintenance requirements for a steer gaining 1 pound/day, met the needs for ruminally degradable protein and exceeded requirements for metabolizable protein, vitamins and minerals.

Steers were blocked into four replicate groups because of limited pen space and infusion apparatus, and randomly assigned to continuous duodenal infusion treatments of 3.55 ± 0.19 pounds/day of raw cornstarch with either 0 (control; n = 8), 4.16 ± 0.25 ounces L-glutamic acid/day (n = 8) or 15.1 ± 0.68 ounces casein/day (n = 6) on a dry-matter (DM) basis. Treatments were infused continuously through Tygon tubing with water using a peristaltic pump for 58 days.

At the conclusion of the 58-day infusion period, steers were slaughtered via captive bolt stunning and exsanguination, and gastrointestinal tracts were removed and weighed, and digestive organs were separated for individual weights and subsample collection. Pancreatic and intestinal subsamples were flash-frozen in liquid nitrogen and assayed for carbohydrase activities according to the methods of Trotta et al. (2020). Data were analyzed using the GLM procedure of SAS.

Results and Discussion

Small-intestinal starch digestion in ruminants is potentially limited by inadequate production of pancreatic (α-amylase) and small-intestinal (maltase, isomaltase, glucoamylase) carbohydrases. Pancreatic and small-intestinal carbohydrases contribute to luminal and membrane-bound hydrolysis of starch to oligosaccharides and disaccharides and then to glucose. However, regulation of post-ruminal digestive enzymes in cattle is complex and numerous neurohormonal signaling mechanisms are involved in digestive enzyme synthesis and secretion.

Previous experiments have demonstrated that post-ruminal protein supply can increase pancreatic α-amylase activity and small-intestinal starch digestion in cattle and sheep. In the current study, casein dramatically increased pancreatic α-amylase activity ($P < 0.05$), which agrees with several experiments conducted previously in our laboratory.

Interestingly, duodenal casein supply also increased maltase ($P < 0.03$), glucoamylase ($P < 0.06$) and isomaltase ($P < 0.12$) activities in the jejunum in the current experiment. What is unclear is if increases in small intestinal carbohydrases with casein infusion are directly related to increased luminal protein flow because peptide hydrolysates and free amino acids from casein may influence neuroendocrine signaling to increase carbohydrase activity in the small intestine.

Alternatively, increased luminal protein flow may cause increases in carbohydrase activities indirectly. Increased flow of luminal substrates (maltose, isomaltose, limit dextrins) as a result of greater hydrolysis of amylose and amylopectin in response to increases in pancreatic α-amylase activity may modulate increases in small-intestinal carbohydrase activities. Further delineations are needed to understand the hydrolytic limit to small-intestinal

Table 1. Effects of duodenal infusions of raw cornstarch with casein or glutamic acid on pancreatic and small-intestinal carbohydrase activities in steers.[1]

	Treatment				
Item	Control	Glutamic Acid	Casein	SEM[2]	*P*-value
Pancreatic mass, g	199	205	208	16.7	0.88
Jejunal mass, kg	1.54	1.46	1.51	0.142	0.88
α-Amylase					
U/g pancreas	82.0[a]	71.3[a]	217[b]	44.4	0.05
U/g protein	758[a]	764[a]	2500[b]	456	0.02
Isomaltase					
U/g jejunum	1.66	1.21	2.30	0.390	0.10
U/g protein	24.1	17.8	31.6	5.15	0.12
Maltase					
U/g jejunum	1.84[a]	1.42[a]	3.14[b]	0.455	0.03
U/g protein	26.7[a]	21.6[a]	43.5[b]	5.71	0.02
Glucoamylase					
U/g jejunum	0.183	0.194	0.390	0.0664	0.06
U/g protein	2.74[a]	2.74[a]	5.41[b]	0.784	0.03

[1]Abbreviations: U = unit. Least square means with different superscripts within a row differ ($P \leq 0.05$).

[2]Standard error of the mean (for Casein, n = 6).

starch digestion and regulation of post-ruminal digestive enzyme activity in cattle.

Brake et al. (2014) demonstrated that a combination of nonessential amino acids similar to the nonessential amino acid profile of casein increased small-intestinal digestion while essential amino acids did not. Additionally, duodenal glutamic acid infusions have resulted in increases in small-intestinal starch digestion similar to casein.

With the exception of duodenal maltase (data not shown), glutamic acid appears to have failed to increase most enzymes important for small-intestinal starch digestion. One major difference from previous studies where glutamic acid increased starch digestion was the length of the infusion period.

In the current study, steers were infused with starch or a combination of starch and casein or glutamic acid for 58 days, while previous experiments only evaluated small-intestinal starch digestion up to six or 12 days. This may suggest that glutamic acid is not effective in improving small-intestinal starch digestion long-term.

In conclusion, the duodenal casein supply increased pancreatic and small-intestinal carbohydrase activities in steers. The glutamic acid supply had minimal influence on post-ruminal carbohydrase activities.

Data from the current study suggest that casein may modulate increases in small-intestinal starch digestion by increasing post-ruminal carbohydrase activities in cattle. A greater understanding of the complex relationships among luminal nutrient flows, gut signaling and digestive enzyme regulation is needed to identify mechanisms to potentially increase small-intestinal starch digestion in cattle.

Acknowledgments

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Comparison of winter cow feeding strategies on cow performance and offspring performance, carcass composition and meat quality

Janna J. Block[1], Erin R. Gubbels[2], Christopher S. Schauer[1], Don Stecher[1], Donny Drolc[1], Robin R. Salverson[2], Cody L. Wright[2], Kristi M. Cammack[2], Zach K. Smith[2], Judson K. Grubbs[2], Keith R. Underwood[2], Ken C. Olson[2] and Amanda D. Blair[2]

The objective of this study was to investigate the effects of maternal prepartum dietary energy source (forage vs. concentrate) during mid- and late gestation on cow performance and offspring feedlot performance, carcass composition and meat quality. The maternal diet had minimal impacts on cow performance and did not influence feedlot performance or carcass characteristics of offspring, with only minor impacts on meat quality of the offspring. These results indicate that grain-based diets for gestating beef cows are an acceptable nutritional management strategy and do not appear to have a significant influence on offspring performance or carcass traits.

Summary

Mature Angus-based spring-calving cows from the NDSU Hettinger Research Extension Center (n = 67) were utilized in a study to evaluate the impacts of maternal dietary energy source (forage [FOR] vs. grain-based diets [CONC]). Cows were evaluated for pregnancy in the fall of 2017 and assigned to dietary treatments based on cow age and body weight (BW). Cows were provided the treatment diets beginning around day 94 of gestation and continuing through approximately 30 days prior to calving. Both diets were formulated to maintain cow body condition, with BW and body condition scores (BCS) collected at the beginning, midpoint and end of the treatment period to evaluate cow performance. At the end of the treatment period, cows were returned to rangeland and managed as a common group through weaning with no further treatments applied. Following weaning, a subset of 40 calves (n = 20 heifers, n = 20 steers) closest to the mean weaning weight were fed backgrounding and finishing diets and then harvested at a commercial packing facility, with individual carcass characteristics collected. No differences were observed for cow BCS due to treatment or time ($P > 0.28$); however, CONC cows tended ($P = 0.07$) to weigh more than FOR cows at the end of the treatment period. Calf birthweights and weaning weights were similar ($P > 0.05$) between treatments. No differences ($P > 0.05$) were detected in feedlot performance, intake, feed efficiency or carcass characteristics of offspring. Steaks from offspring had similar ($P > 0.05$) tenderness and flavor attributes; however, moisture content and juiciness scores of steaks from a consumer panel were increased ($P = 0.05$) for offspring from dams on CONC vs. FOR treatments. Concentrate and forage-based diets resulted in acceptable cow performance. Maternal diet did not affect feedlot performance of offspring and had limited influence on beef product quality.

[1]Hettinger Research Extension Center, NDSU
[2]Department of Animal Science, South Dakota State University, Brookings

Introduction

Winter feeding costs account for the majority of annual operating costs in a cow-calf operation, and forages are typically a major component of beef cow diets. However, high prices and/or limited availability of forage may lead producers to consider alternatives such as grain or byproduct feeds. Limit-fed grain-based rations have the potential to reduce winter feed costs while having minimal effects on cow performance.

Research indicates that the maternal nutritional environment experienced by the fetus during gestation can influence development of skeletal muscle tissue and adipocytes that provide sites for intramuscular fat (marbling) accumulation or development. One of the major challenges facing the beef industry is the production of a consistent, flavorful and tender meat product. One possible strategy for optimizing livestock growth and quality of beef is utilization of gestational diets that could influence fetal skeletal muscle and marbling stores.

Volatile fatty acids (VFA) are the main products of the digestion of feed by bacteria in the rumen, and they provide greater than 70% of the

ruminant animal's energy supply by serving as substrates for synthesis of glucose and fat. Grain-based diets high in readily fermentable carbohydrate (starch) result in increased production of propionate, compared with forage-based diets.

Propionate is the only VFA that contributes directly to the net synthesis of glucose, which is a major energy substrate utilized by uterine and placental tissues for fetal growth (Ferrell et al., 1982). Our hypothesis was that variations in the proportion of fatty acids produced in the gestating cow between forage and concentrate-based diets during mid- and late gestation would differentially influence fetal development, ultimately leading to differences in performance and meat quality of offspring.

The objective of this study was to investigate the effects of maternal prepartum dietary energy source (forage vs. concentrate) during mid- and late gestation on cow performance and offspring feedlot performance, carcass composition and meat quality.

Experimental Procedures

Mature Angus-based spring-calving cows from the NDSU Hettinger Research Extension Center (n = 67) were evaluated for pregnancy in the fall of 2017 and randomly assigned to forage-based (FOR; n = 34) or limit-fed concentrate-based (CONC; n = 33) dietary treatments (Table 1) based on cow age and BW.

Feed intake was controlled so that cows in both treatments consumed equal levels of protein and energy. Cows were provided the treatment diets beginning on approximately day 94 of gestation through 30 days prior to calving, with both diets formulated to maintain cow body condition. Cow performance data were collected at the beginning (day 0), midpoint (day 52) and the end (day 117) of the treatment period.

Individual cow BW was recorded and BCS was determined using a 9-point scale (1 = extremely emaciated to 9 = extremely obese; Wagner et al., 1988) with observations from the same two trained independent observers at each timepoint. At the end of the treatment period, cows were returned to native pastures for calving.

Calves were weighed and tagged within 24 hours of birth. Pairs were managed as a common group through weaning, with no further treatments applied to dams or their offspring.

Offspring Management

At weaning, a subset of 40 calves (n = 20 heifers, n = 20 steers) closest to the mean weaning weight of the herd were selected to be followed through finishing and harvesting processes. Calves were fed a backgrounding diet containing hay, barley silage, protein pellets, corn and oats for approximately one month at the NDSU Research Extension Center in Hettinger, N.D.

On day 28 of the backgrounding period, calves were weighed to monitor performance and ultrasounded to determine backfat thickness (BF), muscle depth (*longissimus dorsi*) and intramuscular fat (IMF) measured at the 12th/13th rib. They then were shipped to the South Dakota State University Cottonwood Field Station near Philip, S.D.

Calves were fed a common receiving diet consisting of grass hay and dried distillers grains with solubles for an additional 35 days before being transported approximately 328 miles to Brookings, S.D., for the finishing phase of the study. Calves were stratified by sex and initial body weight into group pens (four pens/treatment with five head/pen) and finished at the SDSU Ruminant Nutrition Center (RNC).

Finishing diets consisted of dry rolled and high-moisture corn, dried distillers grains with solubles, oatlage, and a protein and mineral supplement. Following a step-up period, calves were administered an initial growth-promoting implant on day 23 and again on day 80 of the finishing period (Synovex-Choice, Zoetis Inc., Parsippany, N.J.). A second ultrasound also was conducted on day 80 of the finishing period.

Table 1. Dietary components (dry-matter basis) consumed by cows receiving a forage-based (FOR) or concentrate-based diet (CONC) during mid- and late gestation.

Ingredient	CONC[1]	FOR[1]
Wheat straw	24.1 %	71.9 %
Grass/alfalfa hay	---	21.8 %
Corn silage	---	3.7 %
Suspension supplement[2]	4.6 %	2.6 %
Corn grain	56.6 %	---
Modified distillers grain w/ solubles	13.3 %	---
Limestone	1.4 %	---

[1]Diets formulated based on National Research Council (NRC, 2000) requirements.
[2]Suspension supplement: 20% crude protein (≤ 20% nonprotein nitrogen), 3.55-4.55% Ca, 0.20% P, 0.30% Mg, 1% K, 528.63 ppm Mn, 12.65 ppm Co, 480 ppm Cu, 5.50 ppm Se, 1,440 ppm Zn, 40,000 IU/lb Vit. A, 11,300 IU/lb/lb Vit. E, 400 g/ton monensin.

The harvest target for each treatment group was determined when the predicted group average was 0.5 inch of backfat. Cattle were weighed the morning of slaughter to determine final live bodyweight and shipped 146 miles to a commercial packing facility.

Carcass Evaluation and Sample Collection

All cattle were tracked individually through the slaughter process. Following carcass chilling (approximately 24 hours), hot carcass weight (HCW), rib-eye area (REA), backfat (BF), marbling score, carcass maturity and objective color measurements (L*, a* and b*) were recorded for each individual carcass.

Yield grade (YG) was calculated using HCW, REA and BF. Marbling score and carcass maturity were used to determine quality grade (QG) of each carcass.

A strip loin was collected from each carcass, transported back to SDSU and portioned into 1-inch steaks. Four steaks were aged for three, seven, 14 or 21 days for evaluation of Warner-Bratzler shear force (WBSF). Additional steaks were designated for determination of crude fat using ether extraction and consumer palatability of 14-day aged samples using a trained sensory panel.

Statistical Analyses

Response variables were analyzed using generalized linear mixed model procedures (SAS GLIMMIX, SAS Inst. Inc., Cary, N.C.). Cow performance and suckling calf data were analyzed using a completely randomized design with time point included as a repeated measure for variables that were measured more than once, including cow BW and BCS.

A randomized complete block design was used to evaluate offspring feedlot performance and carcass characteristics to determine the effects of treatment, calf sex and their interaction. For WBSF, aging period (AP) was added to the model as a repeated measure and peak cooking temperature was included as a covariate. Separation of least squares means was conducted using protected LSD with an alpha level of 0.05.

Results and Discussion

No differences were observed for cow BCS due to treatment or time ($P > 0.28$); however, a tendency ($P = 0.07$) for a treatment × time interaction was observed for cow BW. When means were separated, we found no differences ($P > 0.10$) between CONC and FOR treatments at the beginning or midpoint of the trial; however, CONC cows tended ($P = 0.07$) to weigh more than FOR cows at the end of the treatment period (1,588 vs. 1,504 pounds ± 47.2, respectively).

No differences were observed ($P = 0.79$) for calf birthweight between FOR and CONC treatments (87.8 vs. 88.3 pounds ± 1.50; respectively). Weaning weights were similar between offspring from dams on FOR and CONC treatments ($P = 0.98$; mean 596 ± 8.1 pounds). As expected, bull calves were heavier than heifer calves at birth ($P = 0.0002$; 92 vs. 84 pounds ± 1.6, respectively) and weaning ($P = 0.006$; 613 vs. 580 pounds ± 8.1, respectively).

No treatment main effects or treatment × sex interactions ($P > 0.05$) were detected for offspring BW, average daily gain (ADG), dry-matter intake (DMI) or feed-to-gain ratio (F:G) during the finishing period (Table 2). Radunz et al. (2012) also reported similar feedlot performance among calves whose dams were fed diets based on hay, corn or distillers grains with solubles during late gestation.

In another study by Wilson et al. (2016), limit-fed diets consisting of corn coproducts and cornstalks or grass hay were fed to pregnant cows during the last trimester of gestation. While cows consuming the corn diet had increased BW and BCS after calving, the researchers found no differences in progeny feedlot performance or carcass characteristics. Although energy source has the potential to influence cow performance, maternal diets in the current study did not appear to result in differential programming effects on offspring growth or feedlot performance.

We found no differences between treatments for offspring BF, muscle depth or intramuscular fat percentage as determined by ultrasound during the backgrounding phase ($P > 0.50$). Ultrasound measurements during the finishing phase indicated that offspring from dams on the CONC treatment had increased ($P = 0.03$) BF, compared with offspring from FOR dams (0.35 vs. 0.3 in. ± 0.011, respectively).

However, maternal treatment did not influence ($P > 0.05$) HCW, REA, BF, marbling score or objective color values (L*, a* or b*) of carcasses (Table 2). We found no effect of treatment ($P > 0.05$) for crude fat content, WBSF or consumer sensory responses for tenderness or flavor of steaks. Offspring from the CONC treatment had increased ($P = 0.04$) moisture content, and consumer panel responses showed increased ($P = 0.05$) juiciness scores for steaks from offspring of dams on CONC vs. FOR diets (Table 2).

Results from this study suggest that variation in winter cow diets during mid- and late gestation has limited influence on progeny performance. Provided that nutrient requirements are met, utilizing alternative diets for the beef cow herd does not appear to significantly influence progeny performance and beef product quality. This provides

Table 2. Least squares means for feedlot performance, carcass characteristics and meat quality of offspring from dams receiving a forage-based (FOR) or concentrate-based diet (CONC) during mid- and late gestation.

	Treatment[1]			
	CONC	FOR	SEM[2]	*P*-value[3]
Feedlot performance				
Initial BW, lbs.	733	731	14.7	0.93
Ending BW, lbs.	1,206	1,209	35.5	0.93
ADG, lbs.	3.61	3.65	0.106	0.82
DMI, lbs.	20.61	20.28	0.615	0.72
F:G	5.72	5.57	0.168	0.57
Carcass characteristics				
Hot carcass weight, lbs.	725	725	22.75	0.99
Rib-eye area, in.^{2}	12.8	12.7	0.35	0.83
12th rib fat thickness, in.	0.37	0.40	0.012	0.23
USDA Yield grade	2.7	2.9	0.037	0.06
Marbling score[4]	486	497	28.90	0.71
Objective color measurements				
L*[5]	42.27	42.26	0.464	0.99
a*[6]	25.51	25.36	0.117	0.41
b*[7]	10.56	10.54	0.119	0.90
USDA Quality Grade[8]				
Low Choice, %	55.84	33.90	0.778	0.26
Select, %	17.82	21.30	0.687	0.81
USDA Yield Grade[8]				
Yield Grade 2, %	66.67	44.50	0.506	0.41
Yield Grade 3, %	25.00	50.00	0.615	0.40
Meat quality attributes				
Crude fat, %	5.06	5.54	0.513	0.09
Moisture, %	72.67	72.45	0.294	0.04
WBSF[9], lbs.	7.85	7.81	0.315	0.86
Tenderness[10]	12.42	11.74	0.337	0.25
Juiciness[10]	10.44	9.68	0.172	0.05
Flavor[10]	8.79	9.17	0.283	0.41

[1]Diets formulated based on NRC (2000) requirements for dams fed a limit-fed concentrate or ad-libitum forage diet during mid- and late gestation.
[2]Standard error of the mean.
[3]Probability of difference among least square means.
[4]Marbling score: 200 = traces^0, 300 = slight^0, 400 = small^0, 500 = modest^0
[5]L*: 0 = black, 100 = white; recorded three days postmortem.
[6]a*: Negative values = green; positive values = red; recorded three days postmortem.
[7]b*: Negative values = blue; positive values = yellow; recorded three days postmortem.
[8]Calculated proportions of USDA Quality and Yield Grade (data did not converge for USDA Prime or upper 2/3 Choice, or USDA Yield Grade less than a 2 or greater than a 3).
[9]Warner-Bratzler Shear Force.
[10]Strip loin samples were evaluated for juiciness (1 = extremely dry; 18 = extremely juicy), tenderness (1 = extremely tough; 18 = extremely tender), and beef flavor (1 = extremely bland; 18 = extremely intense).

flexibility for cow-calf producers to feed gestating cows available energy sources during drought and/or variable growing conditions without concern for offspring performance or carcass traits.

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Effects of feeding a vitamin and mineral supplement and rate of gain during the first 83 days of pregnancy on beef heifer performance, concentrations of progesterone, and corpus luteum size and fetal body measurements

Kacie L. McCarthy[1], Jocelyn Nestande[1], Cierrah J. Kassetas[1], Ana Clara B. Menezes[1], Friederike Baumgaertner[1], James D. Kirsch[1], Sheri T. Dorsam[1], Tammi L. Neville[1], Alison K. Ward[1], Pawel P. Borowicz[1], Lawrence P. Reynolds[1], Kevin K. Sedivec[2], J. Chris Forcherio[3], Ronald Scott[3], Joel S. Caton[1] and Carl R. Dahlen[1]

Our objectives were to determine the influence of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on beef heifer growth performance, circulating concentrations of progesterone (P4), corpus luteum (CL) size and fetal body measurements. By design, heifers targeted for moderate rates of gain had greater average daily gain, compared with heifers targeted for low rates of gain (1.74 vs. 0.62 ± 0.08 pounds per day [lb/d], respectively; P < 0.0001). Feeding heifers to achieve moderate rates of gain during early gestation resulted in heavier CLs, greater circulating concentrations of P4 and greater fetal femur growth, whereas providing VTM supplements enhanced fetal liver growth.

Summary

The objectives were to determine the influence of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on beef heifer growth performance, circulating concentrations of progesterone (P4), and corpus luteum (CL) size and fetal body measurements. Crossbred beef heifers (n = 35; initial body weight [BW] = 792.6 ± 15.7 pounds) were blocked by weight and assigned to one of four treatments (eight or nine heifers per treatment group) in a 2 × 2 factorial arrangement with main effects of VTM (NoVTM or VTM) and rate of gain (low gain [LG], 0.62 lb/d, vs. moderate gain [MG], 1.74 lb/d). The VTM factor was initiated at least 71 days before artificial insemination (AI). At breeding, heifers were maintained on their respective diets (target gain of 0.62 lb/d) or fed a starch-based protein/energy supplement (target gain of 1.74 lb/d). Heifers received treatments until the experiment endpoint of day 83 ± 0.27 after breeding, at which time heifers were ovariohysterectomized. Body weights and serum samples were collected on days 14, 28, 42, 56, 70 and 83 after AI and serum samples were analyzed for concentrations of P4. On day 83, gravid reproductive tracts were collected and fetuses were dissected. Performance and body measurement data were analyzed using the MIXED procedure of SAS and P4 data were evaluated as repeated measures in time. By design, MG heifers had greater average daily gain (ADG), compared with LG heifers (1.87 vs. 0.75 ± 0.09 lb/d, respectively; $P < 0.0001$). A rate of gain × day interaction ($P = 0.006$) was observed for P4, where no differences ($P > 0.05$) were observed between MG or LG heifers on days 14 to 56, while concentrations of P4 tended to be greater in MG heifers on day 70. On day 83, concentrations of P4 were greater ($P = 0.002$) for MG than LG heifers (6.74 vs. 4.85 ± 0.43 nanograms per milliliter [ng/mL], respectively). Gravid uterine weight, fetal body weight, and fetal heart, pancreas, hindlimb and brain weights were not affected ($P \geq 0.22$) by VTM, rate of gain or their interaction, whereas rate of gain affected CL weights $P = 0.003$) with greater values in MG than LG heifers (4.86 vs. 3.94 ± 0.32 grams [g], respectively). Additionally, fetuses from MG dams had greater ($P = 0.009$) femur weights than fetuses from LG dams (0.39 vs. 0.34 g, respectively). Fetal liver weight was greater ($P = 0.05$) from dams fed VTM than NoVTM (4.80 vs. 4.42 ± 0.12 g, respectively). Overall, moderate rates of gain during early gestation resulted in heavier CLs, greater circulating concentrations of P4 and greater fetal femur growth, whereas providing a VTM supplement enhanced fetal liver growth.

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]Central Grasslands Research Extension Center, NDSU
[3]Purina Animal Nutrition LLC, Gray Summit, Mo.

Introduction

Vitamin and mineral supplementation at different stages of production may have greater impacts on reproduction and animal performance, which may affect fetal development (Ashworth and Antipatis, 2001). Additonally, strategic supplementation of protein and energy can be beneficial to maintain targeted production goals for growth and reproductive performance (Cappellozza et al., 2014). Further, protein and energy intake modulates body weight gain and circulating concentrations of progesterone, which is a steroid required for maintenance of pregnancy and is important for conceptus growth and development (Garrett et al., 1988).

There is a huge variation in mineral and protein/energy supplementation strategies in beef operations; thus, understanding the impacts that pre-breeding trace mineral and energy supplementation have on reproductive processes and fetal growth and development would be beneficial to our industry. Therefore, our objectives were to determine the influence of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on beef heifer performance, concentrations of progesterone (P4), and corpus luteum (CL) size and fetal body measurements.

Experimental Procedures

All procedures were approved by the North Dakota State Institution for Animal Care and Use Committee.

Animals, Housing and Diet

Thirty-five crossbred Angus heifers (initial BW = 792.6 ± 15.7 pounds) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplementation (VTM or NoVTM) and rate of gain [low gain (LG) 0.62 lb/d or moderate gain (MG) 1.74 lb/d]. Briefly, the VTM supplement was initiated at least 71 days before artificial insemination.

At breeding, heifers were maintained on their respective diets (LG) or fed a starch-based protein/energy supplement (MG). This resulted in the following treatment combinations: 1) No vitamin and mineral supplement, low gain (NoVTM-LG; n = 9); 2) No vitamin and mineral supplement, moderate gain (NoVTM-MG; n = 9); 3) Vitamin and mineral supplement, low gain (VTM-LG; n = 9); 4) Vitamin and mineral supplement, moderate gain (VTM-MG; n = 8). Heifers were fed individually in Calan gates, and supplements were top dressed over the total mixed ration (Table 1). Heifers received treatments until the experiment endpoint of day 83 ± 0.27 after breeding, at which time heifers were ovariohysterectomized.

Estrous Synchronization, Breeding, and Fetal Measurements

All heifers were estrus synchronized using the seven-day CO-Synch plus controlled internal drug

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

Chemical Composition	Total Mixed Ration[1]	Supplements		
		No VTM[2]	VTM[3]	Starch-based protein/energy[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
Nonfiber 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

[1]Proportion of ingredients: prairie grass hay (55%), corn silage (38%) and dried distillers grains plus solubles (7%).
[2]NoVTM: No vitamin mineral supplement was a pelleted 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 (consisting of 113 g of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).
[4]An energy/protein supplement formulated with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea; targeting gain of 1.74 lb/d for moderate gain and 0.62 lb/d for low-gain heifers.

release and timed-artificial insemination (AI) protocol. Additionally, all heifers received an estrus detection patch (Estrotect; Rockway Inc., Spring Valley, Wis.) to determine heat state. Heifers were bred using female-sexed semen from a single sire by AI.

Pregnancy diagnosis was performed 42 days after AI using transrectal ultrasonography to determine AI pregnancy rates. Fetal measurements via transrectal ultrasonography were performed at 56, 70, and 82 days following AI.

Blood Sampling and Analyses

Blood samples were collected every 14 days via jugular venipuncture into serum tubes (10 milliliter [mL]; Becton Dickinson Co., Franklin Lakes, N.J.), allowed to clot for 30 minutes and centrifuged at 1,500 × g at 4 C for 20 minutes. Serum samples were separated and stored in plastic vials at minus 20 C until further analysis.

Serum samples were analyzed for progesterone (P4) concentrations by competitive chemiluminescent immunoassay using the Immulite 1000 (Siemens, Los Angeles, Calif.). Briefly, a 50-microliter (µL) sample of maternal serum was analyzed in duplicate.

Lesser, medium and greater P4 pools were assayed in duplicate (0.94 ± 0.12, 8.44 ± 0.94 and 19.6 ± 0.54 ng/mL, respectively). The intra- and interassay coefficients of variation (CV) were 4.15 and 8.96%, respectively.

Tissue Collection and Analysis

Utero-placental and fetal tissues were collected via ovariohysterectomy (McLean et al., 2016) on day 83 ± 0.27 of gestation. Immediately following ovariohysterectomy, weights of gravid uterus, ovary and CL were recorded. The fetus was removed from the gravid uterus and weighed, and fetal liver, heart, intestine, pancreas, hindlimb and brain were collected, individually weighed and stored for further analysis.

Statistical Analysis

Body weight and progesterone data were analyzed as repeated measures using the MIXED procedure of SAS for effects of treatment, day and a treatment × day interaction. Maternal performance, uterine measurements and fetal measurements were analyzed using the MIXED procedures of SAS for effects of VTM, rate of gain and a VTM × rate of gain interaction. Heifer was considered the experimental unit in all analyses and significance was set at $P \leq 0.05$, while tendencies were determined if $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

A rate of gain × day interaction ($P < 0.0001$) was observed for BW, where MG heifers were heavier than LG on day 83 (940.9 vs. 854.5 ± 13.0 pounds respectively). We observed no interactions between VTM and rate of gain ($P = 0.35$; Table 2) for ADG.

By design, MG heifers had greater ADG than LG heifers (1.87 vs. 0.75 ± 0.08 lb/d, respectively $P < 0.0001$), while VTM did not influence ($P = 0.72$) the ADG. Similar results were observed by Cappellozza et al. (2014), where ADG was greater for heifers receiving and energy/protein supplement compared with control heifers.

Dry-matter intake ($P \geq 0.11$) and gain-to-feed (G:F) ratio ($P \geq 0.10$) were not impacted by VTM or a VTM × rate of gain interaction. However, MG heifers consumed more feed than LG heifers (17.02 vs. 10.97 ± 0.008 pounds, respectively; $P < 0.0001$), which was by design so that targeted gains would be met, and MG heifers had greater values of G:F than LG heifers ($P < 0.0001$).

A rate of gain × day interaction ($P = 0.006$; Figure 1) was observed for P4, whereas no differences ($P > 0.05$) were observed between MG or LG heifers on days 14 to 56, while concentrations of P4 tended ($P = 0.09$) to be greater in MG heifers on

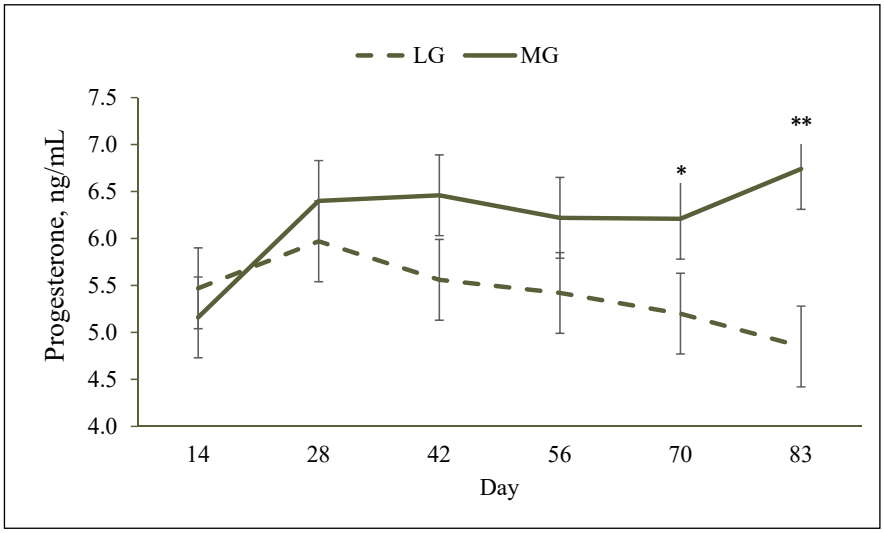

Figure 1. Effect of two different rates of gain during the first 83 days of pregnancy on circulating concentrations of progesterone (P4) in beef heifers (Low gain [LG], 0.62 lb/d and moderate gain [MG], 1.74 lb/d)). *denote days at which concentrations of P4 tended to be different between treatments ($0.05 < P \leq 0.10$). **denote days at which effect of treatments on concentrations of P4 were significant ($P \leq 0.05$).

day 70. On day 83, concentrations of P4 were greater ($P = 0.002$) for MG than LG heifers (6.74 vs. 4.85 ± 0.43 ng/mL, respectively).

No interactions ($P \geq 0.49$; Table 3) between VTM and rate of gain were observed for dam CL or gravid uterine weights. In addition, gravid uterine weight was not influenced ($P \geq 0.43$) by main effects of VTM or rate of gain.

Table 2. Effect of a vitamin and mineral (VTM) supplement and rates of gain during the first 83 days of pregnancy on performance and intake of beef heifers.

	NoVTM[1]		VTM[2]			*P*-values		
Item	LG	MG[3]	LG	MG[3]	SEM[4]	VTM	Rate of gain	VTM × Rate of gain
ADG[5], lb/d	0.77	1.81	0.71	1.94	0.08	0.72	< 0.0001	0.35
Forage DMI[6], lb/d	9.35	12.19	10.82	11.51	0.55	0.49	0.003	0.08
Starch-based supplement DMI, lb/d	-0.02	4.29	0.04	4.29	0.13	0.70	< 0.0001	0.91
Total DMI, lb/d	10.21	17.35	11.77	16.69	0.64	0.50	< 0.0001	0.11
G:F[7]	0.075	0.104	0.060	0.116	0.008	0.72	< 0.0001	0.10

[1]NoVTM: No vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day with no added vitamin and mineral supplement.
[2]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day (consisting of 113 g of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).
[3]Heifers fed with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil, urea, targeting a gain of 1.74 lb/d.
[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).
[5]ADG: Average daily gain
[6]DMI: Dry matter intake
[7]G:F: gain:feed ratio

Table 3. Effect of a vitamin and mineral supplement and(or) rates of gain during the first 83 days of pregnancy of beef heifers on the gravid reproductive tract and fetal body measurements.

	NoVTM[1]		VTM[2]			*P*-values		
Item	LG	MG[3]	LG	MG[3]	SEM[4]	VTM	Rate of gain	VTM × Rate of gain
Reproductive tract, g								
Gravid uterus	1,916.9	1,765.4	1,763.5	1,757.0	100.0	0.44	0.43	0.49
Corpus luteum	3.98	4.78	3.89	4.93	0.32	0.79	0.003	0.82
Fetal measurements, g								
Body weight	117.5	117.24	116.16	125.78	4.54	0.41	0.27	0.28
Liver	4.50	4.34	4.70	4.90	0.19	0.05	0.90	0.33
Heart	1.02	1.00	1.10	1.07	0.06	0.27	0.66	0.89
Intestine	2.56[a]	2.47[a]	2.42[a]	2.87[b]	0.11	0.24	0.09	0.03
Pancreas	0.292	0.269	0.265	0.292	0.044	0.96	0.97	0.57
Hindlimb	7.71	7.70	7.51	7.52	0.49	0.69	0.99	0.98
Femur	0.337	0.363	0.347	0.422	0.019	0.08	0.009	0.22
Brain	3.67	3.51	3.60	3.67	0.19	0.84	0.79	0.56

[1]NoVTM: No vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day with no added vitamin and mineral supplement.
[2]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day (consisting of 113 g of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).
3Heifers fed with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil, urea, targeting a gain of 1.74 lb/d.
[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).

However, MG heifers had greater CL weights than LG heifers (4.86 vs. 3.94 ± 0.32 g, respectively; $P = 0.003$). Our results indicate that moderate rates of gain during early gestation resulted in heavier CLs that consequently resulted in greater serum P4 concentrations. This is an important finding because progesterone is necessary for maintenance of pregnancy and for conceptus growth and development (Garrett et al., 1988).

A VTM × rate of gain interaction ($P = 0.03$; Table 3) was observed for fetal intestine weight, with greatest values in fetuses from VTM-MG dams and lowest values in fetuses from VTM-LG dams. Gravid uterine weight, fetal body weight, and fetal heart, pancreas, hindlimb and brain weights were not affected ($P \geq 0.22$) by VTM, rate of gain or their interaction, whereas rate of gain affected CL weights $P = 0.003$), with greater values in MG than LG heifers (4.86 vs. 3.94 ± 0.32 g, respectively).

Additionally, fetuses from MG dams had greater ($P = 0.009$) femur weights than fetuses from LG dams (0.39 vs. 0.34 g, respectively). Fetal liver weight was greater ($P = 0.05$) from dams fed VTM than NoVTM (4.80 vs. 4.42 ± 0.12 g, respectively).

In conclusion, moderate rates of gain during early gestation resulted in heavier CLs, greater circulating concentrations of P4 and greater fetal femur growth, whereas providing a VTM supplement enhanced fetal liver growth.

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Effects of two different rates of gain during early gestation in beef heifers on body weight, concentrations of IGF-1 and calf characteristics

Friederike Baumgaertner[1], Sarah R. Underdahl[1], Kevin K. Sedivec[3], James D. Kirsch[1], Sheri T. Dorsam[1], Ana Clara B. Menezes[1], Wellison J.S. Diniz[1], Alison K. Ward[1], Kacie L. McCarthy[2], Joel S. Caton[1] and Carl R. Dahlen[1]

The objectives of this study were to evaluate the impact of two different rates of gain in replacement heifers during the first trimester of gestation (84 days) on heifer growth, concentrations of IGF-1 and calf characteristics. Our results indicate that feeding heifers to achieve moderate rates of gain during the first 84 days of gestation increased rib fat and rib-eye area and impacted body weight and concentrations of IGF-1 throughout gestation. While no effects on fetal size in utero were detected, calves from heifers targeted for moderate gain were heavier at birth.

Summary

We hypothesized that rate of gain during the first trimester of gestation would affect heifer body weight (BW), body composition traits, concentrations of IGF-1, fetal size, and calf BW and measurements at birth. Crossbred Angus heifers (n = 48; initial BW = 818.2 ± 8.7 pounds) were estrus synchronized, bred via artificial insemination (AI), and assigned to a basal diet to achieve a low gain (**LG**, target gain of 0.625 pounds per day [lb/d]) or a basal diet plus a starch-based protein/energy supplement to achieve a moderate gain (**MG**, target gain of 1.75 lb/d). Heifers were individually fed for 84 days utilizing the Insentec feeding system (Insentec Marknesse, The Netherlands) and feed delivery was adjusted biweekly to achieve targeted gains. After day 84, heifers were managed as a single group on pasture, then in a dry lot until calving with access to free-choice mineral. Heifer BW and concentrations of serum IGF-1 were analyzed using the MIXED procedure of SAS and carcass traits, average daily gain, fetal measurements, calf birth weight, calving characteristics and calf body measurements were analyzed using the GLM procedure of SAS. By design, MG heifers were heavier than LG heifers ($P < 0.01$) at the end of the 84-day feeding period, with average daily gains being 1.21 lb/d greater ($P < 0.01$) in MG heifers (1.65 ± 0.04 lb/d), compared with LG heifers (0.44 ± 0.04 lb/d). The weight divergence was maintained throughout gestation, with MG heifers being 90.4 pounds heavier at calving ($P < 0.01$). For MG, concentrations of IGF-1 were greater by day 42 and continued throughout gestation ($P \leq 0.02$). Moderate-gain heifers had increased ($P < 0.01$) rib fat and rib-eye area at day 84, but the percent of intramuscular fat was not affected ($P = 0.69$) by nutritional treatment. Fetal size at days 42, 63 or 84 ($P \geq 0.20$) was not affected by rate of gain; however, calves from MG heifers were 4.8 pounds ($P = 0.03$) heavier and had greater chest circumference ($P = 0.04$) at calving, compared with calves from LG heifers. Early gestation nutrition impacted heifer BW and concentrations of IGF-1 throughout gestation, leading to increased calf birth weight and potential for additional post-natal impacts on calf performance and reproductive potential.

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

Introduction

The first trimester is a critical development stage, as the placenta is established, vascularization occurs, and fetal organogenesis takes place (Wu et al., 2004; Funston et al., 2010). Our lab has demonstrated that maternal nutrition and environmental factors during pregnancy affect fetal development which may impact offspring post-natal development and physiology. For instance, providing an energy/protein supplement to pregnant heifers during the first 83 days of gestation increases blood concentrations of maternal glucose and IGF1 (McCarthy et al., 2020). This is important because glucose provides most of the energy for the neural system.

Dietary restriction during gestation results in reduced concentrations of maternal IGF-1, leading to decreased fetal growth and lower calf weights at birth (Sullivan et al., 2009; Micke et al., 2010). For instance, providing a vitamin and mineral supplement and targeting moderate rates of gain (via energy/protein supplement) resulted in in-

creased fetal femur growth, heavier corpus lutea (McCarthy et al., 2020) and increased concentrations of key amino acids in the allantoic fluid and maternal serum (Menezes et al., 2020).

These studies raise the question of whether the metabolic changes demonstrated during the first trimester of pregnancy will be maintained throughout gestation and after birth as well. Thus, our objectives were to evaluate the impact of low and moderate rates of gain during the first 83 days of pregnancy on heifer body weight and composition, concentrations of IGF-1, fetal size and calf characteristics.

Experimental Procedures

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

One hundred crossbred Angus-based heifers were transported from the Central Grasslands Research Extension Center (CGREC) near Streeter, N.D., to the Beef Cattle Research Complex (BCRC) in Fargo, N.D., where they were trained to the Insentec Feeding System (Hokofarm B.V., Marknesse, the Netherlands) prior to estrus synchronization using a Select Synch plus CIDR and TAI protocol.

Between 48 and 72 hours following CIDR removal, heifers were bred by artificial insemination (AI) using female-sexed semen from a single sire. At breeding, heifers were assigned to one of two treatments, based on body weight and antral follicle count (determined via transrectal ultrasonography), heifers received: 1) a basal total mixed ration (TMR; low gain [LG] 0.625 lb/d; n = 23) or 2) the basal TMR diet with the addition of a starch-based protein/energy supplement (moderate gain [MG] 1.75 lb/d; n = 25, Table 1).

Only heifers pregnant to first-service AI gestating female calves were included in this study (LG, n = 23; MG, n = 25). All remaining heifers (n = 48; initial BW = 818.2 ± 8.7 pounds) were transported back to the CGREC on day 85, where they were managed as one pasture group, and then in a dry lot until calving. Heifers continued to have access to free-choice mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral [Land O'Lakes Inc.] Arden Hills, Minn.).

Heifers were weighed on two consecutive days at the beginning and end of the feeding trial, and every 14 days throughout the 84-day period prior to morning feeding, then on days 164, 234, 262 and at the time of calving. Body composition was assessed via carcass ultrasonography (500 V Aloka with 3.5-MHz transducer, Wallingford, Conn.) at the initiation of estrus synchronization and at the end of the feeding trial. Specific measurements included rib fat, rib-eye area and percent of intramuscular fat.

Maternal serum was collected on days minus 10, 42, 84, 164, 234 and 262 using vacutainer tubes and analyzed for concentrations of IGF-1 using an Immulite 1000 (Siemens, Los Angeles, Calif.). All heifers were evaluated for presence of fetus and crown-rump length (CRL) on day 42, and for fetal presence, biparietal distance (BPD) and fetal sex on day 63 and day 84 using transrectal ultrasonography (500 V Aloka with 5.0-MHz transducer, Wallingford, Conn.).

A total of 46 heifers carried female pregnancies to term (LG, n = 23; MG, n = 23). At calving, a calf vigor score (1 = normal calf, 2 = weak calf that nursed unassisted, 3 = weak calf assisted to nurse [lived], 4 = weak calf assisted to nurse [died] and 5 = stillborn) and a calving ease score (1 = no assistance, 2 = easy assist, 3 = difficult assist, 4 = caesarian, and abnormal presentation) were recorded.

Calf weights were recorded pre-suckling, and calf measurements were collected approximately 12 to 24 hours postpartum, with calves standing naturally (head raised and weight on all four feet). Body measurements included crown-rump length (from the top of the head to the beginning of the tail head), heart girth (posterior to foreleg), abdominal girth (circumference around the abdominal cavity at the umbilicus behind the last rib) and hip height (linear distance from the trochanter major of the femur to the floor).

Table 1. Ingredient composition of the rations fed to heifers during the first 84 days of gestation.

	Treatment	
Item	LG[1]	MG[2]
Ingredient, % of DM		
Corn silage	37	29
Prairie hay	53	41
DDGS	10	5
Energy/protein supplement[2]	–	25

[1]Basal TMR contained a commercially available 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, targeting gain of 0.625 lb/d.
[2]The supplement fed was an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 lb/d.

Heifer BW was analyzed as repeated measures using the MIXED procedure of SAS for effects of treatment, day and a treatment × day interaction. Daily gain, body composition traits and fetal measurements were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Heifer was considered the experimental unit in all analyses and significance was set at P ≤ 0.05.

Results and Discussion

As expected, feeding heifers to gain 1.75 lb/d by providing an energy/protein supplement during the first 84 days of gestation impacted heifer growth throughout gestation (Figure 1). Heifer body weights diverged by day 14 ($P = 0.01$) after treatment initiation and differed by 122.1 pounds at the end of the treatment period ($P < 0.01$).

This divergence continued ($P < 0.01$), until calving, at which time heifers in the MG treatment remained 90.4 pounds heavier than LG heifers ($P < 0.01$). During the feeding period, the average daily gain (ADG) of LG heifers was 0.44 ± 0.04 lb/d, while MG heifers had an ADG of 1.65 ± 0.04 lb/d ($P < 0.01$; Table 2), which is close to the targeted gains of 0.625 lb/d and 1.75 lb/d for LG and MG heifers, respectively.

Rib fat ($P < 0.01$) and rib-eye area ($P < 0.01$) were affected by treatment at day 84, with greater values for MG heifers. No differences ($P = 0.69$) were observed for percentage of intramuscular fat (Table 3). Through time, LG heifers lost rib fat and rib-eye area, while MG heifers increased for these measurements ($P \leq 0.01$).

While the present study assessed carcass characteristics at the beginning and end of the feeding period during early gestation, others found differences in rib fat, rib-eye area and percent of intramuscular fat at 140 days postweaning for replacement heifers fed to appetite or restricted (Roberts et al., 2007). Differences to our observations could be explained not only by time of measurement but also by differences in study design. Roberts et al. (2007) had a control and a restricted treatment, whereas in our study, the low- and moderate-gain targets are within the range observed in production scenarios.

Concentrations of IGF-1 were increased by day 42 and were maintained until parturition in MG heifers

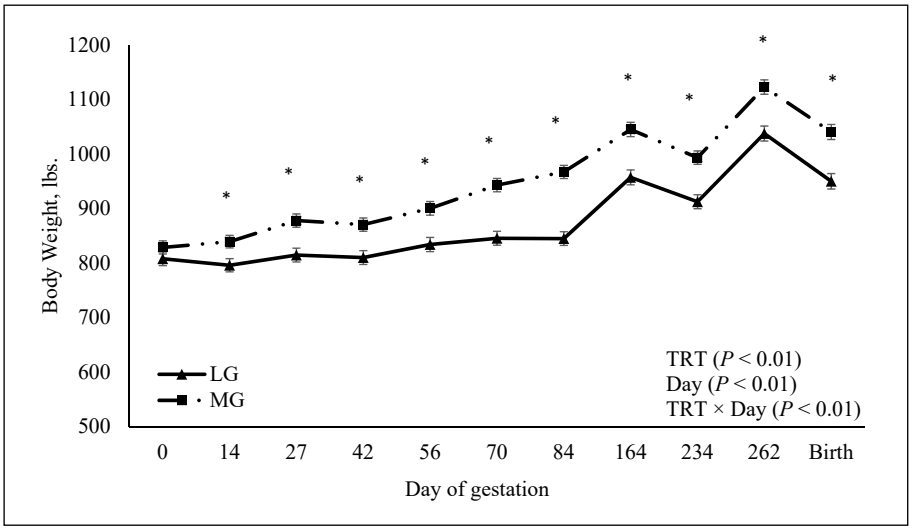

Figure 1. Impact of rate of gain (low gain [LG], targeting gain of 0.625 lb/d; medium gain [MG], targeting gain of 1.75 lb/d) on mean body weights and SEM from initiation of the 84-day feeding period until calving in beef heifers (n = 48). Asterisks denote days at which effect of treatments on body weights are significant ($P < 0.01$).

Table 2. Impact of rate of gain of replacement heifers on average daily gain and fetal measurements during early gestation.

	Treatment[1]			
Item	LG	MG	SEM[2]	*P*-Value
No. of heifers	23	25		
ADG[3], lb./d	0.44	1.65	0.04	<0.01
Fetal size				
CRL[4], in	0.85	0.86	0.0098	0.50
BPD[5] at d 63, in	0.61	0.61	0.0059	0.35
BPD at d 84, in	1	1.01	0.0075	0.20
BPD change[6], in	0.39	0.4	0.0091	0.66

[1]Treatment: 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 lb/d for moderate gain and 0.625 lb/d for low gain heifers.
[2]SEM = Standard error of the mean (n = 48).
[3]ADG = Average daily gain.
[4]CRL = Crown-rump length evaluated at day 42 of gestation.
[5]BPD = Biparietal diameter; measure of skull width taken via ultrasonography.
[6]BPD change = BPD at day 84 – BPD at day 63; to calculate fetal growth rate.

($P < 0.01$; Figure 2). Similarly, Sullivan et al. (2009) found that diets increased in protein resulted in greater concentrations of maternal IGF-1, which coincides with results from Cappellozza et al. (2014), who reported that not only was ADG increased when a protein or energy supplement was fed, but also concentrations of IGF-1 were increased in supplemented heifers.

We found no effect of maternal treatment on crown-rump length ($P = 0.50$) or fetal biparietal diameter (BPD) at day 63 (P = 0.35) or day 84 ($P = 0.20$; Table 2). However, calf weights at birth were 4.8 pounds greater ($P = 0.03$) and had greater chest circumference ($P = 0.04$) for MG heifers (Table 4). This may indicate that increased concentrations of maternal IGF-1 throughout gestations are related to fetal growth and calf weights at birth.

In conclusion, developing heifers to moderate rates of gain targeting 1.75 lb/d during the first 84 days of gestation, compared with low rates of gain targeting 0.625 lb/d, has the potential to increase heifer growth and concentrations of IGF-1, alter rib fat and rib-eye area, and result in greater calf weights and measurements at birth.

Acknowledgments

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Table 3. Impact of rate of gain of replacement heifers on carcass ultrasonography measurements at the beginning and end of the feeding period.

	Treatment[1]			
Item	LG	MG	SEM[2]	*P*-Value
No. of heifers	23	25		
Rib fat[3], in				
Beginning	0.16	0.16	0.010	0.67
End	0.13	0.21	0.009	<0.01
Change[6]	-0.021	0.053	0.007	<0.01
Rib-eye area[4], in^2				
Beginning	8.90	9.34	0.170	0.07
End	8.63	9.97	0.200	<0.01
Change[6]	-0.28	0.63	0.159	<0.01
Intramuscular fat[5], %				
Beginning	4.64	4.56	0.207	0.79
End	4.51	4.61	0.178	0.69
Change[6]	-0.13	0.05	0.153	0.41

[1]Treatment: 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 lb/d for moderate gain and 0.625 lb/d for low gain heifers.
[2]SEM = Standard error of the mean (n = 48).
[3]Rib fat (measured at 12th rib).
[4]Rib-eye area (measured at 12th rib).
[5]% intramuscular fat (measured at 12th rib).
[6]Change = measurement at end of feeding – measurement at beginning of feeding.

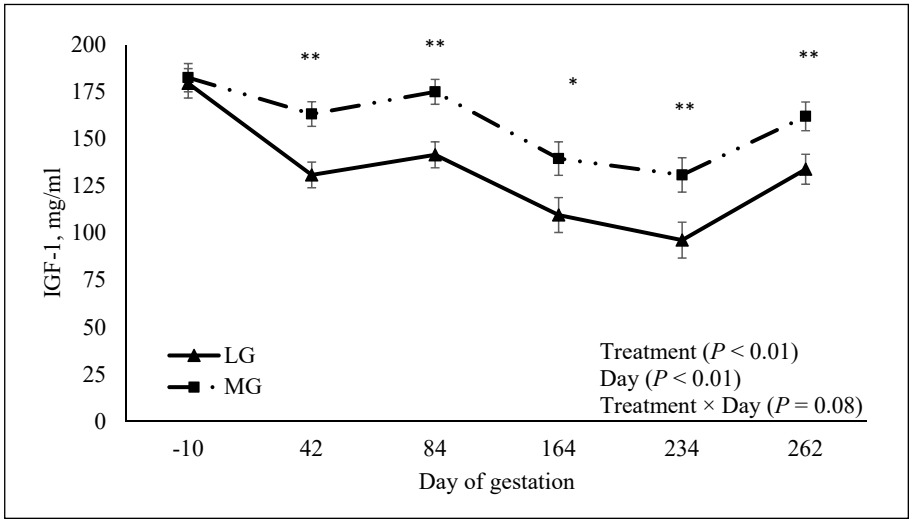

Figure 2. Impact of rate of gain (low gain [LG], targeting gain of 0.625 lb/d; medium gain [MG], targeting gain of 1.75 lb/d) on serum IGF-1 concentrations and SEM from initiation of the 84-day feeding period until d 262 of gestation in beef heifers (n = 48). * denote days at which effect of treatments on serum IGF-1 concentration is significant ($P = 0.02$). ** denote days at which effect of treatments on serum IGF-1 concentration is significant ($P \leq 0.01$).

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Table 4. Impact of rate of gain of replacement heifers during early gestation on heifer calf weights and measurements at birth, and calving characteristics.

	Treatment[1]			
Item	**LG**	**MG**	**SEM[2]**	***P*-value**
No. of calves	23	23		
Calf birth weight[3], lbs.	63.1	67.9	1.52	0.03
Calf body measurements[4], in				
Chest circumference	29.2	30	0.28	0.04
Heart girth circumference	28.3	28.7	0.37	0.40
Crown-rump length	31.6	31.9	0.39	0.69
Hip height	27.9	28.5	0.28	0.11
Calving Characteristics				
Calving ease	1.1	1.2	0.08	0.47
Calf vigor	1.0	1.2	0.09	0.20

[1]Treatment: 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 lb/d for moderate gain and 0.625 lb/d for low-gain heifers.
[2]SEM = Standard error of the mean (n = 46).
[3]All calf birth weights were pre-suckling weights.
[4]All calf body measurements were collected approximately 12 to 24 hours post calving.

Effects of feeding a vitamin and mineral supplement and rate of gain during the first 83 days of pregnancy on concentrations of amino acids in beef heifer serum and fetal fluids

Ana Clara B. Menezes[1], Kacie L. McCarthy[2], Cierrah J. Kassetas[1], Friederike Baumgaertner[1], James D. Kirsch[1], Sheri Dorsam[1], Tammi L. Neville[1], Alison K. Ward[1], Pawel P. Borowicz[1], Lawrence P. Reynolds[1], Kevin K. Sedivec[3], J. Chris Forcherio€, Ronald Scott[4], Joel S. Caton[1] and Carl R. Dahlen[1]

The objective of this study was to evaluate the effects of feeding vitamin and mineral supplement and two different rates of gain during the first 83 days of pregnancy on amino acid concentrations in maternal serum, and allantoic and amniotic fluid. Our results show that providing a vitamin and mineral supplement and targeting moderate rates of gain altered concentrations of amino acids in maternal serum and allantoic fluid, which may be an important link to future performance of the offspring.

Summary

The objective of this study was to evaluate the effects of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on amino acid (AA) concentrations in maternal serum, allantoic fluid and amniotic fluid. Thirty-five crossbred Angus heifers (initial body weight [BW] = 792.6 ± 15.7 pounds) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplement (VTM or NoVTM) and rate of gain (low gain [LG], 0.62 pounds per day (lb/d), vs. moderate gain [MG], 1.74 lb/d). The VTM treatment (113 grams (g)/heifer/day) was initiated at least 71 days before artificial insemination (AI). At breeding, heifers were maintained on their respective diets (target gain of 0.62 lb/d) or fed a starch-based protein/energy supplement (target gain of 1.74 lb/d). Heifers were ovariohysterectomized on day 83 of gestation and samples of maternal serum, allantoic fluid and amniotic fluid were collected. Samples then were analyzed for concentrations of neutral amino acid (AA): alanine (Ala), asparagine (Asn), cysteine (Cys), glutamine (Gln), glycine (Gly), isoleucine (Ile), leucine (Leu), methionine (Met), phenylalanine (Phe), proline (Pro), serine (Ser), threonine (Thr), tryptophan (Trp), tyrosine (Tyr) and valine (Val); cationic AA: arginine (Arg), histidine (His) and lysine (Lys); and anionic AA: aspartic acid (Asp) and glutamic acid (Glu). In serum, a VTM × rate of gain interaction ($P = 0.02$) was observed for Glu, with greater concentrations for VTM-LG than VTM-MG. Concentrations of serum Cys, Met and Trp were greater ($P \leq 0.03$) for MG than LG. In allantoic fluid, concentrations of Glu were affected by a VTM × rate of gain interaction, where VTM-MG was greater ($P < 0.01$) than all other treatments. Further, allantoic fluid from VTM had increased ($P \leq 0.05$) concentrations of His, Asp and 12 of the 14 neutral AA, whereas rate of gain affected concentrations of Arg, Cys and Asp, with greater concentrations ($P \leq 0.05$) in MG heifers. In amniotic fluid, AA concentrations were not affected ($P \geq 0.10$) by VTM, rate of gain or their interaction. In conclusion, increased concentrations of AA in maternal serum and allantoic fluid of beef heifers were observed at day 83 of gestation in response to VTM supplementation and moderate rate of gain, which raises important questions regarding the mechanisms responsible for AA uptake and balance between the maternal circulation and fetal fluid compartments.

Introduction

Replacement heifers require nutrients for growth, pregnancy maintenance and fetal development (NASEM, 2016). Additionally, the developing fetus requires amino acids (AA) as key molecules to support its growth, metabolism and osmoregulation of fetal fluids (Wu et al., 2014).

Proper mineral and vitamin nutrition is essential to optimize growth and reproductive performance of beef cattle (Kegley et al., 2016). Minerals and vitamins

[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, NDSU
[2]Department of Animal Sciences, University of Nebraska-Lincoln
[3]Central Grasslands Research Extension Center, NDSU
[4]Purina Animal Nutrition LLC, Gray Summit, Mo.

are efficiently transferred during gestation from dam to fetus to be partitioned for metabolic use and stored as a postnatal mineral reserve (Hostetler et al, 2003).

However, producer decisions about whether to provide micronutrient supplements to gestating cattle vary widely (Davy et al., 2019). Further, considering that energy and protein requirements of heifers are greater than for mature cows, nutritional strategies that target moderate rates of gain may optimize pregnancy rates and maternal-fetal transfer of nutrients, and increase offspring birth weights.

Therefore, the primary aim of this study was to test the hypothesis that vitamin and mineral supplementation and rate of gain during the first trimester of gestation would impact the concentrations of AA in maternal serum and allantoic and amniotic fluids.

Experimental Procedures

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

Thirty-five crossbred Angus heifers (initial BW = 792.6 ± 15.7 pounds) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplementation (VTM or NoVTM) and rate of gain [low gain (LG) 0.62 lb/d or moderate gain (MG) 1.74 lb/d]. Briefly, the VTM supplement was initiated at least 71 days before artificial insemination.

At breeding, heifers were maintained on their respective diets (LG) or fed a starch-based protein/energy supplement (MG). This resulted in the following treatment combinations: 1) No vitamin and mineral supplement, low gain (NoVTM-LG; n = 9); 2) No vitamin and mineral supplement, moderate gain (NoVTM-MG; n = 9); 3) Vitamin and mineral supplement, low gain (VTM-LG; n = 9); 4) Vitamin and mineral supplement, moderate gain (VTM-MG; n = 8). Heifers were fed individually in Calan gates, and supplements were top dressed over the total mixed ratio (Table 1).

Heifers were ovariohysterectomized on day 83 ± 0.27 of gestation. At the time of ovariohysterectomy, samples of maternal serum, allantoic fluid and amniotic fluid were collected. Aliquots of the fluids were placed in 2 milliliter microtubes and snap frozen on dry ice and stored at minus 80 C for subsequent AA analysis.

Concentrations of neutral AA (Ala, Asn, Cys, Gln, Gly, Ile, Leu, Met, Phe, Pro, Ser, Thr, Trp, Tyr and Val); cationic AA (Arg, His and Lys); and anionic AA (Asp and Glu) were determined using the ACQUITY Ultra-Performance Liquid Chromatography System (Waters Corporation, Milford, Mass.). Data were analyzed using the MIXED procedures of SAS for effects of VTM, rate of gain and a VTM × rate of gain interaction. Differences were considered significant at a *P*- value ≤ 0.05.

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

		Supplements		
Chemical Composition	Total Mixed Ration[1]	NoVTM[2]	VTM[3]	Starch-based protein/energy[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
Nonfiber 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

1Proportion of ingredients: prairie grass hay (55%), corn silage (38%), and dried distillers grains plus solubles (7%).

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

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

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

Results and Discussion

In maternal serum, a VTM × rate of gain interaction ($P = 0.02$) was observed for Glu concentration, with greater concentrations for VTM-LG than VTM-MG heifers (Figure 1A); furthermore, concentrations of Cys, Met and Trp were greater ($P \leq 0.03$) for MG than LG heifers. In allantoic fluid (Table 2), concentrations of Glu were influenced by a VTM × rate of gain interaction ($P < 0.01$), with VTM-MG heifers having greater concentrations that all others (Figure 1B).

Further, allantoic fluid from VTM had increased ($P \leq 0.05$) concentrations of His, Asp and 12 of the 14 neutral AA, whereas rate of gain affected concentrations of Arg, Cys and Asp, with greater concentrations ($P \leq 0.05$) in MG heifers. In amniotic fluid, AA concentrations were not affected ($P \geq 0.10$) by VTM, rate of gain or their interaction.

A major finding from this study is that a vitamin and mineral supplement resulted in a greater concentration of neutral AA in the allantoic fluid of beef heifers. In addition, enhanced rate of gain resulted in increased concentrations of amino acids in serum and allantoic fluid. As this is a period of intense metabolic activity, due to organogenesis and placentation, an increased uptake of these key AA may represent a critical supply to the developing fetus.

Our data show that VTM heifers with moderate rates of gain had the greatest concentrations of Glu in allantoic fluid and the lowest serum concentrations at day 83 of gestation, suggesting a synergy between VTM and moderate rates of gain increased Glu utilization by fetal tissues because Glu is likely to be quantitatively the principal fuel amongst the AA.

In conclusion, moderate rate of gain and a VTM supplement during the first trimester of gestation influenced the concentrations of AA in serum and allantoic fluid at day 83 of gestation in beef heifers, with a significant increase in the concentrations of neutral AA in the allantoic fluid of heifers consuming vitamin and mineral supplements. Data contained herein provide useful information about the impacts of rate of gain and mineral and vitamin supplements on the fetal environment during early gestation in beef heifers, which may be an important link to future performance of the offspring.

Acknowledgments

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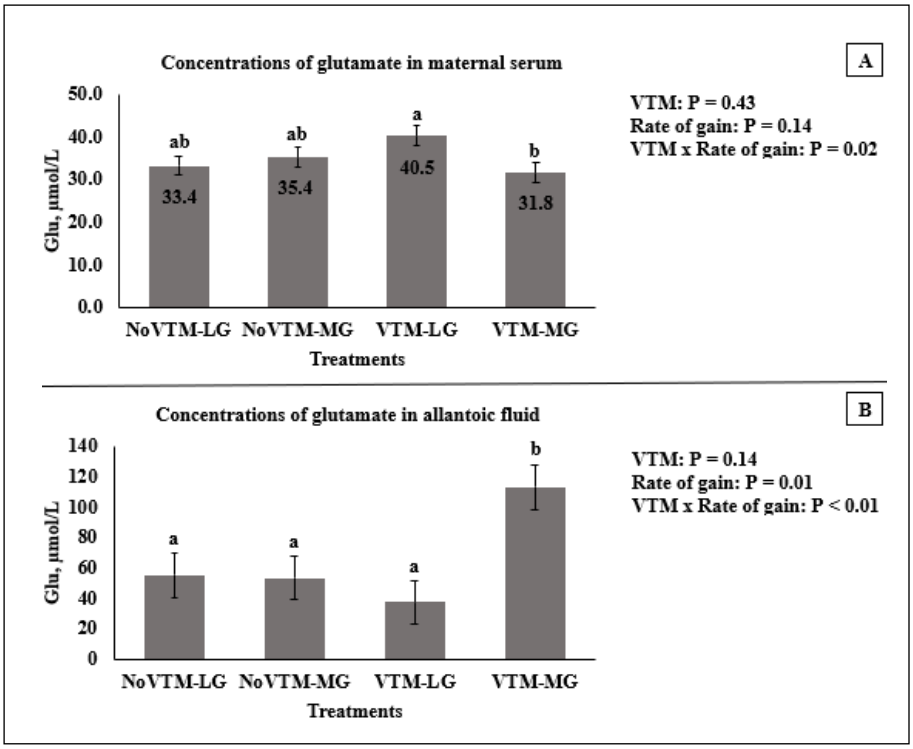

Figure 1 Concentrations of glutamate in maternal serum (A) and allantoic fluid (B) of beef heifers on day 83 of gestation. Treatments were: 1) No vitamin and mineral supplement, low gain (NoVTM-LG; n = 9); 2) No vitamin and mineral supplement, moderate gain (NoVTM-MG; n = 9); 3) Vitamin and mineral supplement, low gain (VTM-LG; n = 9); 4) Vitamin and mineral supplement, moderate gain (VTM-MG; n = 8). ab Differences indicated when the *P*-values were ≤ 0.05.

Table 2. Concentrations of amino acids in allantoic fluid from heifers at day 83 of gestation as influenced by vitamin and mineral (VTM) supplement and two different rates of gain.

Amino acid concentrations, µmol/L	NoVTM[1]		VTM[2]			*P*-value		
	LG	MG[3]	LG	MG[3]	SEM[4]	VTM	Rate of gain	VTM × Rate of gain
Total	12389.0	13745.0	15599.0	19773.0	1751.5	<0.01	0.11	0.41
Neutral								
Ala	1767.5	1794.0	2032.6	2516.9	183.1	<0.01	0.16	0.20
Asn	209.9	227.5	252.7	338.6	36.5	0.04	0.15	0.34
Cys	50.3	68.0	68.2	90.4	9.8	0.04	0.04	0.81
Gln	2070.8	2416.6	2880.9	3490.2	344.7	<0.01	0.16	0.69
Gly	2851.4	2735.1	3242.1	3949.5	364.7	0.03	0.40	0.25
Ile	139.7	151.3	161.7	219.1	23.2	0.05	0.13	0.31
Leu	362.5	407.4	405.3	581.7	59.7	0.07	0.06	0.26
Met	376.8	451.8	471.7	638.7	73.7	0.05	0.09	0.52
Phe	412.1	499.3	560.8	792.7	109.3	0.04	0.14	0.49
Pro	455.5	443.4	475.3	661.8	59.5	0.05	0.14	0.09
Ser	697.0	597.1	736.7	1006.0	106.8	0.04	0.41	0.08
Thr	415.4	720.6	855.1	919.4	118.6	<0.01	0.11	0.29
Trp	110.2	169.7	162.8	224.8	36.7	0.14	0.09	0.97
Val	486.3	517.6	583.3	775.2	78.1	0.02	0.15	0.29
Cationic								
Arg	638.3	825.0	749.5	1060.5	129.3	0.17	0.05	0.62
His	985.1	1371.0	1706.5	2079.7	307.9	0.02	0.21	0.98
Lys	288.7	275.1	193.8	280.0	47.7	0.33	0.43	0.28
Anionic								
Asp	16.2	20.5	21.9	33.9	3.8	0.01	0.03	0.29
Glu	55.6[a]	53.9[a]	37.8[a]	113.8[b]	14.6	0.14	0.01	<0.01

[1]NoVTM: No vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day with no added vitamin and mineral supplement.
[2]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb/heifer/day (consisting of 113 g of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).
[3]Heifers fed with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea, targeting a gain of 1.74 lb/d.
[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).
[ab] means without a common superscript differ (P ≤ 0.05).

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Effects of feeding 60% dried corn distillers grains plus solubles or the equivalent sulfur as $CaSO_4$ to yearling Angus bulls on glucose, urea nitrogen and trace mineral concentrations in serum and seminal plasma

Cierrah J. Kassetas[1], Joel S. Caton[1], James D. Kirsch[1], Sheri T. Dorsam[1], Kacie L. McCarthy[1], Matthew S. Crouse[1], Kevin K. Sedivec[2], Bryan W. Neville[3] and Carl R. Dahlen[1]

The objectives of this study were to investigate the effects of feeding 60% dried corn distillers grains plus solubles (DDGS) or the equivalent sulfur (S) as $CaSO_4$ on glucose, urea nitrogen (N) and trace mineral concentrations in serum and seminal plasma. Thirty-six half-sibling Angus bulls were fed in a Calan gate system to target an average daily gain of 1.6 kilograms per day (kg/d) for 112 days. The results from this study indicate that sulfur may not be the only factor in DDGS influencing semen characteristics.

Summary

Thirty-six half sibling Angus bulls from the Central Grasslands Research Center near Streeter, N.D., were fed one of three treatments: 1) 60% corn-based concentrate diet (CON; S = 0.18%; n = 12); 2) diet containing 60% DDGS as a replacement for corn (60DDGS; S = 0.55% DM; n = 12); 3) CON diet + equivalent S of the 60DDGS diet added as $CaSO_4$ (SULF; S = 0.54%; n = 12). Bulls were fed indoors in a Calan gate system and targeted to gain 1.6 kg/d for 112 days. Blood and semen samples were collected on days 0, 56 and 112, then evaluated for concentrations of glucose, urea-N and trace mineral concentrations in serum and seminal plasma. In serum, at days 112 and 56, bulls had greater ($P < 0.01$) concentrations of glucose, compared with day 0. In seminal plasma, glucose concentrations were greater ($P < 0.02$) at day 112 (231.6 milligrams per deciliter [mg/dL]), compared with days 0 (109.2 mg/dL) and 56 (171.5 mg/dL). At day 0, serum urea-N concentrations were not different ($P > 0.77$) among treatments; however, at days 56 and 112, 60DDGS had greater ($P < 0.01$) concentrations of urea-N, compared with SULF and CON. For seminal plasma urea-N, 60DDGS had a greater ($P < 0.01$) concentration when compared with CON and SULF. For trace mineral concentrations in serum, treatment × day interactions were observed for cobalt (Co), copper (Cu), zinc (Zn), selenium (Se) and molybdenum (Mo) ($P < 0.03$). At day 0, no differences ($P > 0.3$) were observed for Co, but on day 56, CON was greater ($P < 0.01$) than 60DDGS and SULF, with no divergence observed among treatments at day 112 ($P \geq 0.09$). For Cu, no differences ($P > 0.15$) were observed at days 0 or 56, but at day 112, DDGS was reduced ($P < 0.01$), compared with SULF and CON. At day 0, Zn was greater ($P < 0.01$) in SULF, compared with CON, whereas 60DDGS was intermediate and, at day 112, SULF was reduced ($P = 0.03$), compared with CON. In serum, at day 0, no differences ($P > 0.09$) were observed for Se; however, at days 56 and 112, Se was greater ($P < 0.01$) in 60DDGS, compared with CON and SULF. For Mo, at day 0, 60DDGS was greater ($P = 0.03$) than CON, whereas SULF was intermediate. At days 56 and 112, CON was greater ($P < 0.01$) than SULF and 60DDGS for Mo. In seminal plasma, treatment × day interactions were observed for Cu and Mo ($P < 0.02$). For Cu, no differences ($P \geq 0.09$) were observed on days 0 or 56, but on day 112, CON and 60DDGS were greater ($P < 0.01$), compared with SULF. For Mo, at day 0, 60DDGS was greater ($P = 0.03$) compared with SULF, whereas CON was intermediate, but at days 56 and 112, CON was greater ($P < 0.01$) than DDGS and SULF. In addition, seminal plasma Se was greater ($P = 0.02$) for DDGS, compared with SULF, whereas CON was intermediate. Feeding 60% DDGS in the diets of young beef bulls altered urea-N and trace mineral concentrations; however, this response may not be due solely to sulfur.

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

Introduction

Attainment of puberty and semen quality in young bulls can be influenced by nutrition. Research indicates that bulls on a high plane of nutrition early in life have reduced age at puberty and increased testes weight, resulting in greater daily sperm production (Thundathil et al., 2016).

One ingredient that has been increasingly utilized in beef cattle diets to supply the animal with more protein and energy is dried corn distillers grains plus solubles (DDGS). However, DDGS contains an elevated concentration of sulfur, which is in the form of sulfuric acid and S- containing amino acids. Therefore, when DDGS is fed at greater percentages of the diet, it may be influencing growth and reproductive performance in beef cattle (Drewnoski et al., 2014).

This study was conducted to investigate the effects of feeding 60% DDGS or the equivalent sulfur as $CaSO_4$ on glucose, urea-N and trace mineral concentrations in serum and seminal plasma of yearling Angus bulls.

Experimental Procedures

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

Animals and Diets

Thirty-six half-sibling Angus bulls [256 ± 8 days; mean initial body weight (BW) = 320 ± 2 kg] were assigned to one of three treatments: 1) corn-based diet containing 60% concentrate [CON; S = 0.18% dry matter (DM); n = 12]; 2) diet containing 60% dried corn distillers grains plus solubles (DDGS) as a replacement for corn (60DDGS; S = 0.55% DM; n = 12); 3) CON diet + equivalent sulfur of the 60DDGS diet added as CaSO4 (SULF; S = 0.54% DM; n = 12). All bulls were housed indoors in the Animal Nutrition and Physiology Center in Fargo, N.D. Bulls were individually fed in a Calan gate system and individual intakes were adjusted to target a 1.6 kg/d average daily gain (ADG) for 112 days.

Blood and Seminal Plasma Collection

Body weights were recorded every 14 days during the 112-day study, with a two-day weight at the beginning and end of the study. Blood samples were collected in tubes containing heparin for plasma before the morning feeding on days 0, 56 and 112 via jugular venipuncture. Semen was collected on days 0, 28, 56, 84 and 112 via electroejaculation (Pulsator IV; Lane Manufacturing Inc; Denver, Colo.) into disposable plastic semen collection bags.

All blood and semen samples were centrifuged at 1,500 × g for 20 minutes at 4 C (Sorvall ST 16R; Thermo Scientific Inc.; Waltham, Mass.). The supernatant from the plasma blood tubes and semen tubes were pipetted into 2-milliliter screw cap tubes and stored at minus 20 C.

Laboratory Analyses

Glucose was analyzed on a microplate spectrophotometer using the Infinity glucose kit from Thermo Scientific containing the hexokinase/glucose-6-phosphate dehydrogenase method (Pittsburgh, Pa.). Serum urea-N was analyzed based on the procedures of Jung et al. (1975). A QuantiChrom Urea Assay Kit (BioAssay Systems; Hayward, Calif.) containing o-phthaldialdehyde and primaquine diphosphate was analyzed on the microplate spectrophotometer.

A trace mineral panel was evaluated on all serum and seminal plasma samples. This panel consisted of Co, Cu, manganese (Mn), Mo, Se, iron (Fe) and Zn. All samples were analyzed at the Veterinary Diagnostic Lab at Michigan State University (Lansing). Results were considered significant when *P*-values were ≤ 0.05.

Results and Discussion

In serum, at days 56 and 112, bulls had greater ($P < 0.01$) concentrations of glucose, compared with day 0. In seminal plasma, glucose concentrations were greater ($P < 0.02$) at day 112, compared with days 0 and 56.

At day 0, serum urea-N concentrations were not different ($P > 0.77$) among treatments; however, at days 56 and 112, 60DDGS had greater ($P < 0.01$) concentrations of urea-N, compared with SULF and CON. For seminal plasma urea-N concentrations, 60DDGS was greater ($P < 0.01$) when compared with CON and SULF.

For trace mineral concentrations in serum, treatment × day interactions were observed for Co, Cu, Zn, Se and Mo ($P \leq 0.02$; Figure 1). At day 0, no differences ($P \geq 0.38$) were observed for Co, but at day 56, CON was greater ($P < 0.01$) when compared with 60DDGS and SULF; however, no differences ($P \geq 0.09$) were observed among treatments for Co at day 112.

For Cu, no differences ($P \geq 0.15$) were observed at days 0 or 56, but at day 112, DDGS was reduced ($P < 0.01$) when compared with SULF and CON. For Se, at day 0, no differences ($P \geq 0.09$) were observed; however, at days 56 and 112, 60DDGS was greater ($P \leq 0.01$) when compared with CON and SULF. For Mo, at day 0, 60DDGS was greater ($P = 0.03$) than CON, whereas SULF was intermediate. At days 56 and 112, CON was greater ($P < 0.01$) than SULF and 60DDGS for Mo.

For seminal plasma trace mineral concentrations, treatment × day interactions were observed for Cu and Mo ($P = 0.02$, 0.01, respectively; Figure 2). For Cu, no differences ($P \geq 0.09$) were observed at days 0 or

56, but at day 112, CON and DDGS were greater ($P < 0.01$), compared with SULF.

For Mo, at day 0, 60DDGS was greater ($P = 0.03$), compared with SULF, whereas CON was intermediate. At days 56 and 112, CON was greater ($P < 0.01$), compared with 60DDGS and SULF for Mo. Furthermore, a treatment effect was observed for Se where 60DDGS was greater ($P = 0.02$), compared with SULF, whereas CON was intermediate (Figure 3).

Increased urea-N concentrations for 60DDGS may have been observed because of the percentage of crude protein (CP) in the diet. The 60DDGS diet had 22% CP, whereas the CON and SULF treatments had 13% CP. The nitrogen from this protein will be converted to microbial protein in the rumen then absorbed as amino acids by the small intestine, excreted or transported to the liver, where other amino acids will be synthesized.

Many interactions between trace minerals have been reported, but the relationship among Cu, Mo and S may explain some of the differences observed. In brief, Mo and S can influence the absorption of Cu, which can affect the synthesis of enzymes and hormones and influence the regulation of cell replication (Baker et al., 2006).

Diets containing greater concentrations of sulfur can cause Cu and Mo concentrations to decrease in serum through the production of thiomolybdates (Suttle, 1974). In this study, we observed that the diets containing greater amounts of sulfur had reduced Mo; however, for Cu, a different trend was observed.

The different sources of sulfur may be an explanation for the conflicting responses observed for Cu and Mo. Calcium sulfate from the SULF treatment may have been more readily converted to ruminal H_2S, which is less likely to enter circulation and effect Cu concentrations in serum.

Selenium is another trace mineral that can be influenced by increasing concentrations of dietary sulfur because both elements have similar chemical and physical properties (Ivancic and Weiss, 2001). Additionally, Se is a major component of glutathione peroxidase, which aids in the protection of sperm from oxidative damage (Baker, 2006).

In this study, Se concentrations in seminal plasma paralleled well

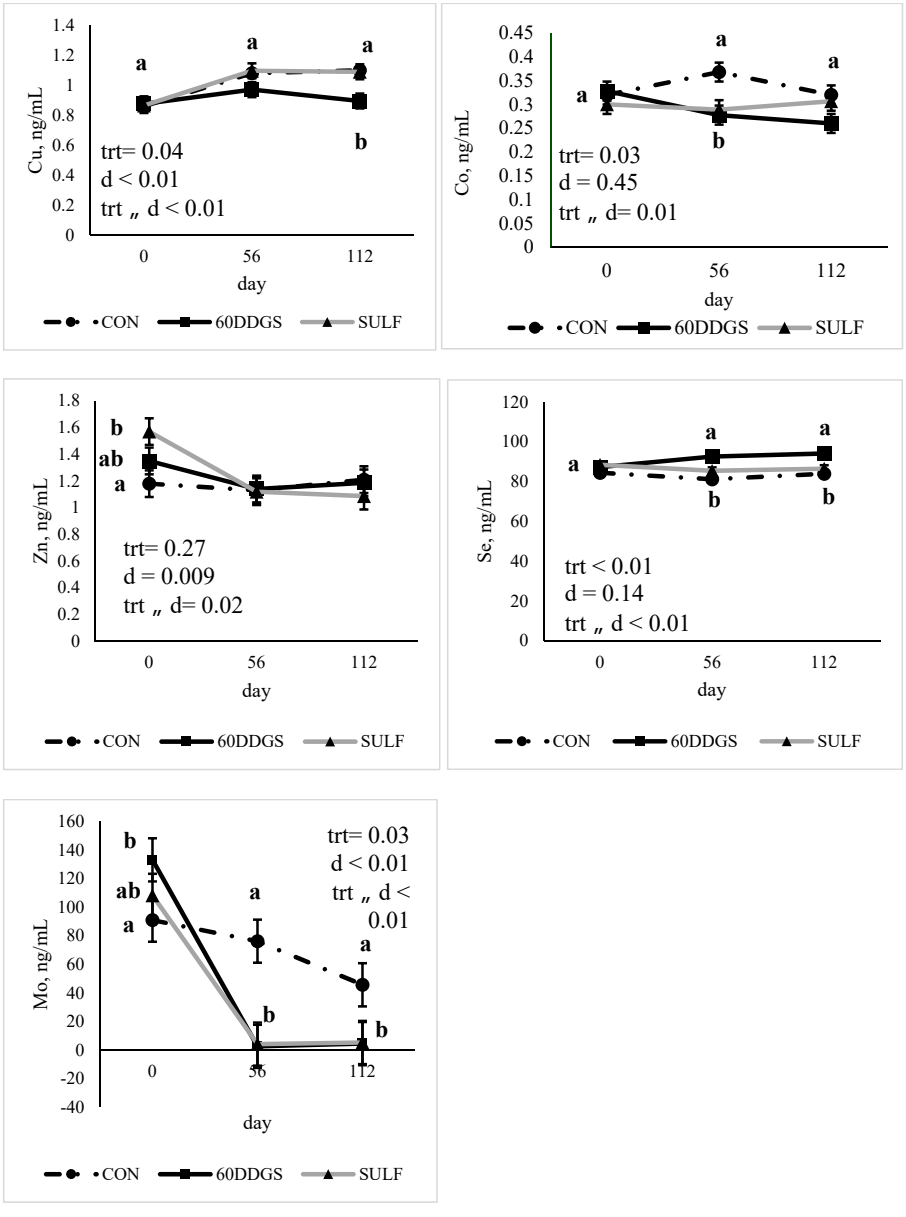

Figure 1. Treatment × day interactions for trace mineral concentrations in serum. Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60%; DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). ab Differences indicated when the *P*– values were ≤ 0.05.

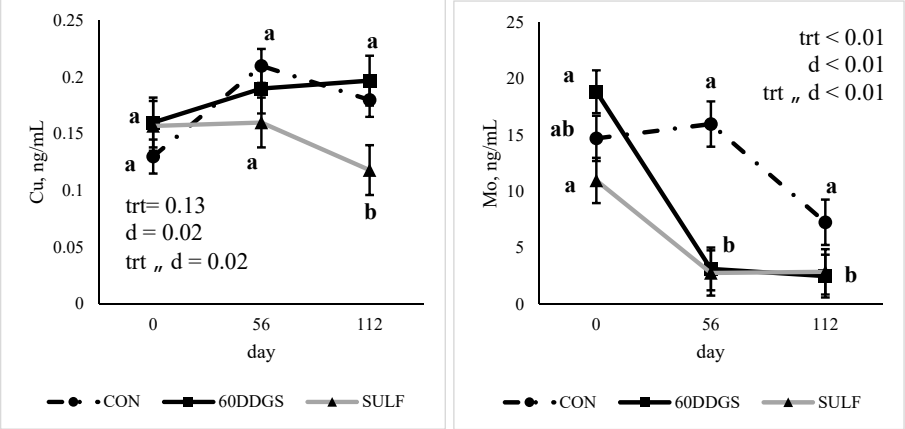

Figure 2. Treatment × day interactions for trace minerals in seminal plasma. Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60%; DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). ab Differences indicated when the *P*– values were ≤ 0.05.

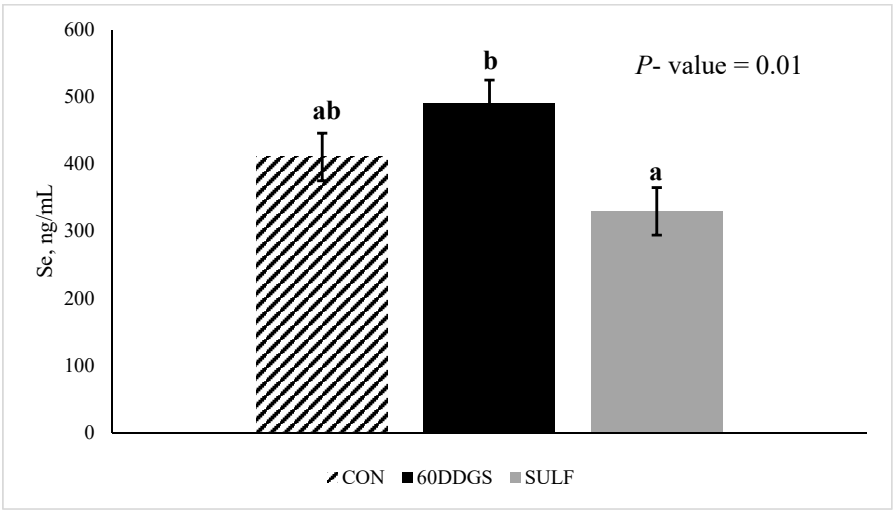

Figure 3. Effects of treatment for Se concentrations in seminal plasma. Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60%; DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). ab Differences indicated when the *P*– values were ≤ 0.05.

with seminal plasma glutathione peroxidase concentrations that were reported previously. However, additional research is necessary to evaluate the DNA and RNA structure and integrity of these bulls to further elucidate how DDGS influenced these populations of sperm.

In summary, concentrations of glucose increased in serum and seminal plasma as bulls were maturing, demonstrating that components of seminal plasma change as bulls approach puberty. Additionally, differences in trace mineral concentrations in serum and seminal plasma may have been observed in response to the increase of dietary sulfur and, therefore, the necessary enzymes were synthesized to maintain proper sperm function. Furthermore, factors other than sulfur may be influencing semen characteristics when DDGS are fed to beef bulls.

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Consumer sensory characteristics differences between ram and wether lambs of light, medium and heavy slaughter weights

Travis W. Hoffman[1], Laura K. Grube[1], Steven E. Anderson[1] and Lauren L. Hanna[1]

The production of intact male lambs versus castrated wethers resulted in increased growth, greater end-product quantity and minimal impact on expected lamb consumer satisfaction. Our results lead to the conclusion that intact ram lambs up to at least 6.5 months of age (198 days) provide little to no detriment to consumer palatability.

Summary

American lambs often are overfinished and lack consistent quality. Some research has suggested that leaving male lambs intact can decrease U.S. Department of Agriculture Yield Grade (carcass fatness) and improve growth efficiency. However, ram lamb carcasses are underutilized because of potential issues, the most crucial being potential off-flavor. We studied the effects of castration and slaughter weight on sensory characteristics to determine if ram lamb growth and efficiency can be advantageous without detriment to eating satisfaction.

Introduction

Many studies have been performed regarding lamb meat characteristics, most of which show the relationship among diet, breed, slaughter age and genetics on carcass characteristics and some sensory traits. The majority of these studies are outdated and have not utilized a full sensory taste panel. However, this study provides vital sensory characterization of lamb meat quality through sensory differences, which is a critical tool to improve meat quality.

Furthermore, the higher lamb flavor intensity of ram lambs in this study was found to be closer to the JAR point ("just about right" flavor, based on consumer preference) than of wethers, which is important because according to the 2015 National Lamb Quality Audit, lamb's distinctive flavor is the most important decider for lamb consumers. A majority of consumers prefer to have lamb that is relatively lean, tender, juicy and mild in flavor.

These results showed that ram lamb scores were similar in palatability to wether lambs based on these four consumer criteria (leanness, tenderness, juiciness and mild flavor). Flavor profile characteristics showed that ram lambs, especially light and medium weight (122 and 146 pounds) ram lambs provide a high degree of palatability to consumers. Furthermore, based on the sensory characteristics determined in this study, we can suggest that intact lambs up to around 200 days of age and about 150 pounds live weight will produce a carcass that could result in a satisfactory eating experience.

Further research in consumer familiarity and satisfaction is needed to determine the cause of off-flavor scores attained by ram lambs and heavy weight lambs in this study.

Experimental Procedures

A total of 20 fall-born (September to October 2016) Dorset lambs were acquired from the NDSU Sheep Unit. At birth, the lambs were assigned randomly to a ram or wether treatment group (10 rams, 10 wethers).

Lambs assigned to the wether group were castrated within seven days of birth, and all lambs were penned together and fed the same grain-based diet for the duration of the study. All lambs were weighed on a weekly basis starting in December 2016, with ad libitum access to feed and water, and growth data (ADG) was calculated.

Animals were balanced for mean age and 90-day weight and assigned to appropriate slaughter group. Lambs were harvested in three weight groups, light (122 ± 3.3 pounds; n = 6), medium (146 ± 2.9 pounds; n = 8) and heavy (171 ± 3.3 pounds; n = 6), with an even distribution of rams and wethers in each group. Light lambs were slaughtered at day 42 of the trial, medium lambs on day 56 and heavy lambs on day 90 to represent different degrees of maturity and weight. Actual harvest weights are shown in Table 1.

All lambs were less than 215 days (7 months) of age at harvest and averaged well under 200 days of age. Lambs in all slaughter

[1]Department of Animal Sciences, NDSU

Table 1. Mean age and live weight of lambs based on weight group and sex.

	Weight Group			Sex	
Traits	Light	Medium	Heavy	Ram	Wether
Age, day	147.5 ± 3.0	166.6 ± 2.6	197.7 ± 3.0	168.6 ± 2.3	172.6 ± 2.3
End live weight, lb.	122.4 ± 3.3	146.2 ± 2.9	171.1 ± 3.3	158.8 ± 2.4	134.1 ± 2.4

groups were taken off feed 24 hours prior to slaughter and then harvested at the NDSU Meats Laboratory.

Following harvest, carcasses were chilled for two days at 2 C and fabricated, and primal cut yields were recorded. Boneless legs were wet aged for 14 days, ground and formed into 1-ounce patties for sensory analysis.

Pre-screened sensory panelists (n = 107) who consumed lamb at least once within the past year were recruited from students and staff of the University of Minnesota. The untrained panelists evaluated meat sensory characteristics, which included flavor profile, juiciness, tenderness and overall liking. The panel was held during a two-day period with assistance from the University of Minnesota's Sensory Center, Department of Food Science and Nutrition (St. Paul, Minn.) and required panelists to consume nine samples of 0.5-ounce lamb patties per day.

Pre-formed patties (1 ounce) were cooked in a conventional oven to an internal temperature of about 71 C and cut in half to form 0.5-ounce patties. The patties were served plain (no seasonings) in 60-milliliter sample cups and nested in insulated foam trays to maintain temperature. Panelists were able to cleanse their palate between samples with water.

Panelists evaluated lamb samples based on two different scales: 1) liking and intensity ratings were evaluated on a 120-point labeled affective magnitude (LAM) scale (ex. dislike extremely-13, dislike moderately-39.5, neutral-60, like moderately-81, like extremely-104); characteristics on this scale included overall liking, flavor liking, texture liking, lamb flavor intensity, juiciness, toughness and off-flavor intensity, and 2) flavor intensity, juiciness and toughness ratings were evaluated on a 150-point just-about-right (JAR) scale, with 75 just about right, less than 75 not enough and greater than 75 too much of the attribute.

Results and Discussion

We found no significant interaction between castration effects and slaughter weight for all sensory characteristics. Meat from wether lambs had the greatest (Table 2) flavor liking and light lambs were favored over heavy lambs, but we observed no differences between heavy and medium weight groups and light and medium weight groups (Table 3).

Table 2. Least square means for sensory attribute scores in lamb burgers by sex.

	Sex			
Sensory Attributes	Ram	Wether	SEM	*P*-Value
Overall liking	70.6	73.5	1.44	0.0008
Flavor liking	70.4	70.4	1.45	0.0004
Texture liking	70.8	72.2	1.39	0.085
Lamb flavor intensity	34.6	30.3	1.62	<0.0001
Toughness intensity	28.2	26.5	1.44	0.03
Juiciness intensity	26.5	27.0	1.50	0.55
Off-flavor intensity	24.7	20.7	1.83	<0.0001

Table 3. Least square means for sensory attribute scores in lamb burgers by slaughter weight group.

	Weight Group				
Sensory Attributes	Light	Medium	Heavy	SEM	*P*-Value
Overall liking	73.4	71.9	70.9	1.62	0.08
Flavor liking	73.2^{a}	72.0^{ab}	70.3^{b}	1.64	0.04
Texture liking	72.4	70.9	71.2	1.53	0.30
Lamb flavor intensity	31.9^{ab}	31.3^{a}	34.2^{b}	1.80	0.03
Toughness intensity	26.4	27.4	28.5	1.58	0.20
Juiciness intensity	26.6	25.7	27.9	1.80	0.05
Off-flavor intensity	21.0^{a}	22.5^{ab}	24.6^{b}	2.05	0.02

^{ab}Least squares means in the same row lacking a common superscript differ ($P < 0.05$).

Ram lambs were rated to have greater (Table 2) lamb flavor intensity than wethers and heavy lambs were preferred (Table 3) over medium weight lambs. The higher flavor intensity found in ram lambs was rated closer to the flavor JAR point than in wethers (Table 4) and heavy weight lambs were closer (Table 5) to the flavor JAR point, compared with light weight lambs. Even so, panelists rated ram lambs and wethers as not having enough lamb flavor intensity.

Lamb originating from rams had greater (Table 2) off-flavor intensity scores than wethers, and heavy weight lambs had greater (Table 3) off-flavor intensity scores than light weight lambs. Furthermore, we found no (Tables 2 and 3) texture or juiciness differences based on sex or slaughter weight. However, we found differences in toughness based on sex, where meat from ram lambs was tougher (Table 2) than wether meat, but no (Table 3) differences based on weight group.

When looking at toughness JAR, wethers were rated closer (Table 4) to the JAR point than rams, and light/medium weight lambs were rated closer (Table 5) to the JAR point than heavy lambs. We found no (Tables 4 and 5) differences in juiciness JAR based on sex and weight group. Overall, meat from wether lambs had greater (Table 2) overall liking than ram lambs, and we observed no (Table 3) differences between weight groups.

Sensory evaluation determined that meat from ram lambs had greater lamb flavor intensity than from wethers, and meat from wether lambs had greater overall liking than from ram lambs. Interestingly, the more intense lamb flavor found in ram lambs aligned closer to the preferred lamb flavor profile for consumers.

Lamb originating from rams had greater off-flavor intensity scores than wethers, and heavy weight lambs had greater off-flavor intensity scores than light/medium weight lambs. Furthermore, we found no texture liking or juiciness intensity differences based on sex or slaughter weight.

Intact ram lambs provide the sheep industry an opportunity to improve growth, increase muscularity and decrease USDA Yield Grade while providing a satisfactory eating experience. Ram lamb flavor intensity was more preferred by consumers, yet compounding of advanced physiological maturity and harvesting intact rams increased incidence of off-flavors.

Acknowledgments

Funding was provided by the National Sheep Industry Improvement Center to facilitate the North Dakota State University and University of Minnesota research collaboration.

Table 4. Least square means for just-about-right (JAR) scores in lamb burgers by sex.

	Sex			
Sensory Attributes	Ram	Wether	SEM	*P*-Value
Flavor JAR	68.7	64.3	1.55	<0.0001
Juiciness JAR	57.2	58.2	1.89	0.27
Toughness JAR	77.1	74.6	0.99	0.0008

Table 5. Least square means for just-about-right (JAR) scores in lamb burgers by slaughter weight group.

	Weight Group				
Sensory Attributes	Light	Medium	Heavy	SEM	*P*-Value
Flavor JAR	66.6^{ab}	64.7^{a}	68.1^{b}	1.72	0.02
Juiciness JAR	57.7	56.8	58.5	2.20	0.35
Toughness JAR	75.2^{a}	74.9^{a}	77.5^{b}	1.12	0.001

^{ab}Least squares means in the same row lacking a common superscript differ ($P < 0.05$).

Integration of Crop and Livestock Systems in North Dakota

Miranda A. Meehan[1], Mary Keena[2], Marisol Berti[3], Kevin Sedivec[4,5], Mike Ostlie[2] and Erin Gaugler[5]

North Dakota farmers and ranchers are increasingly interested in integrating livestock into cropping systems because of the ecological and economical returns. The benefits of integrated systems include enhanced nutrient cycling, reduced inputs and livestock feeding costs, and improved environmental and economic sustainability of operations. NDSU researchers and Extension personnel are working together to provide improved information and management recommendations to farmers and ranchers interested in integrating livestock into their cropping systems.

Summary

Cover crops have gained in popularity as a practice implemented by producers across the U.S. North Dakota is no exception to this trend, with producers incorporating cover crops to improve soil health, increase soil nutrients and soil microbial populations, reduce swings in crop yields, increase crop yields, reduce soil erosion and increase forage options for livestock. Despite the ecological benefits of incorporating cover crops into a cropping system, the economic benefits may not be realized if livestock are not incorporated into the system.

Introduction

In recent years, producers have expressed an increased interest in integrated crop-livestock systems because of ecological and economic benefits. The benefits of integrated systems include enhanced nutrient cycling, reduced inputs and livestock feeding costs, and improved environmental and economic sustainability of operations.

The majority of research evaluating integrated crop-livestock systems (ICLS) has been conducted in regions characterized by humid climates, such as Brazil and the southeastern portion of the U.S. A limited body of research is available on the ecological impacts of ICLS in semi-arid ecosystems, such as the northern Great Plains.

NDSU researchers and Extension personnel are working together to provide improved information and management recommendations to farmers and ranchers in the state wanting to integrate livestock into their cropping systems.

[1]Animal Sciences Department, NDSU
[2]Carrington Research Extension Center, NDSU
[3]Plant Sciences Department, NDSU
[4]School of Natural Resources Sciences, NDSU
[5]Central Grasslands Research Extension Center, NDSU

Extension

NDSU Extension has been seeing an increase in interest and inquiries pertaining to the integration of livestock into crop systems or grazing cover crops. To answer this need, several specialists and agents have made this a focus of their programming.

One of Extension's first steps was to equip personnel with the knowledge and tools to support farmers and ranchers. In January 2020, we hosted an in-person in-service training with 45 Extension agents, specialists and researchers, as well as government collaborators.

Topics covered included rules and regulations pertaining to cover crops, the debut of a new cover crop cost calculator, residual herbicide issues, grazing options best for cropping systems and cover crop identification. This activity was funded by the North Central-Sustainable Agriculture Research and Education (NC-SARE) Professional Development Program's "Cover Crops and Forage Grazing Training Program in North Dakota."

In March 2020, NDSU Extension specialists and researchers hosted a webinar series pertaining to grazing cover crop management. This was intended to be an in-person workshop; however, due COVID-19 restrictions, the team changed the format to a five-day, nine-topic series that was broadcast live to 203 people from 18 states/provinces (Figure 1).

The audience consisted of a broad range of attendees who included producers, Extension personnel and personnel from government agencies. They participated in live

discussions of topics including cover crop seed regulations, herbicide residual considerations, economic and soil impact of cover crops based on NDSU research, the NDSU forage grazing calculator, cover crop toxicity issues, and cover crop characteristics and identification.

The recordings from this series are available at www.ag.ndsu.edu/livestockextension/grazing-management-folder/cover-crops. The majority of participants found the webinars to be relevant to their work, with 67% of the 203 participants rating the series as high to very high usefulness (Figure 2).

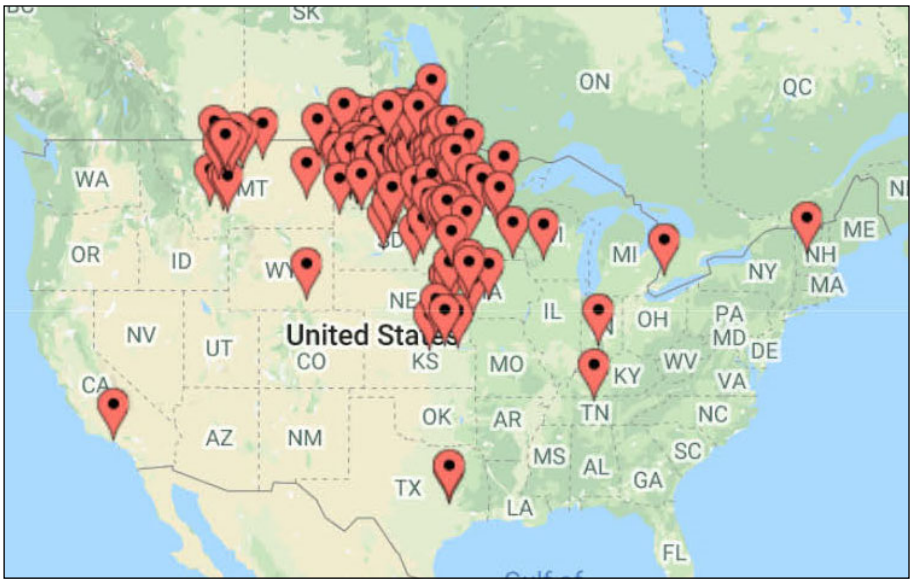


Figure 1. Geographic representation of the Grazing Cover Crops Webinar participants.

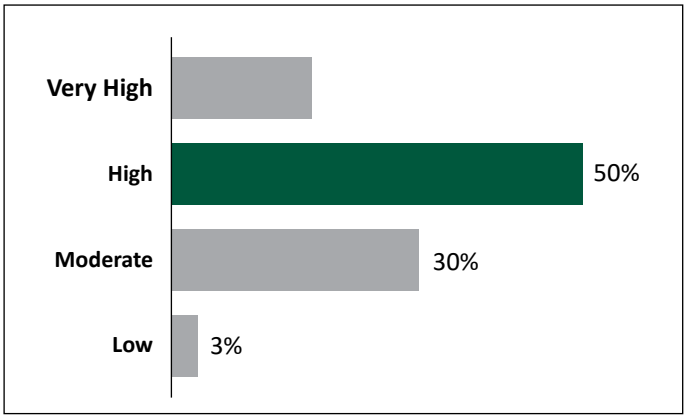


Figure 2. Participant rating of the usefulness of the Grazing Cover Crop Webinars to their work.

Research

As 2020 progressed, so did NDSU research involving cover crops. A project sponsored by NC-SARE titled "Wholistic Approach to Integrated Crop/Livestock Management" is in its second of three years. This project is hosted at the NDSU Carrington Research Extension Center, and the objectives include determining the value of cover crops to a crop farmer, with and without grazing, as well as comparing the value of cover crops for a livestock farmer versus alternatives such as dry lot management.

For this project, corn and wheat are planted as cash crops. After the wheat is harvested, a cover crop of turnips, radish, field peas and volunteer spring wheat is planted and grazed in the fall. Once the corn crop reaches the V4 to V6 stage, a cover crop of turnips, radish, lentils, barley and winter rye is planted in between the rows. The corn is harvested for grain and the cover crop continues to mature after harvest and then is grazed in the fall.

This project also includes three producer cooperators who are planting rye into their corn grain crops and grazing in the fall. While 2019 proved to be a challenging year because of harvest issues, the conditions in 2020 look to be more typical. Project updates will be discussed during winter meetings in 2021.

Producer cooperators have been the driving force behind much of the grazing cover crop research done at NDSU. As we round out 2020, we are looking forward to our first fall grazing on a three-year study involving six producers from five counties in central North Dakota. This project, titled "Grazing Management Practices to Enhance Soil Health in the Northern Great Plains," will assess the environmental and economic sustainability of producer-led grazing management strategies on annual cover crops within an integrated crop livestock system.

Specifically, we will study the influence of stock density and forage

utilization of grazing livestock on 1) soil physical, chemical and biological properties, 2) crop production, 3) livestock production and 4) economics. To evaluate the effects of stock density, an annual forage crop will be subjected to moderate and high stocking density. Additionally, two forage utilization rates (50% and 75%) will be evaluated. A non-grazed area will serve as the control.

Despite challenging spring conditions, a full-season cover crop mix was seeded in June and will be grazed in September. The sites will be grazed again in 2021, followed by a cash crop in 2022. To learn more about this project, view this video (www.youtube.com/watch?v=xSNyg_RzeSI&list=PLn n8HanJ32l6SGAm9ofO4Y6mSAp9ox7_k&index=113&t=0s) from the Central Grassland Research Extension Center's virtual field day.

The knowledge gained from these producer-driven demonstration projects has the potential to increase the profitability and sustainability of the cash crop and livestock enterprises in North Dakota. NDSU Extension personnel and researchers are planning more events to share the knowledge gained from these and other projects focused on the integration of crop and livestock systems at events such as café talks, workshops and tours. Be sure to join us for these events if you are interested in learning more and sharing your experiences with these systems.

Acknowledgments

These efforts are supported by funding from the NC-SARE. Thanks to the participating farmers and ranchers: Adam Weigel, Mike Keily, Jerry Doan, Cole Johnson, Alice Laber, Kim Saueressig, Topp Land and Cattle, Wendel Livestock and Rex Hollenbeck. Thank you to all the NDSU Extension agents, including Penny Nester, Sheldon Gerhardt, Crystal Schaunaman, Alicia Harstad and Tyler Kralicek, for their roles in hosting programs and supporting farmers and ranchers.

Bovine Emergency Response Program

Lisa Pederson[1]

Public safety always is a concern when dealing with accidents involving animals. The first step in assuring public and human safety is training first responders on the correct procedures for addressing incidents involving the transportation of livestock.

Summary

Several hundred thousand head of cattle are on the roadways in the U.S. daily. University and Extension faculty from across the country developed the Bovine Emergency Response Plan (BERP) and teaching curriculum as a framework for emergency responders to more appropriately address accidents involving cattle transport vehicles. The plan includes standardized recommendations, suggestions and materials for emergency personnel in call taking, scene arrival and assessment, containment and security, extraction of cattle, relocation of cattle, mortality disposal, securing the wrecked transport vehicle, euthanasia and debriefing.

Experimental Procedures

At educational programs conducted in North Dakota, South Dakota, Nebraska, Georgia and West Virginia, participants participated in classroom training, table-top exercises, demonstrations and practicums on the subjects of call taking, scene arrival and assessment, containment and security, extraction of cattle, relocation of cattle, mortality disposal, securing the wrecked transport vehicle, euthanasia and debriefing. The training is targeted toward first responders and others interested in responder safety, public safety and animal care and well-being.

Results and Discussion

The attendees of the BERP training sessions included farmers, ranchers, veterinarians, fire department staff, county emergency managers, law enforcement, ambulance, tow truck drivers and Extension agents.

Participants took a pre and post-test to compare knowledge before and after the training. Overall, attendees' post-test scores improved 22% over their pretest scores.

Participants also completed a course survey to determine participant knowledge before and after the program is the following areas: introduction and local emergency planning, transportation hazards, biosecurity, euthanasia and mortality issues, debriefing and safety, and animal care and handling. Attendees were asked if they learned what they expected and if the program was worth the cost to attend.

Follow-up surveys indicate participants have implemented practices taught in the BERP trainings.

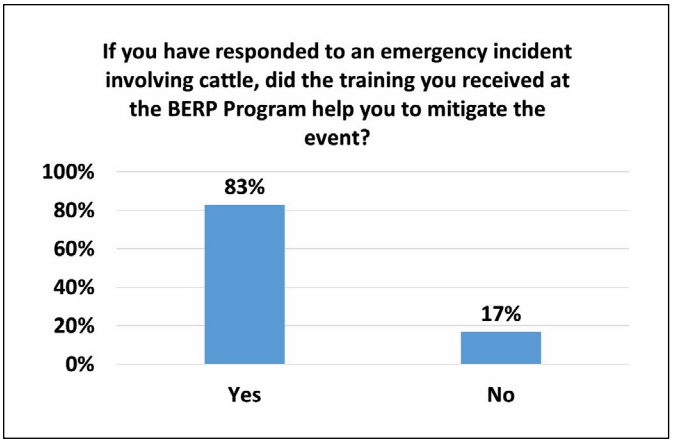
Here is what participants had to say about the program:

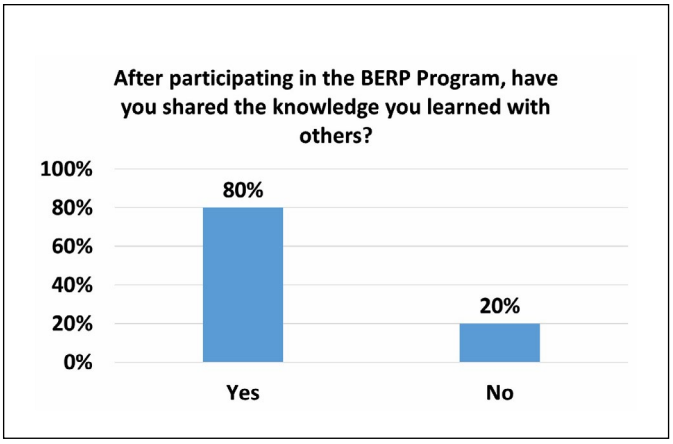
- "Every time the livestock panels go out, it's a learning experience for the fire departments and law enforcement. They are gaining a lot of confidence in working with animals properly now, confidence they didn't have before the BERP class or interaction with BERP-trained responders."
- "This training also applies to all live animal incidents, not just bovine transport incident response. The biggest improvement I have seen so far has been the animal handling recommendations, thinking like an animal and pen setup recommendations directly from the class to create a successful outcome."
- "As a veterinarian, it's crucial for us to know how to proceed when these emergencies occur, and much of what was covered is not emphasized in vet school."
- "We used some of the information learned to capture a horse that was loose on the highway."
- "I shared some of the information with other officers at the state police academy. I believe it should be taught to all basic and cadets."

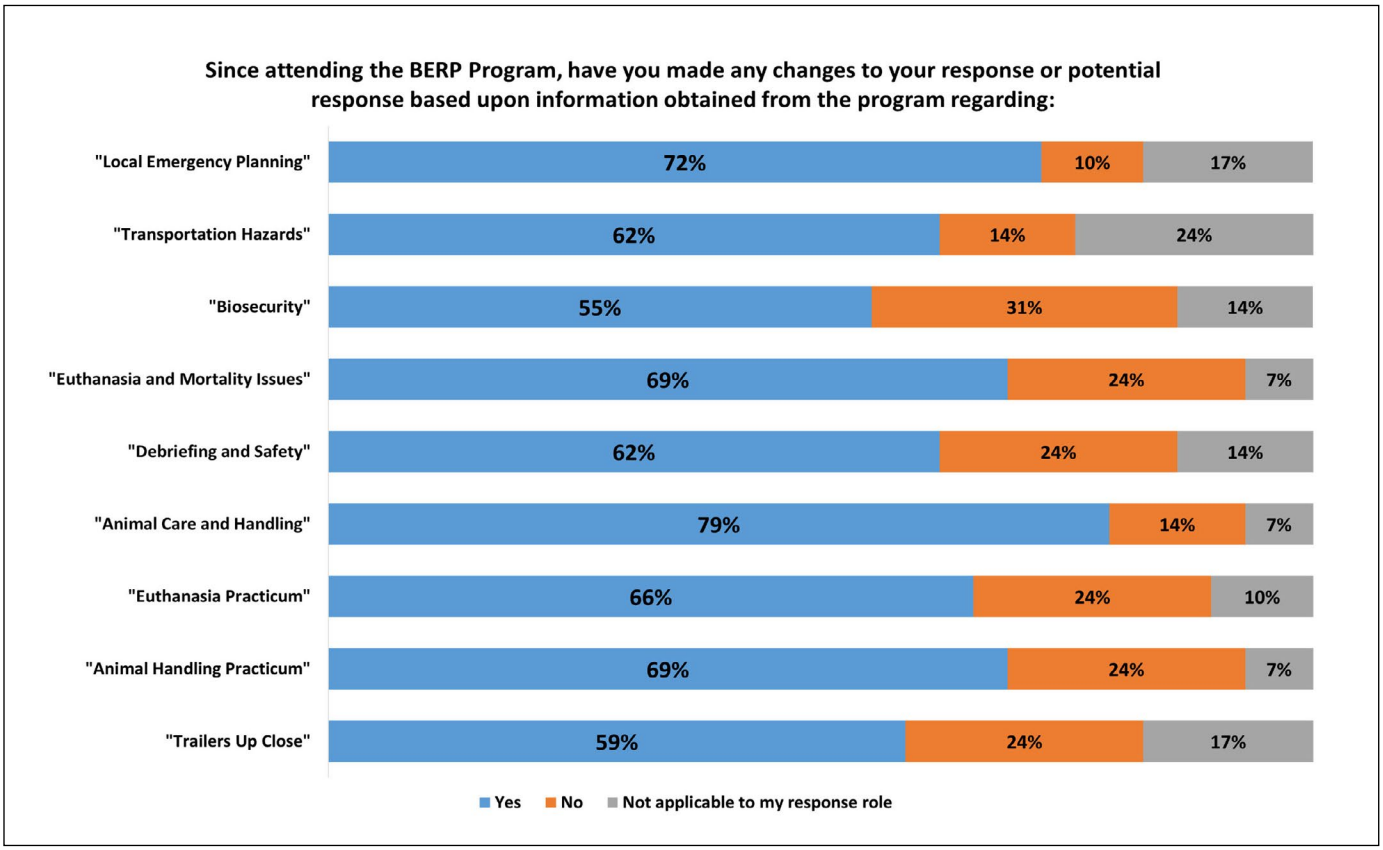
Acknowledgments

Others involved in developing the program were: Jerry Yates, West Virginia University; David Workman, West Virginia University (emeritus); Steve Boyles, The Ohio State University; and Jan Shearer, Iowa State University. This program was jointly funded by the North Dakota Beef Commission and the Beef Checkoff.

[1]Central Grasslands Research Extension Center, NDSU







Results of participant course surveys at completed BERP training sessions.

Gearing Up for Grazing

Miranda Meehan[1]

Grazing start date is one of the most important decisions made by land managers, impacting forage production, livestock production and ecosystem health. Selecting the proper grazing start date increases productivity and resilience of grazing resources, enhancing the sustainability of ranches and rural communities. Enhanced health of these ecosystems will benefit the public by enhancing biodiversity, water quality, wildlife habitat and opportunities for recreation.

Summary

Many livestock producers in North Dakota start grazing pastures prior to plants reaching grazing readiness, the developmental stage at which they can withstand the stress of grazing. Starting grazing too early reduces plant leaf area for photosynthesis, reducing plant vigor and forage production, and increasing disease, insect and weed infestations. Grazing too early can be costly in terms of total forage production during the entire grazing season. Grazing before grass plants reach the grazing readiness phase causes a reduction in herbage production, which can reduce the stocking rate and animal performance. Pastures and range damaged by grazing too early may take several years of deferment or even rest before the stand regains productivity. However, grazing too late increases forage loss and waste through trampling or reduced palatability, and increases the presence of exotic cool-season grasses.

Procedures

In 2017, NDSU Extension initiated the Gearing Up for Grazing Program. The goals of this project were to: 1) enhance NDSU Extension agents' knowledge of grazing readiness while establishing new relationships with producers in their counties and 2) improve the condition of grazing resources through improving producer knowledge of grazing readiness. This was accomplished by developing training opportunities and curriculum for agents. Agents in 22 counties then worked with ranchers to monitor and report the growth stage of key range and pasture species until they reached grazing readiness.

Results and Discussion

Monitoring data was utilized in the development of Extension curriculum, including one Extension publication, one presentation, one video and seven news releases. To date, this curriculum has been presented to 248 people at meeting and ranch visits.

"As a new agent, I really appreciated the opportunity to reach out to area producers about coming onto their land and doing the grazing readiness program," reported Hannah Nordby, Extension's agriculture and natural resources (ANR) agent in Adams County. "The couple of producers I worked with are now individuals I call on when I do have questions about what is going on in the county. This program gave me the chance to build relationships and also get out into the countryside, both of which are not easy feats only being in the position a couple of months before participating in the Grazing Readiness Program. I also was able to hone my plant ID and also evaluate pastures in Adams County to help me better understand management practices and potential needs that could be met by Extension programming."

Katelyn Hain, Extension's ANR agent in Nelson County, said: "The Gearing Up for Grazing presentation sparked a lot of management discussion between about 35 producers' questions in Aneta at the Cattle Update this February. What I most enjoyed about teaching the grazing readiness presentation and working with producers to monitor their grasses in the spring is that this program is just the beginning of the conversation about pasture and land management for livestock. It led to an understanding that identifying key species to help monitor for grazing readiness can keep desirable plants coming back, which helps keep pastures healthy. This program set up the basics for further management discussions."

Producers in McHenry County who participated in the Gearing Up for Grazing Program provided the following feedback:

- "I really liked the grazing talk you did in the county and would love to listen to more."
- "Has really sparked my interest in what is going on in my own pastures."

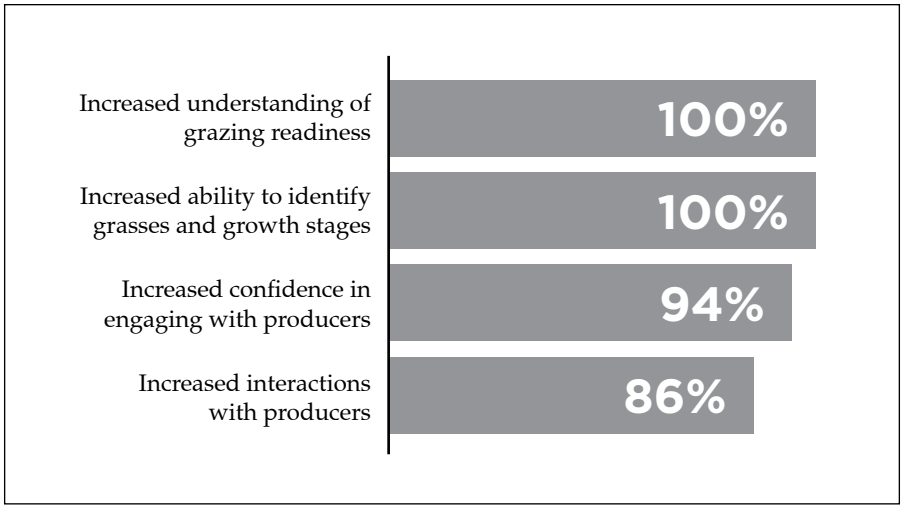
[1]Department of Animal Sciences, NDSU

- "I was better able to watch my grass this year and know when to pull my cows out."

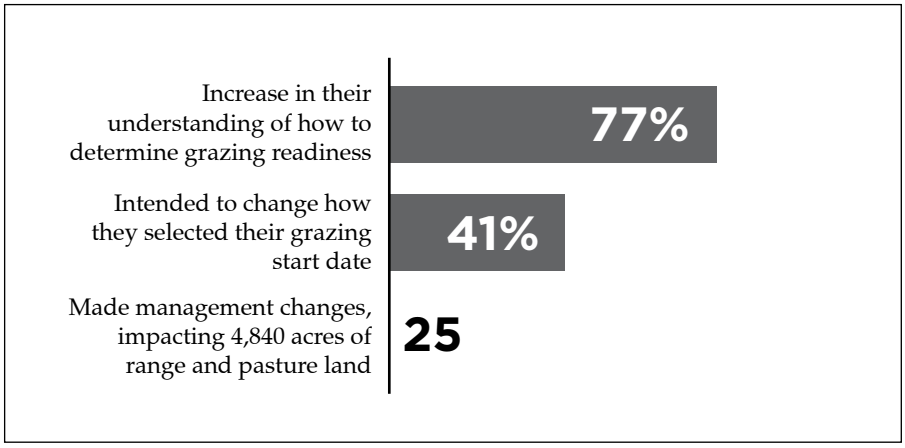
Visit www.ag.ndsu.edu/naturalresources/gearing-up-for-grazing for more information about the program.

Acknowledgments

Others involved in the program were Kevin Sedivec, Extension rangeland management specialist; Erin Gaugler, former Bowman County ANR agent; Kelcey Hoffmann, former Cass County ANR agent; Greg Benz, Dunn County ANR agent; Katie Wirt, former Grant/Sioux County ANR agent; Tessa Keller, Grant/Sioux County ANR agent; Penny Nester, Kidder County ANR agent; Sheldon Gerhardt, Logan County ANR agent; Rachel Wald, McHenry County ANR agent; Crystal Schaunaman, McIntosh County ANR agent; Morgan Wisness, former McKenzie County ANR agent; Devan Leo, McKenzie County ANR agent; Calla Edwards, McLean County ANR agent; Craig Askim, Mercer County ANR agent; Marissa Leier, former Morton County ANR agent; Rick Schmidt, Oliver County ANR agent; Yolanda Schmidt, former Pierce County ANR agent; Nicole Wardner, former Sheridan County ANR agent; Shelby Hewson, Slope County ANR agent; Lindy Berg, Towner County ANR agent; Paige Brummund, Ward County ANR agent; Lindsay Maddock, Wells County ANR agent; and NDSU Agriculture Communication staff.



Impact on Extension agents involved in Gearing Up for Grazing.



Impact on producers involved in Gearing Up for Grazing.

Nutrient management educational support program: A five-year review

Mary Keena[1]

Educating and assisting crop and livestock producers in adopting nutrient management practices specific to manure will reduce adverse impacts on water quality, leading to increased confidence and acceptance of agricultural practices by the public.

Summary

Livestock production is a major industry in North Dakota, with approximately 1,690,000 cattle, 151,000 hogs and 73,000 sheep being inventoried annually on more than 31,900 farms. The manure produced by these livestock is identified as a major source of surface water contamination in many watersheds across the state. According to the North Dakota 2018 Integrated Water Quality Assessment Report, 26,439 acres of lakes and reservoirs are impaired by nutrient loading, of which animal feeding operations (concentrated livestock feeding and wintering operations) are a source. Geographically, North Dakota has two distinct livestock production areas. The eastern portion of the state has a more rolling topography and receives higher rainfall, giving rise to potholes and more year-round flowing streams, with an increased risk of frequent water runoff events in the watersheds. The western portion of the state has a steeper topography and receives significantly less rainfall but is prone to higher intensity of runoff during the less frequent events. The precipitation and topography split also dictates two different cultures of livestock production.

Experimental Procedures

The NDSU Nutrient Management Educational Support Program, under the direction of the current livestock environmental management (LEM) specialist, has evolved since its inception 22 years ago. The focus has shifted from regulatory compliance issues and proper manure application to alternative livestock feeding options and the characteristics of handling livestock manure once it is contained in North Dakota's climate.

Along with numerous invited talks, the specialist coordinates annual events such as the North Dakota Custom Manure Hauler Training and Composting Demonstration Days. These events target not only producers, but also 319 Watershed coordinators, and Natural Resources Conservation Service and NDSU Extension personnel. This report will show the reach and impact that having a focused manure management Extension specialist can have on the stakeholders of North Dakota.

Results and Discussion

This report provides impacts and feedback from three selected programs (youth program, in-service format and general manure management) from 2015 through 2019.

Kids, Compost, Crops and Consumption

Eighty third- and fourth-grade students at a low-income school in the Fargo School District participated in the pilot program Kids, Compost, Crops and Consumption. This program consisted of six lessons: livestock production, compost and manure, soils, plant growth and human nutrition, with a review at the end to complete the cycle. Follow-up evaluations were completed by 63 students three months after the last lesson and indicated students applied the knowledge they gained:

- 73% planted the square-foot garden that was provided by the program
- 37% harvested the plant and the majority ate it as a salad
- 57% planted another garden besides the one the program provided
- 62% had a parent participate in the garden activity
- 29% consumed two serving of vegetables per day during the summer break month

Teacher feedback:

- "The most valuable part of the program was exposing the students to agriculture in ways they have not experienced. Very hands-on and having something to take home to try was excellent. As one student said, 'Showing us real life.'"
- "I noticed the kids were attentive and really participated in discussions."

After the pilot, Kids, Compost, Crops and Consumption was turned into a packaged program and has been used in nine counties in North Dakota and by one educator in

[1]Carrington Research Extension Center, NDSU

Minnesota. It is available to NDSU Extension agents, educators and Soil Conservation Districts for the 2020 programing year.

Equine Encounters

When the 2012 equine inventory for North Dakota was compiled by the National Agricultural Statistics Service, five counties were home to 25% of the total inventory for the state. In 2015, the LEM program, along with NSDU Extension agents, hosted Equine Encounters in three of those counties. These workshops were geared toward small-scale, urban equine owners who have lesser manure management experience.

Fifty-seven percent of the attendees increased their knowledge of proper manure management techniques and 98% of 46 respondents said they would attend another meeting if offered the following year.

In 2016, a fourth county was added and the workshops were hosted again. This time, we added in-field activities (pasture walk, weed ID, compost bin how-to) to go along with the education. When asked to list one behavior they intended to change within three, six or 12 months as a result of the workshop, 35% of participants responded they were going to compost their equine manure.

Most of these small-scale equine owners also are found near urban areas and are at risk for stockpiling excess livestock manure because of minimal land for application and limited space for winter feeding. For the next three years, starting in 2020, the Equine Encounter workshops will be hosted in five North Dakota counties in the spring and fall. The overall goal will be to improve manure and land management techniques to help sustain a small but growing sector of the livestock industry.

Composting Manure

Composting manure has been a major focus for the past five years. The LEM program hosts at least one hands-on composting workshop each year where participants can view compost at various stages, sample for moisture, monitor temperatures and see how a compost turner operates. These workshops typically are hosted at the NDSU Carrington Research Extension Center (CREC).

Because of these workshops, the LEM program has connected with producers in the state and aided in decisions as they purchased compost turners or spreaders, started using compost as a soil amendment, attended national composting workshops and started compost businesses.

The format of the workshops has evolved to include producers as the host sites. In 2019, two producers hosted workshops in the northeastern and northwestern regions of North Dakota. Because of the continued interest in composting manure in North Dakota, a $50,000 North Central Region Sustainable Agriculture Research and Education grant was awarded to the NDSU LEM and University of Minnesota Manure Management Extension programs for workshops in 2020 and 2021, which will include the help of four producer-composters.

The following is feedback from a composting business:

- "The most useful part of working with NDSU Extension and CREC has been the wealth of resources and depth of knowl-

Extension Response

768 One-on-one Consultations

10 Publications

- Manure Spreader Calibration for Nutrient Management Planning
- N.D. CAFO Operators Record Book
- Animal Carcass Disposal Options
- Environmental Implications of Excess Fertilizer and Manure on Water Quality
- Nitrogen Behavior in the Environment
- North Dakota Manure Fertilizer Use Recommendations
- Phosphorus Behavior in the Environment
- Alternative Winter Feeding Strategies for Beef Cattle Management
- Containment Pond Management
- 5 Easy Steps for Composting Dead Livestock

2 Packaged Programs

- Mortality Management
- Kids, Compost, Crops and Consumption: Introducing the Whole Food Cycle to Urban Youth

120 Presentations

16 Nutrient Management Demonstrations/Tours

Other Actvities

- Updating the LEM website
- Preparing LEM News for 300 recipients
- Timely press releases and radio interviews

edge that the professional staff provided to us through the service. Through printed materials, we could dive deeply into programs, grant opportunities and educational offerings, then follow internet links to even more information. During in-person meetings, we were able to ask specific questions and trust that the advice and guidance provided to us by Mary Berg [Keena] and other staff members was based on current, top-of-the-line research directly related to our business. Mary's availability to meet and willingness to share her fund of knowledge - and passion about manure management - on multiple occasions has been greatly appreciated by us all!"

Visit www.ag.ndsu.edu/lem for more information about the LEM program.

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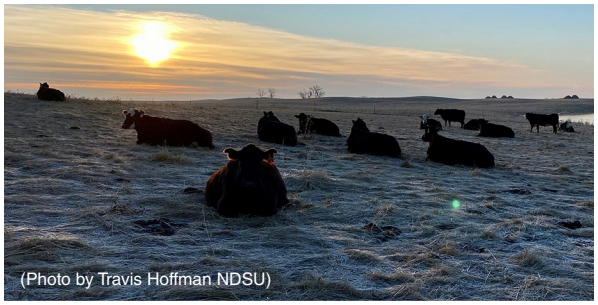
(Photo by Sarah Underdahl, NDSU)


(Photo by Miranda Meehan, NDSU)


(Photo by Travis Hoffman NDSU)

2020 North Dakota Beef and Sheep Report


(Photo by Travis Hoffman NDSU)


(Photo by Miranda Meehanl, NDSU)


(Photo by Karl Hoppe, NDSU)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