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2016 North Dakota Beef Report

NDSU NORTH DAKOTA STATE UNIVERSITY

(Photo by Lauren Hanna, NDSU)

2016 North Dakota Beef Report

Welcome to the 2016 North Dakota Beef Report.

North Dakota State University; the College of Agriculture, Food Systems, and Natural Resources; and the North Dakota Agricultural Experiment Station are pleased to be able to provide this report to the beef industry and cattle ranchers in the state. The report provides the most recent results from research related to beef cattle, beef products, and environmental and range sciences from North Dakota.

The beef research 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 cattle and beef using sustainable and safe approaches.

This report includes a broad range of research from on-campus departments, schools and centers, as well as Research Extension Centers across the state, and provides producers and stakeholders with one document that contains all beef-related research conducted at NDSU each year.

We thank the federal, state and industry sponsors who support our research programs. Without this support, this research would not be possible. We also thank all of the faculty, staff, and graduate and undergraduate students who have contributed to this work.

We hope you enjoy reading this research report and that the information is useful to your operation. We look forward to continuing to serve the North Dakota beef industry in the coming year and in the future.

Sincerely,

Ken Grafton
Vice President for Agricultural Affairs
Dean of the College of Agriculture, Food Systems, and Natural Resources
Director of the North Dakota Agricultural Experiment Station

North Dakota is proud of its strong and prosperous beef industry. The success of the industry doesn't happen by chance, however. It takes the vision and commitment of industry leaders to identify needs and set goals.

One key component of that success is the industry leaders' commitment to supporting beef research and Extension at NDSU.

Through the NDSU Extension Service, we are able to provide the beef industry with research-based information in the areas of genetics and reproduction, nutrition, animal care and health, range management, resource stewardship and market economics through our state and area Extension specialists.

I thank the beef industry for its continued support of NDSU Extension's beef programs.

I also thank the dedicated NDSU animal scientists and Extension specialists for their innovative and valuable research and Extension programs. The results of their numerous projects are reported between the covers of this 2016 North Dakota Beef Report. The report contains a wealth of information on current applied and basic research and project results. I hope you take time to review this information for ideas and to stay abreast of the latest in beef research at NDSU.

I encourage you to contact the scientists or Extension specialists who are involved in these projects if you have questions or additional input. They always are interested in hearing your thoughts.

Thank you for your continued support of these beef research projects and the other animal science programs as well. We want to work together with you to support the successful future of North Dakota beef.

Sincerely,

Chris Boerboom
Director of the NDSU Extension Service

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Updates From Our Research Locations

This is always an exciting time of the year for me as I work on coordinating the publication of the annual North Dakota Beef Report. Seeing all the great work that is being done in beef cattle research in North Dakota and helping get this information out to our producers and industry is enjoyable for me.

For this year's report, I thought providing an update from our research locations on new happenings, such as new hires, updates in facilities, renewed focus on improving cattle quality and facilities, etc., would be a nice addition. Many new, exciting things are going on at our research locations aside from just the research results (see updates below from our research locations in no particular order).

I believe we are working hard toward improving our beef cattle research program to be one of the best in the country. We have much momentum and are aggressively improving and moving our program forward.

I am taking this opportunity to thank Ellen Crawford and Deb Tanner for their great contributions in editing and formatting the reports so that we can publish a great statewide combined report. I also thank the contributors to the North Dakota Beef Report, and thanks to all the employees and students who help with all of the research, teaching, and Extension activities related to beef cattle.

Our goal is to make this a comprehensive report describing research from across the state so readers have one report that provides results they can use to improve their operations or improve their business. I feel this statewide report has improved greatly during the first few years of its publication.

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 research in North Dakota.

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NDSU Beef Teaching and Research Unit

The Beef Teaching and Research Unit has undergone some changes within the past year. It has been one year since my full-time employment, and we have made strides in strengthening our interdepartmental communication and upgraded livestock-handling equipment, and are progressing toward our ultimate cow-calf production goals.

Our Beef Committee, or "B Team," as I like to call it, is made up of a group of staff and faculty members from the NDSU Animal Sciences Department, including me, who are passionate about NDSU's beef program. This committee acts as the hub for ideas and concerns to be discussed to help solidify our beef program goals.

The committee is co-chaired by Kendall Swanson, an expert in beef cattle nutrition and physiology, and Gerald Stokka, who specializes in livestock stewardship and beef cattle health. This committee has become more active to assist the beef unit manager in management decisions and deciding future directions for the program.

As a committee, we have developed a mission statement: "The NDSU Beef Teaching and Research Unit provides facilities and beef cattle to integrate research, teaching and Extension to serve the NDSU beef program, NDSU Animal Sciences and the community." We also are working on better defining our vision for improving cattle genetics, nutrition programs, health programs and other management strategies.

We have been privileged to upgrade our livestock-handling equipment this past year. Having a safer, more modern handling system will aid in the flow and improve the safety of our animals, staff and students, as well as allowing handling of the animals to be completed more diligently.

We have our herd of 200 breeding-age females broken into three separate groups of cattle: Purebred Angus, Purebred Simmental and 100 Commercial cows. I have approached managing these cattle the way the average North Dakota producer would, by expecting the cow to do her job.

With the utilization of NDSU's beef experts, we have put in place a strict nutrition and health program in which I can provide the cow with everything she needs to be successful and provide us with a healthy calf every year.

With my background in agricultural economics, I also have started better tracking production costs and returns per cow and calf to aid in improving our management and genetic selection programs.

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NDSU Beef Cattle Research Complex

I can hardly believe that as of May this year, we have been in operation for five years!

We are in the midst of our 20th experiment at the NDSU Beef Cattle Research Complex. This summer, we are implementing a heat watch system that assists animal handlers in identifying behaviors (signs of estrous) of cycling heifers. This project is a cooperative effort utilizing heifers from the NDSU Dickinson Research Extension Center.

Combining the heat-detection information with data from our Insentec feed troughs, scientists hope to gain insight on cycling females' feeding behaviors/efficiency during periods of estrous. This project is a multiyear study investigating the impact of frame size, efficiency and longevity in the commercial beef cow herd.

During the last five years, we have conducted research in heifer development, fetal programing with gestational cows, and backgrounding/finishing studies with growing cattle.

Utilizing the advanced technology of the Insentec feed system, NDSU animal scientists continue to invest their research energies in the sustainability of the North Dakota beef industry.

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Carrington Research Extension Center

The Carrington Research Extension Center (CREC) has a new animal scientist – Dr. Uchenna Anele. He joined from Agriculture and Agri-Food Canada, Lethbridge Research Center.

The primary research efforts at the CREC are focused on applied and interdisciplinary research on cow-calf and feedlot cattle. Anele is undertaking some studies on the use of exogenous enzymes to improve fiber digestion of several coproducts and crop residues generated in North Dakota and use of pre- and probiotics (synbiotics) in the feedlot. Anele is looking at maximizing the value and use of byproducts generated in the state with the intent of reducing the cost of finishing cattle.

The livestock unit at Carrington recently expanded its research capability with the addition of an in vitro gas fermentation technique and six cannulated steers for in situ assessment of the nutritional quality of feeds. These two techniques are being used to screen different synbiotics for use in feedlot trials this fall.

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Central Grasslands Research Extension Center

The Central Grasslands Research Extension Center (CGREC) has research responsibilities covering range science, forage agronomy and animal sciences. Historically, the range sciences research program has focused on long-term changes to plant communities in response to grazing management. The forage agronomy program has focused efforts toward variety testing and, recently, cropping systems utilizing cover crops.

The animal science programs are led by two scientists, Michael Undi and Bryan Neville. Undi's research has focused on winter grazing systems, including grazing of crop residues, bale grazing and inter-seeding cover crops into growing corn, as well as supplementation practices to improve animal performance and forage digestibility of low-quality forages. Undi has further interest in quantifying forage intake under winter grazing systems.

Neville's research has focused on utilizing dried distillers grains with solubles (DDGS) as a supplement to yearling beef cattle grazing native rangelands and has explored the possible implication of supplementation on subsequent feedlot performance as well as meat quality. More recent research is aimed at exploring the impacts of grazing intensity and advancing the season on forage intake and digestibility of yearling steers supplemented with DDGS.

In addition to the work conducted by scientists at CGREC, a number of collaborative efforts are ongoing with scientists from NDSU's Animal Sciences Department, as well as scientists from the School of Natural Resources. Some of these efforts include:

- Management strategies to improve the utilization of artificial insemination in beef cows (Carl Dahlen)
- Understanding the effects of maternal nutrition on early gestation (Joel Caton)
- Evaluating temperament in beef cattle as it relates to genetic and genomic merit (Lauren Hanna)
- Methods to control Kentucky bluegrass invasion of native rangelands (Ryan Limb)

The Central Grasslands REC also has an area Extension specialist located at the center. Fara Brummer leads the Extension efforts at the CGREC. Brummer has worked to establish a number of events, most notably a Winter Grazing Workshop, which was held in the fall of 2015. Brummer also conducts a number of applied and on-farm research activities with county agents from the area, including a bale-grazing project conducted during the winter of 2015-2016.

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Dickinson Research Extension Center

Where is beef research at the Dickinson Research Extension Center? Perhaps a look at agriculture in general would be good.

Ideally, production agriculture will continue in its present role, but too often the words "sustainable" and "appeasement" are used side by side. The status quo is sufficient.

However, given current data and trends, the sustainability of current systems is a subject of spirited discussion, particularly if community and population trends are added to the equation. Expandable and, we hope, more sustainable systems need to be evaluated to assess current trends.

In the future, all avenues for additional compensation need to be explored to enhance the economic viability for beef producers and the rural areas associated with beef production. This compensation may come from not only beef but synergistic crop production.

For example, small-grain production systems that integrate rotational cropping practices, high-residue management and annual forages, with attention to wildlife habitat enhancement, could be used to diversify income while opening the door to other value-added opportunities for beef production in concert with crop production.

The Dickinson Research Extension Center, as part of NDSU, takes seriously the need for sustainable beef systems. The center is striving to develop sustainable and integrated production strategies that match conditions of western North Dakota and surrounding regions. The inclusion of forages into traditional cropping systems can provide the resources necessary for the development of integrated production strategies that increase sustainability and profitability.

Forage-based cropping systems come closer to the climax native plant community present when homesteaders first arrived in this region. A need exists to develop agro-ecosystems that optimize the balance between forage-based and grain-based crop/livestock systems reflective of the many individual ecosystems. These integrated systems must be synergistic to, or enhance the native and agronomic plant communities, thus providing the base for future beef production.

In addition, enhanced value for commodities produced from forage-based systems is key. As the general population requires protein, a need met by meat and high-protein crops, meeting this demand is a unique opportunity that a forage-based system integrated with crop production can respond to, in addition to current cropland use.

These thoughts are changing how the Dickinson Research Extension Center addresses the future. Previous work certainly has set baseline production for high-residue cropping systems, grassland systems and livestock systems. However further definition, integration and refinement of these system efforts is critical. Beef production needs to think outside the box and the center also needs to do the same.

Challenging the limits of conventional thinking by linking the components of agricultural management systems with value-added opportunities to ensure long-term sustainability of beef and cropping systems within the environment is critical. In response, a new approach needs to be embraced, a concept of integrated agricultural systems that truly entwines crop, beef and forage production as a working unit for betterment of all.

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Hettinger Research Extension Center

The Hettinger Research Extension Center (HREC) is in southwestern North Dakota, four miles from South Dakota and 80 miles from Montana. The range, wildlife and livestock research scientists include Ben Geaumont (range and wildlife scientist) and Christopher Schauer (animal scientist).

Our livestock research facilities include a 200-head calf backgrounding feedlot, 1,000-head lamb finishing feedlot, and a cow herd and sheep flock that are utilized not only at the HREC but in collaboration with the U.S. Department of Agriculture Agricultural Research Service's Northern Great Plains Research Lab in Mandan, N.D., a research project near Fort Yates, N.D., and the Central Grasslands REC and the Carrington REC.

Geaumont's research focus is on evaluating grazing systems with cattle and sheep and their impact and synergies with wildlife, pollinators and rangeland

ecology. His current research projects are evaluating the interactions of wildlife and livestock on prairie dog-impacted grasslands, the utilization of cover crops and sheep grazing in winter wheat production systems. He also is starting a project this year to evaluate the impacts of patch burning in sheep and cattle grazing systems on Conservation Reserve Program lands and the associated impact on rangeland health, pollinators and wildlife habitat.

Schauer's research focus is on nutritional management of cattle and sheep in the feedlot, nutritional impacts on male and female reproduction, and livestock management on the grazing systems research conducted by Geaumont. In addition to the previously mentioned collaborative research with Geaumont, Schauer's current research is evaluating the impacts of dried distillers grains with solubles (DDGS) on male reproduction traits, and a variety of applied lamb finishing research projects evaluating DDGS, particle size, lasalocid, and the interactions of these on lamb growth and production.

Our newest addition to the HREC staff will be of interest to all livestock producers in the region, especially cattle producers. Through the support of the North Dakota Stockmen's Association, the North Dakota State Board of Agricultural Research and Education, and the HREC Advisory Board, the HREC was funded this biennium for an Extension livestock specialist who will focus on beef production systems.

Janna Kincheloe will start at the HREC this winter as the Extension livestock specialist after she completes her Ph.D. at South Dakota State University under the direction of Ken Olson at the West River Ag Center in Rapid City, S.D. She is a former Extension agent from Montana and has spent her graduate career evaluating beef cattle production systems and working with livestock producers in Montana and South Dakota.

She is our first Extension specialist in the 107-year history of the HREC, and we are excited to add her to our staff. Feel free to contact us if you have questions about her upcoming programs as she begins a new and exciting period for the HREC. She is looking forward to working with the Extension agents and livestock producers of the region.

We look forward to seeing everyone at the North Dakota Stockmen's Association meeting this fall.

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Evaluation of response to vaccination with a bacterial-produced plasmid DNA, Zelnate, on feedlot performance of weaned calves

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Our objective was to evaluate the response of a vaccination protocol with Zelnate for bovine respiratory disease complex on growth performance and feeding behavior in recently weaned calves. The use of Zelnate by itself and in combination with a modified live vaccine did not negatively affect growth performance or feeding behavior.

Summary

Bovine respiratory disease complex (BRD) persists as the single most costly disease syndrome associated with commercial beef production in the U.S. To help combat this costly inefficiency, cattle producers have implemented vaccination protocols for their beef herds. Exposing an animal to an antigen can affect their performance in the feedlot negatively (Stokka et al., 1994). To investigate the effects of vaccination on feedlot performance, newly weaned calves (n = 65) were adapted to the Insentec roughage feeders at NDSU's Beef Cattle Research Center. Treatment one was a 2-milliliter (ml) sterile saline negative control subcutaneously injected in the neck. Treatment two was a 2-ml MLV (IBR, PI3, BRSV, BVDV type 1 and 2) vaccine in combination with a *Mannheimia haemolytica toxoid* injected subcutaneously in the neck. Treatment three was 2 ml of Zelnate injected intramuscularly into the neck, and treatment four was a 2-ml MLV (IBR, PI3, BRSV, BVDV type 1 and 2) vaccine in combination with *Mannheimia haemolytica toxoid* and 2 ml of Zelnate. Calves were vaccinated on day 0 of the trial, and weights and blood samples were collected on days 0, 1, 3, 6 and 28 of the trial. Feeding intake and behavior were unaffected by the use of vaccines. All feedlot performance variables were not different among treatment groups. The use of an immune stimulant, Zelnate, by itself or in combination with a modified live virus to newly weaned calves may bolster the calves' ability to fight off infectious agents without negatively affecting feeding behavior or feedlot performance.

Introduction

In livestock, the major causes of death preceding slaughter are due to infectious diseases (Babiuk, 2002). Bovine respiratory disease complex (BRD) persists as the single most costly disease syndrome associated with the commercial beef production in the U.S., accounting for losses in 2010 of 1,055,000 animals valued at $643 million (NASS, 2011). Increased morbidity and mortality, decreased weight gains, decreased feed utilization and decreased carcass quality account for the economic losses associated with BRD (Edwards, 2010).

BRD originally was termed "shipping fever" because signs often occur shortly after arrival at the feedlot (Urban-Chmiel and Grooms, 2012). The morbidity risk of BRD cases in feedlot cattle occurs in the first 45 days after arrival at the feedlot, and the highest risk occurs in weeks 1 to 3. After that, morbidity declines (Buhman et al., 2000; Edwards, 1996).

Vaccination for viruses and bacteria associated with BRD are widespread (Taylor et al., 2010). The viral component of BRD consists of bovine herpesvirus type 1, also known as infectious bovine rhinotracheitis (IBR); bovine viral diarrhea (BVD); parainfluenza virus type 3 (PI-3); and bovine respiratory syncytial virus (BRSV) (Urban-Chmiel and Grooms, 2012). The bacterial component of BRD consists of *Mannheimia haemolyticam, Pasteurella multocida* and *Histophilus somni* (Urban-Chmiel and Grooms, 2012).

Killed and modified live vaccines (MLV) are available in different combinations of viral pathogens (Urban-Chmiel and Grooms, 2012). The appropriate use of these vaccines can reduce the risk of BRD (Urban-Chmiel and Grooms, 2012). The immune responses, which include antigen-specific antibodies, have been shown to confirm vaccine-induced protection against numerous diseases (Casadevall, 2004).

To elicit a vaccine response, the vaccine must provide enough signals from the antigen, or with an adjuvant, to trigger the inflammatory

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reaction that is mediated by cells of the innate immune system (Hoebe et al., 2004). Injection of a vaccine antigen initiates an acute phase inflammatory response, which develops within minutes (Tizard, 2013). In addition, sentinel cells synthesize and secrete a mixture of molecules that trigger inflammation and initiates the first steps of the adaptive immune system (Tizard, 2013).

Immunity is achieved by the maintenance of antigen-specific immune effectors and/or by the induction of immune memory cells that can reactivate if re-exposed to the antigen. These antigen-specific antibodies have been shown to confirm vaccine-induced protection against numerous diseases.

The time required to induce antigen-specific antibodies is approximately 14 days. This delayed response may not confer immunity in time to protect high-risk cattle entering the feedlot. Classically, this delayed response has been covered by the use of prophylactic antibiotic regimes across the first 14 to 28 days to at-risk cattle in the feedlot.

Zelnate is a bacterial-produced DNA liposome that has been shown to increase innate immune cell activity and decrease morbidity and mortality risks in calves exposed to challenge models (Bayer Healthcare Animal Health). This ability to enhance the innate immune system and defend against *Mannheimia haemolytica* within 24 hours may improve feedlot calf health. In addition, enhancing preventive vaccine protocols can result in a more judicious use of antimicrobial treatment regimens.

The objective of this study is to evaluate the response of a vaccination protocol with Zelnate for bovine respiratory disease complex on feedlot performance in newly weaned backgrounding steers.

Experimental Procedures

Animal care and use was approved by the Institutional Animal Care and Use Committee at NDSU, Fargo. This study utilized 65 weaned commercial Angus and Simmental beef calves born Jan. 1, 2015, to March 31, 2015, at NDSU beef barns.

At birth, the calves were vaccinated with Inforce 3 (Zoetis; 100 Campus Drive, Florham Park, NJ 07932) administered via the intranasal route and Ultrabac C & D (Zoetis) administered via the subcutaneous route. On April 1, 2015, calves were vaccinated with Bovishield Gold 5 and Ultrabac 7 subcutaneously and received Dectomax administered via the subcutaneous route. On Sept. 1, 2015, calves received Bovishield Gold VL5 and One Shot Ultra 7 subcutaneously and Dectomax as a pour-on.

Calves were weaned 30 days before being transported to the NDSU Beef Cattle Research Complex. Upon arrival on Oct. 15, 2015, calves (n = 65, body weight [BW] = 797 ± 20.2) were trained for 21 days to the Insentec Roughage Feeders (Insentec; Insentec B. V. Repelweg 10, 8316 PV Marknesse, The Netherlands).

Insentec Roughage Feeders measure feed intake and time of each visit, dry-matter intake (DMI), time spent at the feeder measured in minutes and the number of visits, and the number of meals can be calculated. Body weight was determined on days minus 21, 0, 1, 3, 6, 28 and 29, and average daily gain (ADG), feed conversion ratio (FCR) and gain-to-feed ratio (G:F) were calculated.

Time spent at the feeder, the number of visits and meals were calculated on a 24-hour cycle. A meal is defined as a distinct, separate eating period and visit not separated by intervals longer than seven minutes.

On day 0, calves were blocked by weight, randomly assigned and administered one of four possible treatments. Treatment one was a 2-ml sterile saline negative control subcutaneously injected in the neck. Treatment two was a 2-ml MLV (IBR, PI3, BRSV, BVDV type 1 and 2) vaccine in combination with a *Mannheimia haemolytica toxoid* injected subcutaneously in the neck. Treatment three was 2 ml of Zelnate injected intramuscularly into the neck. Treatment four was a 2-ml MLV (IBR, PI3, BRSV, BVDV type 1 and 2) vaccine in combination with *Mannheimia haemolytica toxoid* and 2 ml of Zelnate.

All data were analyzed using the mixed procedure of SAS (SAS Ins. Inc., Cary, N.C.). Significance was determined with an alpha of $P \leq 0.05$.

Results and Discussion

During an immune response to a pathogen, upregulated signal molecules can have adverse effects on temperature regulation, appetite, energy metabolism and endocrine functions (Klasing, 1988). This could be induced by vaccines with enough antigenic load or adjuvant to elicit a significant immune response. However, in this study, feeding behavior and growth performance were not negatively affected by the injection of a modified live vaccine and adjuvant or a bacterial-produced DNA liposome (See tables 1 and 2).

Treatments one and three tended to have an increased DMI per minute vs. the other two treatments ($P = 0.06$). Treatment one was the negative sterile saline control and treatment three was the bacterial-produced DNA liposome. This tendency was only for an increase of a hundredth of a pound of feed (DM basis) per minute and was not associated with improved growth performance when compared across treatment groups.

The calves used in this study were exposed to vaccine antigens three times prior to the study, were from the same herd and were allowed to acclimate to their new environment for 21 days before the start of this study. Our results suggest that feeding behavior and growth performance were not negatively affected by the injection of a modified live vaccine and adjuvant or a bacterial-produced DNA liposome.

Results using high-stress animals that are weaned, vaccinated and comingled with calves from different herds may have much different results. Further research is needed to evaluate unvaccinated, immune-naïve calves that are weaned and brought together in a backgrounding feedlot environment.

Table 1. Influence of vaccination on feeding behavior in backgrounding steers.

	Treatment[a]					
Item	1	2	3	4	SEM[b]	*P* Value
DMI	18.1	18.3	19	18.7	0.59	0.67
Eating events, no./day						
Visits	23.9	28.9	29.7	26.1	2.5	0.35
Meals/d	10.1	10.5	10.9	9.9	0.83	0.54
Eating time, minutes						
Per visit	6.82	7.17	5.74	7.24	0.55	0.21
Per meal	16.3	17.5	15.2	18.2	1.2	0.25
Per day	157	171	161	173	5.8	0.15
Feed DMI, lbs.						
Per visit	0.79	0.76	0.68	0.8	0.06	0.47
Per meal	1.89	1.86	1.79	2	0.13	0.77
Per minute	0.12	0.11	0.12	0.11	0.003	0.06

[a]1: Sterile saline, 2: Bovishield Gold/Oneshot, 3: Zelnate, 4: Bovishelied Gold/Oneshot + Zelnate
[b]Standard error of the mean (n = 65).

Table 2. Influence of vaccination on growth performance in backgrounding steers.

	Treatment[a]					
Item	1	2	3	4	SEM[b]	*P* Value
Initial BW, lbs.	802	782	793	799	19.9	0.89
Final BW, lbs.	857	846	854	864	21.9	0.95
Gain, lbs.	54.5	64.1	60.3	64.8	6.22	0.62
Weight change						
3 day	1.24	12.09	5.00	5.11	4.43	0.38
6 day	3.61	13.03	4.06	5.71	3.86	0.29
ADG[c]	1.95	2.29	2.15	2.32	0.22	0.62
G:F	0.10	0.12	0.11	0.10	0.01	0.47

[a]1: Sterile saline, 2: Bovishield Gold/Oneshot, 3: Zelnate, 4: Bovishelied Gold/Oneshot + Zelnate
[b]Standard error of the mean (n = 65).
[c]Calculated by dividing the total gain calculated from the average initial and final weights by 28 days

Acknowledgments

The authors thank Zoetis and Bayer for the product support of this project and the staff of the NDSU Beef Cattle Research Complex for assistance with sampling, animal husbandry and handling.

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Seasonlong grazing intensity and parasite load in yearling steers in the northern Great Plains

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A study to evaluate parasite loads with respect to stocking rates in grazing steers was conducted at the Central Grassland Research Extension Center. Results of this study suggest that parasite loads differ in intensity as stocking rates increase, that injectable deworming efficacy is consistent with product claims, and that in spite of repeated seasonlong grazing in the northern Great Plains, parasite load is relatively low. This study also confirms that individual animal parasite load is highly variable and suggests that susceptible young animals may exhibit higher parasite loads in heavily grazed pastures than in moderately or lightly grazed pastures.

Summary

Intestinal parasitism of grazing ruminants can result in poor performance and compromised systems, especially in younger animals, which are intrinsically more susceptible to infection (Stromberg and Gasbarre, 2006). In animals on pasture, the pattern of forage and fecal distribution is affected by the grazing system that is in place, which can be planned systematically to reduce transmission of parasites in grazing animals (Smith et. al, 2009). The intestinal parasite load in four long-term grazing intensity treatments from a light stocking rate to an extreme stocking rate was examined to evaluate the hypothesis that as cattle stocking rates increase in seasonlong systems, the parasite load within animals also increases. This study was conducted in the last year of a 26-year grazing intensity trial in the Missouri Coteau region of the northern Great Plains at the Central Grasslands Research Extension Center. Twelve pastures were stocked with yearling steers from mid-May to mid-October 2015 at four grazing intensities, as they had been for 25 years prior to this study: light (35 percent plant removal), moderate (50 percent plant removal), heavy (65 percent plant removal) and extreme (80 percent plant removal) (Patton and Nyren, 2015). Results demonstrated an increase in parasite load as grazing pressure increased through time. A difference in parasite egg counts per gram was detected among treatment groups ($P \leq 0.05$) in July. Injectable worming treatment before turnout proved effective in the early part of the grazing season because we found no difference among treatments in egg counts in June. In this study, the parasite load also appeared to be somewhat pasture-specific. We observed that the heaviest overall load was in pasture 6, which had an extreme stocking rate. As expected, individual animals within treatment groups showed variable susceptibility to parasitism. In August, individual animals in moderate, heavy and extreme treatments had eggs per gram (epg) at 100 or more. Egg counts of more than 100 epg is a baseline level for concern in animal performance and health (Stromberg et. al., 1997). This study demonstrates an association between high stocking density and increases in detectable parasite load, and supports the conclusion that yearling cattle performance may be impacted by increasing parasitism in seasonlong systems that are heavily stocked, even in the northern Great Plains, where the parasite load typically is not considered a significant issue.

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Introduction

Internal parasites in young grazing animals can compromise performance due to parasitic gastroenteritis and/or competition for nutrients. Grazing management can encourage or discourage parasite load, depending on cattle exposure to plant base level and time spent in pasture.

Weight gain in weaned, yearling ruminants typically occurs through pasturing on grass in the warmer months, so animal performance is essential for cost-effective returns. Intestinal parasites are common inhabitants of pastures, and high levels of parasitism can result in decreased gains, which will decrease the economic potential of the animal (Mertz et. al, 2009).

Intestinal parasites referred to as strongyles include many common cattle pathogens, such as the cattle hookworm, barber's pole worm, brown stomach worm and hair worm, and are implicated in reduced production in cattle (Fox,

1997). This group is in the nematode family and has a direct lifecycle in which eggs or young larvae are ingested, develop into adults within the digestive system of the animal and are finally shed in the manure as a second generation of eggs (Foreyt, 2001).

While some level of parasitism is normal, excessive loads can weaken animals, cause a decrease in feed intake and reduce the immune system. Gastrointestinal parasitism also can have a greater impact on younger grazing animals because they can be naive upon exposure (Stromberg and Gasbarre, 2006).

The potential parasite load is intensified as the animal grazes closer to the base of the plant near the ground (Silangwa, 1964). Although grazing animals typically will avoid manure-soiled areas, heavy grazing pressure for an extended time can expose them to more contaminated areas, which can increase the risk of acquiring a large worm burden.

Interventions, including deworming cattle early in the season before turnout, can be beneficial to cattle producers. Unfortunately, deworming efficacy can be variable and, depending on the product used and the parasite being treated, can be as low as 42 percent (Gasbarre et. al., 2009).

Experimental Procedures

This study was conducted at the Central Grasslands Research Extension Center in Stutsman County northwest of Streeter, N.D., in the Missouri Coteau region. Animal handling and care procedures in this study were approved by the NDSU Animal Care and Use Committee.

Twelve pastures were stocked with yearling steers starting May 13, 2015. These pastures have been grazed at the same intensities for 26 years. The target was to leave 65, 50, 35 and 20 percent of the forage produced in an average year on the light, moderate, heavy and extreme treatments, respectively. Therefore, yearling cattle grazed 35 percent of the light treatment, 50 percent of the moderate treatment, 65 percent of the heavy treatment and 80 percent of the heavy treatment. Each grazing treatment was replicated three times.

Pasture size was 30 acres, on average. Grazing animals shared a common water source, although some pastures had individual open water.

Two hundred steers were allocated across the four treatment groups. Our study sampled a minimum of 10 animals from each replication or 30 percent of the group, whichever was greater. Therefore, the light treatments with the low stocking rate had fewer sampled animals than the extreme treatment with the high stocking rate.

Prior to turnout, all animals were weighed and then randomly chosen from within assigned treatment groups for inclusion in the study. Fecal samples were collected rectally from these animals before deworming. All steers then were dewormed with Dectomax injectable wormer subcutaneously at a dose of 1 cc/110 pounds of live body weight.

During the study period, all cattle were brought in from the pastures to a central point in the field and weighed monthly using a portable livestock chute and digital scale (Weigh-Tronix). Fecal samples were collected from the treatment steers at each weighing period. The same animals in each treatment group replication were used for sampling throughout the course of the study.

All steers also were implanted with Revalor-G to enhance live weight gains. On pasture, all animals were supplemented daily with dry distillers grains with solubles at 0.3 percent of body weight.

Samples were processed for analysis using the Modified Stoll Test (Zajac and Conboy, 2012) and then analyzed under a microscope for the egg per gram of feces. Fecal samples were analyzed by the same two individuals for the duration of this study. Egg counts were transformed and geometric means were used for analyses (PROC GLM SAS 9.4) (Smothers et.al., 1999).

Results and Discussion

Strongyle egg counts differed among certain treatment groups in May, prior to the administration of Dectomax; however, these differences were not apparent in June, demonstrating the efficacy of the deworming treatment. In July (Figure 1), strongyle egg counts began to increase.

The extreme treatment had significantly higher egg counts than the light treatment ($P \leq 0.05$). Moderate and heavy fell between these two values but were not significantly different from each other. We also observed that pasture 6, an extreme treatment, had the greatest number of strongyle egg counts through the course of the study.

In August and September, egg counts per gram were above a baseline of 100 in 23 percent of the animal total in the extreme stocking rate treatment, indicating potentially significant economic parasitism (Zajazc and Conboy, 2012).

Individual animal egg counts were highest in August (Figure 2). Although not statistically different in August, the difference in individual animals within treatment groups is worth noting. The light grazing treatments all showed lower levels of egg counts throughout the course of the study. The moderate and heavily grazed pastures varied, with some pastures tending toward higher loads and others staying relatively low.

Average daily gains of animals in this study were not analyzed relative to pasture load due to other variables in the study, such as protein supplementation and fluctuating forage quality.

Yearling cattle that graze on the northern Great Plains should capitalize on forage resources for maximum economic benefit to the producer. Gastrointestinal parasitism can affect performance because young animals still are developing immunity to parasites. A three-year study conducted on nine ranches in South Dakota showed that beef yearling gains were greater in dewormed animals, compared with control animals (Mertz et.al, 2005).

Our study examined parasite load relative to grazing treatment. While deworming products are effective and relatively inexpensive, efficacy of treatment, as expected, did not last for this five-monthlong seasonlong grazing study. Product efficacy was consistent within a four- to six-week window.

Seasonlong grazing potentially exposes grazing animals repeatedly to contaminated pastures, especially as grazing pressure increases with stocking rates. At the extreme level of grazing, in which 80 percent of the growing forage was defoliated by grazing cattle before removal, fecal egg count means were consistently highest among treatments and significantly different in July.

Mid-July and August are pasture periods of lower forage quality in native and introduced pasture systems. Because this was the period of increased level of parasitism in this study with yearling cattle, performance could stagnate or decrease with the added burden of high levels of parasitism.

Ensuring that grazing yearling animals remain in peak performance to capitalize on ranch resources and investments is imperative. Grazing management should target animal movement and sustainable stocking rates to avoid risking high rates of gastrointestinal parasitism in grazing young animals.

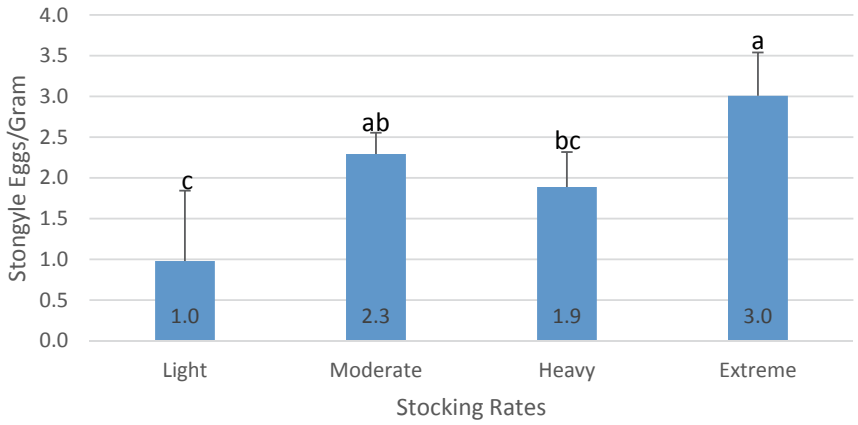

Figure 1. Srongyle Eggs/Gram[1], July 2015

[1]Data for egg counts per gram were transformed to a geometric means for comparitive analyses as represented in this figure.
Treatments labeled with the same letter are not statistically different at the p = 0.05 level.

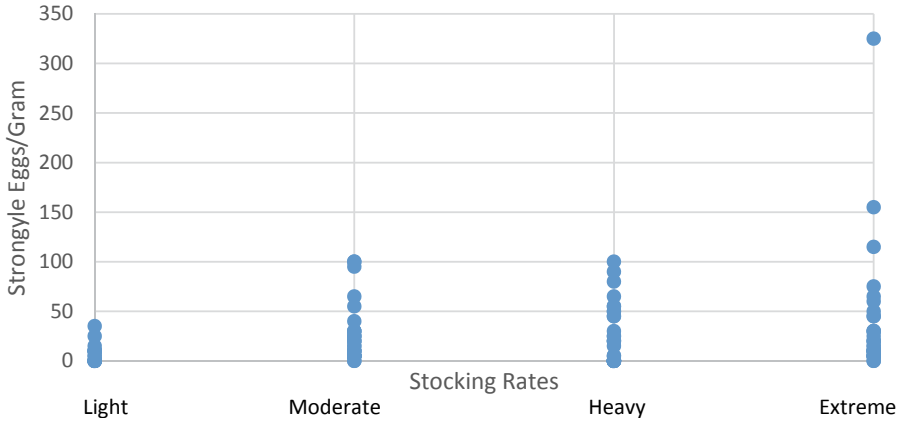

Figure 2. Individual Animal Strongyle Egg/Gram Counts, August 2015

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Effect of two beef cattle yearling steer production systems on grazing and feedlot performance, carcass measurements and systems economics

Sentürklü Songül[1,2], Douglas Landblom[1], Robert Maddock[3] and Steve Paisley[4]

A three-year study of a retained-ownership, vertically integrated, extended-grazing system for steers that included grazing of native and annual forages prior to feedlot entry was compared with a system in which steers were sent directly to the feedlot for growing and finishing. The results suggest that a long-term extended grazing system consisting of a combination of native range, annual forages and a shortened feedlot residency supports superior steer performance, acceptable meat quality and profitability.

Summary

In western North Dakota, yearling steers graze improved and native pastures and routinely are sold during an August-September time frame. Traditional feedlot finishing is a high-risk, low-profit-margin business in which risk is managed using risk management financial instruments. The research question, integrated into a diverse cropping system, was to determine the impact of a long-term grazing period followed by a short-term feedlot finishing period on yearling steer performance, meat quality and profitability. To answer this question, a three-year study was designed using 288 yearling steers (96 steers/year) originating from two beef cattle herds maintained at the Dickinson Research Extension Center (DREC) that were divided into two frame score groups identified as small frame (SF: average frame score of 3.80) and large frame (LF: average frame score of 5.58) and backgrounded at a modest average daily gain (ADG) of 1.33 pounds/day. On the first week of May each year, the steers were assigned randomly to feedlot (FLOT) or grazing (GRAZ) treatments. Both treatment groups of steers were finished at the University of Wyoming's Sustainable Agriculture Research Extension Center (SAREC) in Lingle. The GRAZ steers grazed native range from the first week of May until mid-August (108 days), field pea-barley (32 days) and unharvested grain corn (71 days) for a total grazing period of 211 days and a finishing period of 82 days. The FLOT control steers were in the feedlot for 218 days. SF steers grew slower in the grazing phase ($P = 0.03$) and feedlot finishing growth phase ($P < 0.001$) in comparison with the LF steers ($P < 0.001$). However, under grazing conditions, grazing cost and cost/pound of gain were less for the SF steers in comparison with the LF steers ($250.27 vs. $300.27/steer; $0.5567 vs. $0.6078/pound of gain). Delaying feedlot entry resulted in improved animal performance and profitability. In the feedlot, GRAZ LF steers had greater starting weight ($P < 0.001$), ending weight ($P =$

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0.003), gain ($P < 0.001$) and ADG ($P < 0.001$). GRAZ steer compensatory feedlot gain for LF and SF steers was 26.8 and 24.0 percent greater, respectively, compared with the LF and SF FLOT treatment steers. GRAZ steer hot carcass weight (HCW) was greater for both frame score groups, compared with the FLOT steers ($P = 0.005$). Dressing percent ($P < 0.001$) and marbling score ($P = 0.02$) were greater for SF steers and rib-eye area was greater for the LF steers ($P = 0.001$). Quality grade did not differ between systems or frame score, and we found no meat tenderness ($P = 0.48$) or cooking loss ($P = 0.43$) differences between treatment groups. In the feedlot finishing phase, comparing the average FLOT and GRAZ systems, the finishing feed cost/pound of gain for the GRAZ system averaged 34.0 percent less ($P < 0.001$). Economic analysis of the vertical integration suggested that greater net return would be realized after delayed feedlot finishing, compared with selling the steers at the end of the 211-day grazing period. Net return from selling at the end of grazing was calculated to be $514.02 and $577.74/steer for the GRAZ LF and SF, respectively. At the end of finishing, the three-year average systems net return/steer was $619.94, $499.90, $896.09 and $756.92 for the FLOT LF and SF, and GRAZ LF and SF, respectively. Regardless of frame score, grazing growing steers for an extended period of time was more profitable than traditional feedlot growing and finishing. The greater profitability among the GRAZ steers was realized from a combination of lower grazing and feedlot expenses, feedlot compensatory growth and greater HCW, resulting in a greater and profitable net return for the GRAZ system.

Introduction

The forage quality of improved and native grass species is highest in the spring and early summer and declines in the summer and into fall and early winter, which is one of the primary reasons yearling stocker cattle routinely are marketed during the August-September time frame in the northern Great Plains. Long-term grazing followed by a short-term feedlot period has the potential to be a profitable enterprise, but forages that provide adequate nutrition during the period when perennial forages have lost substantial nutrient quality are needed.

One potential solution for beef producers is to grow annual forages for grazing within a diverse crop rotation. Strategically planting crop mixes and cover crops in a crop rotation preceding or following higher-value crops improves soil nutrient cycling and can provide for a longer-term forage source for yearling steers before feedlot entry.

In an extensive review article comparing calf-fed with yearling-fed cattle, when body weight (BW) or age increased before feedlot entry, average daily gain (ADG), dry-matter intake (DMI) and hot carcass weight (HCW) increased, whereas gain:feed (G:F) and days on feed (DOF) decreased (Reuter and Beck, 2013). Adams et al. (2004) documented that increasing grazing length among gestating June-calving cows and feeding supplemental protein increased net return of the calf at weaning and at slaughter.

Considering the effect that increased BW and age have on steer performance and carcass weight, the objective of this research was to evaluate, within the context of a retained-ownership, vertically integrated model, the impact of a long-term grazing period made possible by integrating annual forage grazing into a diverse crop rotation followed by a short-term feedlot finishing period to determine the effect on yearling steer performance, meat quality and profitability.

Experimental Procedures

During a three-year period, 288 yearling steers (96 steers/year) from two crossbred beef cattle herds maintained at the Dickinson Research Extension Center were used for this study. Traditional and Lowline sired calves were divided into two frame score groups identified as small frame (SF: average frame score of 3.80) and large frame (LF: average frame score of 5.58).

After weaning each fall (2012, 2013 and 2014), the steers were managed as a single group and backgrounded by grazing unharvested corn that was supplemented with mixed hay (alfalfa, bromegrass, crested wheatgrass) and 2 pounds/steer/day of a 32 percent crude protein supplement until the end of April each year.

During the multiyear backgrounding period, the steers grew at a modest ADG of 1.33 pounds/day. The first week of May each year, the steers were assigned randomly to the feedlot (FLOT) or grazing (GRAZ) treatments.

FLOT treatment steers were shipped directly to the University of Wyoming's Sustainable Agriculture Research Extension Center (SAREC) in Lingle for growing and finishing. The GRAZ steers grazed native range from the first week of May to mid-August (108 days) and then moved into a diverse crop rotation grazing field pea-barley intercrop (32 days) and unharvested corn (71 days).

The grazing season cost/steer for native range was determined using a constant cost/pound of BW of $0.00117 multiplied by the start weight and end weight to arrive at a daily grazing cost. Then, using one-half of the total number of days grazed, the first half and second

half grazing charges were added together to arrive at the total grazing charge/steer.

The annual forage grazing cost for the SF steers was reduced by 20.1 percent, based on SF heifer DMI results reported by Senturklu et al. (2015). The overall total grazing period was 211 days before shipment to the University of Wyoming's SAREC feedlot.

The final finishing diet (AF Basis) consisted of 5 percent alfalfa hay, 79 percent whole corn, 14 percent haylage and 2 percent feedlot supplement with Rumensin (200 milligrams/head/day).

Due to system differences, the FLOT control steers were slaughtered in mid-December and GRAZ treatment steers were slaughtered in February-March at the Cargill Meat Solutions packing plant in Ft. Morgan, Colo. Warner-Bratzler shear force tenderness and cooking loss evaluations were conducted at the NDSU Meats Laboratory in Fargo.

Using a vertically integrated economic analysis approach, economics for the two systems and frame scores were evaluated to compare selling the steers at the end of the extended grazing period with selling them at the end of the feedlot finishing period.

Results and Discussion

Farming expenses for the annual forages in the GRAZ system are shown in Table 1. Annual forage enterprise budgets were prepared using actual expenses for seed, fertilizer, chemicals, seed inoculation and crop insurance. All other expenses were adopted from the North Dakota Farm Management education program (Region 4) crop enterprise budgets (2013-2015).

The GRAZ steer performance is shown in Table 2. Feedlot finishing performance is shown in Table 3. Carcass data is shown in Table 4. The effect of the system (GRAZ vs. FLOT) and steer frame score within each system on net return is shown in Table 5.

Results of this systems investigation show that, during the three-year period, the SF steers grew slower under grazing ($P = 0.03$) and during feedlot finishing, compared with the LF steers ($P < 0.001$). Under grazing conditions, grazing cost and cost/pound of gain were lower for the SF steers ($250.27 vs. $300.27/steer; $0.5567 vs. $0.6078/pound of gain).

In the feedlot, LF steers had greater starting weight ($P < 0.001$), ending weight ($P = 0.003$), gain ($P < 0.001$) and ADG ($P < 0.001$). The GRAZ steer compensatory gain in the feedlot for the LF and SF steers was 26.8 and 24 percent greater, respectively, compared with the LF and SF FLOT treatment steers.

Delaying feedlot entry until after 211 days of grazing reduced the finishing period to 82 days on feed (DOF) and associated finishing costs also were reduced for the SF and LF steers. Comparing the average FLOT and GRAZ systems' DM feed cost/pound of gain, the finishing feed cost/pound of gain for the GRAZ system averaged 34 percent less ($P < 0.001$).

Carcass trait measurements collected at Cargill Meat Solutions, Ft. Morgan, Colo., identified economically important differences and similarities. Hot carcass weight (HCW) for the GRAZ system steers was greater than for the FLOT ($P = 0.005$) steers. Dressing percent and marbling score were greater for SF steers in the FLOT and GRAZ treatments ($P < 0.001$; $P = 0.02$).

Rib-eye area was greater for LF steers in the FLOT and GRAZ treatments ($P = 0.001$). Quality grade did

Table 1. Farming input cost per acre for annual forage grazing[1,2].

	Pea Barley	Unharvested Corn
Seed cost/ac, $		
Corn (Pioneer P9690R)	–	58.29
Pea-barley (Perfection pea, Haybet barley)	45.73	–
Machine depreciation/ac, $	6.29	14.88
Fertilizer/ac, $	–	37.60
Fuel and oil/ac	4.81	13.76
Repairs/ac	6.33	16.34
Innoculant/ac, $	4.33	–
Chemical – pea-barley (Glyphosate, AMS, Helfire, Rifle D)/ac	12.50	–
Chemical – corn (Glyphosate, AMS, Helfire)/ac	–	8.60
Crop insurance/ac, $	3.22	11.14
Land rent/ac, $	28.60	35.74
Subtotal	111.81	196.35
Interest, 5%	5.37	9.82
Total crop input cost/ac, $	117.18	206.17
Cost/steer, $ (cost/ac x 4.3 ac fields)/8 steers	62.98	110.81

[1]3-year average crop expenses.

[2]Seed, fertilizer, chemical, inoculant and crop insurance are actual three-year average costs/ac. All other expenses are the three-year average expenses adopted from crop enterprise budgets (Region 4, North Dakota Farm Business Management education program, 2013, 2014, 2015).

not differ between systems and frame score ($P = 0.11$). We found no differences for tenderness ($P = 0.48$) or cooking loss ($P = 0.43$) between treatments.

Economic analysis of the vertical integration suggested that greater net return would be realized after delayed feedlot finishing, compared with selling the steers at the end of the 211-day grazing period. Net return from selling at the end of grazing was calculated to be $514.02 and $577.74/steer for the GRAZ LF and SF, respectively.

At the end of finishing, the three-year average systems net return/steer was $619.94, $499.90, $896.09 and $756.92 for the FLOT LF and SF, and GRAZ LF and SF, respectively. Regardless of frame score, grazing growing steers for an extended period of time was more profitable than traditional feedlot growing and finishing.

The greater profitability among the GRAZ steers was realized from a combination of lower grazing and feedlot expenses, feedlot compensatory growth and greater HCW resulting in a greater and profitable net return for the GRAZ system. During the three-year period of this study, the GRAZ system was consistently more profitable. As with any livestock system, wide changes in feed, pasture, and other production costs could result in smaller profit margins.

The results of this three-year study suggest that a yearling-steer, long-term, extended-grazing system consisting of a combination of native range, annual forages and a shortened feedlot residency produces very acceptable meat quality and favors profitability vs. a traditional feedlot system.

Table 2. Effect of frame score on extended grazing performance and cost[1].

	GRAZ[2] LF[3]	GRAZ[2] SF[3]	SEM[4]	*P*-Value Trt[4]	Yr[4]	Trt x Yr[4]
Number of steers	72	72				
Frame score	5.52	3.77	0.21	<0.001	0.01	0.56
Winter Corn Backgrounding						
Backgrounding days	163	163	0.5889	0.18	<0.001	0.01
Start weight, lb.	566.78	452.67	27.96	0.01	0.001	0.92
End weight, lb.	780.24	674.22	39.09	0.38	0.02	0.86
Gain, lb.	213.46	221.56	16.654	0.75	0.11	0.83
ADG[4], lb.	1.30	1.36	0.098	0.80	0.05	0.95
Overall Total Performance						
Grazed days	211	211				
Start weight, lb.	780.24	674.22	39.092	0.38	0.019	0.86
End weight, lb.	1274.66	1123.82	42.60	0.01	0.002	0.50
Gain, lb.	494.04	449.6	10.96	0.04	0.07	0.27
ADG[4], lb.	2.34	2.13	0.048	0.03	0.40	0.25
Grazing Cost						
Perennial pasture (108 days), $	115.30	100.24				
Field pea-barley (32 days), $[5]	62.98	50.32				
Unharvested corn (71 days), $[5]	110.81	88.53				
32% CP suppl[4]. (0.81 lb/d), $	11.18	11.18				
Grazing cost/head, $	300.27	250.27				
Grazing cost/lb of gain, $	0.6078	0.5567				

[a-b]Means with unlike superscripts differ significantly $P \leq 0.05$.

[1]3-year average.

[2]GRAZ – grazing steers grazed a forage sequence of native range, field pea-barley intercrop and unharvested corn.

[3]SF: small frame; LF: large frame.

[4]SEM: pooled standard error of the mean; Trt: treatment; Yr: year; Trt x Yr: treatment x year; ADG: average daily gain; CP Suppl; crude protein supplement.

[5]SF steer cost reduced by 20.1 percent based on results of Senturklu et al. (2015).

Acknowledgment

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Table 3. Effect of steer frame score and extended grazing on feedlot finishing performance, efficiency and economics[1].

	FLOT[2] LF[3]	FLOT[2] SF[3]	GRAZ[2] LF[3]	GRAZ[2] SF[3]	SEM[4]	*P*-Value Trt[4]	Yr[4]	Trt x Yr[4]
Number of steers	24	24	24	24				
Frame score	5.63	3.82	5.53	3.77	0.262	<0.001	0.001	0.56
Growth Performance								
Grazing days	–	–	211	211				
Feedlot days fed	218	218	82	82	3.51	<0.001	0.04	0.01
Start weight, lb.	767.3	671.4	1229.6	1086.4	42.63	<0.001	<0.001	0.85
End weight, lb.	1515.8	1312.1	1609.8	1400.8	51.93	0.003	<0.001	0.51
Gain, lb.	748.6[a]	640.9[b]	381.6[c]	314.8[d]	16.83	<0.001	0.01	0.09
ADG[4], lb.	3.43[c]	2.93[d]	4.65[a]	3.84[b]	0.12	<0.001	0.94	0.46
Feed Intake and Efficiency								
DM[4] feed/steer/day, lb.	26.83	21.93	29.17	25.49	0.99	0.13	<0.01	<0.21
DM feed/lb. of gain, lb.	7.84	7.50	6.23	6.62	0.39	0.72	<0.05	<0.60
Finishing Economics								
DM feed cost/lb. of gain, lb.	0.807[a]	0.786[a]	0.577[b]	0.612[b]	0.02	<0.001	<0.001	0.01

[a-d]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).

[1]3-Year average.

[2]FLOT steers moved directly to the feedlot for growing and finishing and GRAZ steers grazed a sequence of native range, field pea-barley intercrop and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3]SF: small frame; LF: large frame.

[4]SEM: pooled standard error of the mean; Trt: treatment; Yr: year; Trt x Yr: treatment x year; ADG: average daily gain; DM: dry matter.

Table 4. Effect of steer frame score and extended grazing on carcass trait measurements and value[1].

	FLOT[2] LF[3]	FLOT[2] SF[3]	GRAZ[2] LF[3]	GRAZ[2] SF[3]	SEM[4]	*P*-Value Trt[4]	Yr[4]	Trt x Yr[4]
Hot carcass weight, lb.	875.70[a]	770.06[b]	931.68[c]	822.89d	29.64	0.01	<0.001	0.01
Dressing percent, %	60.22[a]	61.09[b]	60.19[a]	60.84[b]	0.211	<0.001	<0.001	<0.001
Fat depth, in.	0.48[a]	0.50[a]	0.40[b]	0.46[a]	0.204	0.031	<0.001	0.30
Rib-eye area, sq. in.	13.13[a]	11.95[b]	13.93[b]	13.00[c]	0.247	0.001	<0.001	<0.001
USDA yield grade	2.52	2.70	2.23	2.41	0.103	0.72	<0.001	0.95
Marbling score	611.97[a]	640.68[b]	583.44[b]	631.36[b]	10.21	0.02	0.01	0.21
Percent choice, %	93.06	94.24	91.67	97.22	2.73	0.10	0.04	0.19
Carcass value/steer, $	2042.47	1753.88	2243.61	2017.51	91.81	0.79	0.038	0.90
Warner-Bratzler shear force, lb.	5.36	5.32	5.81	5.81	0.14	0.48	<0.001	0.29
Cooking loss, %	17.85	17.61	17.50	15.40	1.17	0.43	<0.001	0.12

[a-d]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).

[1]Three-year average.

[2]Steers were slaughtered at the Cargill Meat Solutions packing plant, Ft. Morgan, Colo.

[2]FLOT steers moved directly to the feedlot for growing and finishing, and GRAZ steers grazed a sequence of native range, field pea-barley intercrop and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3]SF: small frame; LF: large frame.

[4]SEM: pooled standard error of the mean; Trt: treatment; Yr: year; Trt x Yr: treatment x year.

Table 5. Effect of steer frame score, extended grazing and retained ownership vertical integration on system net return at the end of grazing and at feedlot closeout[1].

	FLOT[2] LF[3]	FLOT[2] SF[3]	GRAZ[2] LF[3]	GRAZ[2] SF[3]	SEM[4]	*P*-Value Trt[4]	Yr[4]	Trt x Yr[4]
Cow-calf and Backgrounding Cost								
Annual cow cost, $[5]	602.84	602.84	602.84	602.84				
Winter backgrounding cost, $[6]	153.32	122.50	153.32	122.50				
Total cost, $	756.16	725.34	756.16	725.34				
Grazing Cost								
Grazing cost/steer, $[7]			300.27	250.27				
Total expense, $			1,056.43	975.61				
End grazing Steer value, $			1,570.45	1,553.35	7.37	0.01	<0.001	0.31
Net Return, $			514.02	577.74				
Feedlot Closeout Expenses								
Steer cost, $	756.16	725.34	756.16	725.34				
Feedlot cost/steer, $	674.98[a]	572.84[b]	247.56[c]	218.05[d]	11.71	<0.001	0.001	<0.001
Transportation to packing plant, $[8]	22.25	22.25	23.86	23.86				
Total system expense/steer, $	1,453.23	1,320.09	1,327.42	1,216.91				
Income								
Carcass value/steer, $[8]	2,073.33[b]	1,820.33[d]	2,223.67[a]	1,974.17[c]	77.78	0.001	<0.001	0.02
System net return/steer, $	619.94	499.90	896.09	756.92				

[a-d]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).

[1]3-Year average.

[2]FLOT steers moved directly to the feedlot for growing and finishing, and GRAZ steers grazed a sequence of native range, field pea-barley intercrop and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3]SF: small frame; LF: large frame.

[4]SEM: pooled standard error of the mean: Trt: treatment: Yr: year; Trt x Yr: treatment x year.

[5]Expenses are the three-year average expenses adopted from Beef Cow-Calf Enterprise Analysis (Region 4, North Dakota Farm Management education program, 2013, 2014, 2015).

[6]Expenses are the three-year average expenses adopted from Beef Backgrounding Enterprise Analysis (Region 4, North Dakota Farm Management education program, 2013, 2014, 2015).

[7]From Table 2.

[8]Steers were slaughtered at the Cargill Meat Solutions, Ft. Morgan, Colo.

Effects of feeding two levels of a pelleted 30 percent pea starch and 70 percent dry distillers grain feed in feedlot finishing diets on animal performance and carcass characteristics

Chanda L. Engel[1]

A feed pellet made with 30 percent pea starch and 70 percent dry distillers grains with solubles (DDGS) fed at 15 or 30 percent of the diet dry matter was an effective feed ingredient that can be used to replace DDGS and some corn in feedlot finishing diets. The 30 percent inclusion level may result in a slight improvement in animal performance and feed efficiency vs. the 15 percent inclusion level. Pelleting pea starch with DDGS may allow for greater transportability of DDGS across the country and in export markets. Additional work to improve the manufacturing process would be warranted and valuable.

Summary

One hundred seven Angus and Angus-cross steers (1,006-pound initial body weight) were weighed individually, blocked by body weight and sorted into four weight blocks. Within block, cattle were assigned randomly and sorted into one of 12 pens. Pens were assigned randomly to one of three dietary treatments. Air-fractionated pea starch (PS) and corn dry distillers grains plus solubles (DDGS) were combined at a rate of 30 percent PS and 70 percent DDGS into a small diameter feed pellet (PS-DDGS). The three treatment diets were: control (Con), 15 percent PS-DDGS pellet and 30 percent PS-DDGS pellet (15PS-DDGS and 30PS-DDGS). The Con diet included 20 percent DDGS (no PS). The two PS-DDGS diets included the 30 percent PS-70 percent DDGS pellet at 15 or 30 percent of the diet. Steers were weighed approximately every 28 days and at the time of marketing, for a total of four weight periods. Steers were fed an average of 101 days. Hot carcass weights were recorded on the day of harvest. Carcass 12th rib fat thickness (BF), longissimus muscle area (LMA), and U.S. Department of Agriculture marbling score and yield grades (YG) were recorded following a 24-hour chill. Initial and final body weights were similar for Con, 15 and 30PS-DDGS treatments. Overall, we found a tendency for the 30PS-DDGS-fed cattle to have a lower feed to gain than cattle fed the 15PS-DDGS, and greater average daily gain (ADG) than for cattle on the 15PS-DDGS and Con treatments ($P = 0.10$). All additional performance parameters were similar among the three treatments ($P \geq 0.33$). Hot carcass weight, YG, LMA and marbling score were similar for Con, 15 and 30PS-DDGS treatments. Final BF was similar for 30PS-DDGS and Con, but both were greater than 15PS-DDGS ($P = 0.02$; Table 3).

[1]Carrington Research Extension Center, NDSU

Introduction

North Dakota has a large and expanding pea production and processing industry. Developments in field pea processing have made pea fiber, protein and flour fractions available as individual ingredients for use in human, pet food and livestock markets.

Pea starch flour is a fine-powdered material made from dehulled seeds of field peas. Pea starch flour is created without any processing aids or chemical compounds. It has a nutritional profile of approximately 90 percent dry matter, 13 percent crude protein and 87 percent total digestible nutrients (TDN).

Dry distillers grains with solubles (DDGS) is a widely used and valuable feed ingredient in feedlot diets. However, it tends to bridge and bind during transportation, reducing flowability and increasing unloading challenges. Pelleting distillers grain can improve the flowability and transportability of DDGS. However, DDGS alone does not pellet well.

Adding other feed ingredients such as pea flour, a byproduct of the dry-air-fractionation process of field peas, may improve pellet quality (Anderson and Koch, 2014). Small-scale milling has showed promising results with pelleting pea starch and DDGS, creating a durable, high-quality pellet.

The pelleting has not been tested in a commercial facility. Additionally, the true feeding value of pea starch for beef cattle has not

been quantified. Several studies have evaluated whole field peas in ruminant diets (Anderson et al., 2007; Gilbery et al., 2007; Pesta et al., 2012; Soto-Navarro et al., 2012).

A few studies in swine (Gunawardena et al., 2010) have examined the use of pea starch as a feed ingredient, but no studies in beef cattle could be found. Thus, a feedlot finishing study was conducted to evaluate the feeding value of a 30 percent pea starch/70 percent DDGS commercially produced feed pellet in finishing diets for feedlot steers.

Experimental Procedures

All procedures were approved by the NDSU Animal Care and Use Committee. One hundred seven Angus and Angus-cross steers (1,006-pound initial body weight) consigned to the North Dakota Angus University feedout program were received at the NDSU Carrington Research Extension Center Livestock Unit.

Cattle were weighed individually, vaccinated, given an identification tag, treated for internal and external parasites, and implanted (Revalor-S; 24 mg estradiol 17beta, 120 mg trenbolone acetate). Cattle were blocked by body weight and sorted into four weight blocks. Within block, cattle were assigned randomly and sorted into one of 12 pens. Pens were assigned randomly to one of three dietary treatments.

Air-fractionated pea starch (PS) was obtained from the manufacturer (AGT Foods, Minot, N.D.) and shipped to a commercial feed mill. At the commercial feed mill, DDGS (no fat removal) and PS were combined at a rate of 30 percent PS and 70 percent DDGS into a small-diameter feed pellet (PS/DDGS).

The three treatment diets included control (Con), 15 percent PS-DDGS pellet and 30 percent PS-DDGS pellet (15PS-DDGS and 30PS-DDGS; Table 1). All diets included 13 percent barley straw as the forage base and 2 percent of a vitamin and mineral supplement containing an ionophore (Rumensin). The Con diet included 20 percent DDGS (no PS).

The two PS-DDGS diets included the 30 percent PS/70 percent DDGS pellet at 15 or 30 percent of the diet. The 30 percent treatment had the equivalent of 20 percent DDGS in the diet (similar to control).

The DDGS for the Con diet was received in one batch and was from the same source as the DDGS used to make the PS-DDGS pellet. The amount of dry-rolled corn in the diets was adjusted so each treatment diet had a similar energy value (Net energy for gain = O.59 megacalorie per pound [Mcal/lb]). The 15PS-DDGS diet was lower in crude protein than the other two treatment diets, but no additional nitrogen was added.

Steers were weighed approximately every 28 days and at the time of marketing, for a total of four weight periods. Steers were fed an average of 101 days (97 days for the three heavy blocks and 116 days for the light block).

All pens within a replication block were marketed on the same day at a commercial abattoir (Tyson Foods, Dakota City, Neb.). Hot carcass weights were recorded on the day of harvest. Carcass 12th rib fat thickness (BF), longissimus muscle area (LMA), and USDA marbling score and yield grades (YG) were recorded following a 24-hour chill.

Animal performance and carcass data were analyzed using the GLM procedures of SAS for a randomized complete block design, with pen as the experimental unit. Least square means were separated using the PDIFF statement of SAS.

Results and Discussion

The 15PS-DDGS treatment included 10.5 percent DDGS from the PS-DDGS pellet. The 30PS-DDGS treatment included 21 percent DDGS from the PS-DDGS pellet, which was similar to the DDGS level in the control diet.

While the pellet durability was not measured, we observed that when loaded, transported in bulk (live-bottom, rear-dump semitrailer)

Table 1. Formulation and nutrient composition of diets for yearling steers fed with 20 percent DDGS or 15 or 30 percent of a pellet containing 30 percent pea starch (PS) and 70 percent dry distillers grains with solubles DDGS.

Feedstuffs, dry-mater basis	Control	15% Pea Starch Pellet	30% Pea Starch Pellet
Dry-rolled corn, %	63.7	69.2	54.6
DDGS, %	20.45	–	–
PS-DDGS, %	–	14.9	29.5
Straw, %	13.7	13.8	13.7
Supplement, %	2.18	2.08	2.18
Nutrient Composition			
Crude protein, %	13.7	11.8	14.2
NEm, Mcal/lb.	0.89	0.89	0.89
NEg, Mcal/lb.	0.59	0.59	0.59
NDF, %	23.0	20.7	21.8
Fat, %	4.9	3.9	4.8

and unloaded, the pellets were more brittle and had more fines than expected. Previous work by Anderson and Koch (2014) indicated a pellet durability index (PDI) of 89.7 and 94 for PS-DDGS pellets containing 25 and 75 percent PS and DDGS and 35 and 65 percent PS and DDGS, respectively.

A PDI of 90 percent is considered satisfactory for commercial trade. Based on this data, a ratio of 30 percent PS-to-70 percent DDGS was chosen for the current study. The work by Anderson and Koch (2014) was done on a smaller scale and utilized a DDGS product with 10 percent fat, while the DDGS used in this study had 12 percent fat. Pellet die size was slightly smaller for the current study than in the work of Anderson and Koch (2014; visual observation by authors).

Initial, interim and final body weights, average daily gain (ADG), dry-matter intake and feed to gain were similar for the Con, 15PS-DDGS and 30PS-DDGS treatments, with the exception of the initial 28-day period and days 57 to 84 (Table 2). From day 0 to 28, steers on the 30PS-DDGS treatment had greater BW and ADG, resulting in a lower feed-to-gain ratio than for steers on the Con and 15PS-DDGS treatments.

We found a tendency ($P = 0.07$) for the two PS-DDGS treatments to be similar but have a greater DMI than Con cattle days 57 to 84. Overall, we observed a tendency for the 30PS-DDGS-fed cattle to have a lower feed-to-gain ratio than cattle on the 15PS-DDGS and greater ADG than for cattle on the 15PS-DDGS and Con treatments ($P = 0.10$).

The 15PS-DDGS diet had less total DDGS and thus lower protein than the 30PS-DDGS and Control diets, which may have affected performance. All additional performance parameters were similar among the three treatments ($P \geq 0.33$).

Hot carcass weight, YG, LMA and marbling score were similar for the Con, 15 and 30PS-DDGS treatments. Final BF was similar for 30PS-DDGS and Con, but both were greater than for the 15PS-DDGS ($P = 0.02$; Table 3).

In conclusion, a pellet with 30 percent PS and 70 percent DDGS fed at 15 or 30 percent of the diet

Table 2. Performance of yearling steers fed with 20 percent DDGS or 15 or 30 percent of a pellet containing 30 percent pea starch and 70 percent DDGS.

	Control	15% Pea Pea Starch Pellet	30% Pea Pea Starch Pellet	SEM	*P*-Value
Weight, day 0	1,009	1,011	1,002	4.7	0.46
Weight, day 28	1,152[b]	1,146[b]	1,168[a]	4.8	0.04
Weight, day 56	1,281	1,275	1,309	10.4	0.12
Weight, day 84	1,395	1,394	1,413	12.6	0.53
Final weight	1,481	1,493	1,510	13.4	0.35
ADG, d0-28	5.12[b]	4.83[b]	5.92[a]	0.12	0.002
ADG, d29-56	4.60	4.62	5.04	0.28	0.49
ADG, d57-84	4.07	4.26	3.70	0.29	0.44
ADG, d85-final	4.78	5.87	5.43	0.43	0.27
ADG overall	4.86	4.97	5.24	0.10	0.10
DMI, days 0-28	26.2	25.6	26.0	0.22	0.22
DMI, days 29-56	26.8	28.3	28.3	0.71	0.33
DMI, days 57-84	26.9	30.3	28.3	0.83	0.07
DMI, day 85-final	30.0	32.0	29.9	1.15	0.39
Overall DMI	27.5	29.0	28.1	0.67	0.33
Feed:gain, days 0-28	5.13[b]	5.33[b]	4.41[a]	0.13	0.01
Feed:gain, days 29-56	5.93	6.15	5.64	0.41	0.68
Feed:gain, days 57-84	6.62	7.35	7.67	0.44	0.30
Feed:gain, day 85-final	6.27	5.68	5.53	0.51	0.58
Feed:gain, overall	5.54[ab]	5.68[a]	5.32[b]	0.10	0.10

Table 3. Carcass composition for yearling steers fed with 20 percent DDGS or 15 or 30 percent of a pellet containing 30 percent pea starch and 70 percent DDGS.

Item	Control	Pea Starch 15% Pellet	30% Pea Starch Pellet	SEM	*P*-Value
Hot carcass weight, lb.	890	891	901	8.3	0.63
Yield grade[1]	3.4	3.1	3.2	0.11	0.23
Longissimus muscle area, sq. in.	13.7	13.2	13.3	0.52	0.78
Marbling score[2]	493	467	454	18.8	0.39
Backfat, in.	0.58[a]	0.48[b]	0.55[a]	0.02	0.02

[1]Yield grade is composite calculation of fat to lean yield in a carcass based on a relationship of hot carcass weight, rib-eye area, fat thickness and KPH; low values = lean carcasses.

[2]USDA Quality grades based on marbling scores of 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700+ = prime.

dry matter appears to have been an effective feed ingredient that can be used to replace bulk DDGS and some corn in feedlot finishing diets. In finishing diets, the 30 percent inclusion level may provide a slight improvement in animal performance and feed efficiency, compared with the 15 percent inclusion level.

While pellet quality was not as expected, the pellets in the current study still flowed from the bin and were acceptable in visual quality. Pelleting PS with DDGS may allow for greater transportability of DDGS across the country and in export markets. Additional work to improve the manufacturing process would be warranted and valuable.

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Discovering value in North Dakota calves: Dakota Feeder Calf Show feedout project XIV, 2015-2016

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

The Dakota Feeder Calf Show feedout project assists cattle producers in identifying cattle with superior growth and carcass characteristics. The spread in average profitability between consignments from the top five herds and the bottom five herds was $200.21 per head for the 2015-2016 feeding period.

Summary

The Dakota Feeder Calf Show Feedout project was developed to discover the actual value of spring-born beef steer calves, provide comparisons between 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. 17, 2015. After a 215-day feeding period with 0.98 percent death loss, cattle averaged 1,325.1 pounds (shrunk harvest weight). Feed required per pound of gain was 6.72 (dry-matter basis). Overall pen average daily gain was 3.21 pounds. Feed cost per pound of gain was $0.519 and total cost per pound of gain was $0.774. Profit ranged from $27.11 per head for pen-of-three cattle with superior growth and carcass traits to minus $322.85 per head. Substantial variability in the feeding and carcass value of spring-born calves continues to be discovered through participation in the feedout project.

Introduction

Determining calf value is a learning experience for cow-calf producers. To remain competitive with other livestock and poultry in the meat industry, cow-calf producers need to identify superior genetics and management. Marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

In addition, 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.

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.17, 2015, at the Turtle Lake Weighing Station, Turtle Lake, N.D., for weighing, tagging, 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 205, of which 176 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, dewormed and injected with a prophylactic long-acting antibiotic. Cattle were implanted with Synovex S upon arrival. One calf was returned to an owner due to hoof and leg distress.

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

An open house was held on Feb. 5, 2016, at the Carrington Research Extension Center Livestock Unit, where the owners reviewed the calves and discussed marketing conditions.

The cattle were harvested on May 3, 2016 (eight head), May 18, 2016 (92 head), and May 25, 2016 (102 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Neb., on a grid basis with premiums and discounts based on carcass quality. Carcass data were collected after harvest.

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

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

and recognition for the top-ranking pen of steers.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 629.4 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on Oct. 17, 2015. After an average 215-day feeding period, cattle averaged 1,325.1 pounds (at plant, shrunk weight). Death loss was 0.98 percent (two 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 10.2 on an as-fed basis and 6.7 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.519. The overall yardage cost per pound of gain was $0.104. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.774.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.130250942* initial calf weight, pounds) + 297.316269) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

Overall, the carcasses contained U.S. Department of Agriculture Quality Grades at 2 percent Prime, 69.8 percent Choice or better (including 13.3 percent Certified Angus Beef), 25.7 percent Select, 1.5 percent Standard and 1 percent other, and USDA Yield Grades at 7.9 percent YG1, 43.56 percent YG2, 42.6 percent YG3, 5.4 percent YG4 and 0.50 percent YG5. One carcass (0.50 percent) was greater than 1,050 pounds.

Carcass value per 100 pounds (cwt) was calculated using the actual base carcass price plus premiums and discounts for each carcass. The grid price received for May 3, 2016, was $196.01 Choice YG3 base with premiums: Prime $20, CAB $6, YG1 $6.50 and YG2 $3, and discounts: Select minus $9, Standard (no roll) minus $15, YG4 minus $8, YG5 minus $20 and carcasses greater than 1,050 pounds minus $20.

The grid price received for May 18, 2016, was similar except the Choice YG3 base was $210.51 and the other discount (dark cutter and blood splash) was minus $55. The grid price received for May 25, 2016, was similar except the Choice YG3 base was $207.11 and the Select discount was minus $10.

Profit or loss accounted for initial calf price, feed, yardage, veterinary, freight, brand inspection, beef checkoff, ultrasound and carcass data collection costs, and death loss. Interest costs on cattle or feeding expenses were not included in calculating profit or loss. Final carcass value was assessed using the actual grid pricing for the corresponding harvest group.

For all cattle placed on feed, the feedout calculated a $137.15 loss per head, with death loss included.

Results from the calves selected for the pen-of-three competition are listed in Table 1.

Overall, the pen-of-three calves averaged 418 days of age and 1,334.4 pounds per head at harvest. The overall pen-of-three feedlot average daily gain was 3.29 pounds, while weight per day of age was 3.18 pounds. The overall pen-of-three marbling score was 462.7 (low choice, small marbling).

Correlations between profit and average birth date, harvest weight, average daily gain, weight per day of age or marbling score are shown in Table 2. The average harvest weight, average daily gain and weight per day of age were highly correlated to profitability.

The top-profit pen-of-three calves with superior genetics returned $27.11 per head, while the bottom pen-of-three calves returned minus $322.85 per head. The average of the five top-scoring pens of steers averaged minus $5.03 per head, while the average of the bottom five scoring pens of steers averaged minus $205.24 per head.

For the pen-of-three competition, average profit/loss was minus $107.10 per head. The spread in profitability between the top and bottom five herds was $200.21 per head.

Calf value is improved with superior carcass and feedlot performance. Exceptional average daily gains, weight per day of age, harvest weight and marbling score can be found in North Dakota beef herds. Feedout projects 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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Table 2. Correlation between profit and various production measures (pen-of-three).

	Correlation coefficient
Profit and average birth date	-0.2494
Profit and average harvest weight	0.5082
Profit and average daily gain	0.6205
Profit and weight per day of age	0.3688
Profit and marbling score	0.4656
Profit and yield grade	0.3522

Table 1. Feeding performance – 2015-2016 Dakota Feeder Calf Show Feedout

Pen of Three	Best Three Score Total	Average Birth Date	Average Weight per Day of Age, lbs.	Average Harvest Weight, lbs.	Average Daily Gain, lbs.	Average Marbling Score[1]	Average Calculated Yield Grade	Feeding Profit or Loss/Head
1	2.021	5-Apr-15	3.47	1424.49	3.77	513.67	2.77	$27.11
2	1.928	5-Mar-15	3.21	1387.78	3.22	666.33	3.22	$(26.83)
3	1.897	2-Mar-15	3.25	1436.45	3.42	492.33	2.53	$(11.49)
4	1.853	7-Apr-15	3.38	1391.24	3.84	519.33	3.38	$8.73
5	1.852	7-Mar-15	3.12	1375.39	3.57	572.33	3.26	$(22.65)
Average Top 5 herds	**1.910**	**18-Mar-15**	**3.286**	**1,403.068**	**3.562**	**552.800**	**3.034**	**$(5.03)**
6	1.795	9-Mar-15	3.23	1404.66	3.39	455.00	2.60	$(20.52)
7	1.791	19-Jan-15	3.11	1503.36	3.67	561.00	3.70	$5.20
8	1.781	18-Apr-15	3.51	1383.47	3.51	532.33	3.40	$2.65
9	1.776	6-Apr-15	3.44	1410.72	3.66	442.67	2.94	$(5.00)
10	1.775	27-Apr-15	3.56	1388.40	3.50	442.67	2.34	$(72.15)
11	1.763	18-Mar-15	3.10	1317.83	3.22	478.00	1.83	$(147.54)
12	1.761	20-Jan-15	3.21	1530.97	3.82	478.33	3.16	$(33.05)
13	1.755	1-Apr-15	3.20	1334.01	3.43	416.00	2.24	$(62.90)
14	1.747	17-Apr-15	3.02	1216.27	3.38	579.00	3.37	$(45.60)
15	1.732	4-Apr-15	3.00	1243.22	3.23	599.33	2.58	$(167.02)
16	1.727	17-Apr-15	3.40	1360.58	3.27	463.00	2.64	$(44.11)
17	1.723	25-Mar-15	3.39	1421.11	3.38	482.33	3.14	$(4.73)
18	1.704	13-Mar-15	3.28	1425.01	3.82	415.33	3.07	$(21.21)
19	1.640	1-Apr-15	3.31	1364.01	3.32	514.33	2.85	$(113.50)
20	1.634	21-Apr-15	3.16	1260.72	3.04	459.33	2.05	$(148.21)
21	1.613	21-Mar-15	2.85	1223.05	3.11	427.67	2.12	$(129.21)
22	1.606	1-Feb-15	3.33	1531.56	3.90	515.00	3.58	$(100.94)
23	1.580	4-Apr-15	3.01	1250.79	3.25	482.00	3.21	$(56.46)
24	1.579	2-Apr-15	3.35	1374.77	3.54	449.00	3.55	$(16.04)
25	1.562	29-Mar-15	3.30	1376.43	3.26	422.67	2.50	$(116.42)
26	1.537	8-Mar-15	3.27	1428.39	3.37	411.33	2.55	$(125.98)
27	1.504	12-Feb-15	2.88	1323.36	3.18	504.00	3.32	$(92.88)
28	1.498	16-Apr-15	3.24	1291.61	2.91	392.00	1.76	$(185.63)
29	1.494	2-May-15	3.17	1230.14	3.02	401.00	2.34	$(126.18)
30	1.491	15-Apr-15	3.36	1345.50	3.23	544.00	3.54	$(110.88)
31	1.476	12-Apr-15	3.12	1248.08	2.92	381.00	2.07	$(145.05)
32	1.466	28-Feb-15	2.98	1326.88	3.11	420.33	3.13	$(57.43)
33	1.456	27-Mar-15	3.10	1296.24	3.02	426.00	2.64	$(126.74)
34	1.453	3-Apr-15	3.09	1280.49	3.13	496.00	3.19	$(125.64)
35	1.412	16-Apr-15	3.24	1307.69	3.25	376.67	2.18	$(201.50)
36	1.404	10-Apr-15	3.38	1367.45	3.24	525.00	3.85	$(98.09)
37	1.368	14-Apr-15	3.18	1285.15	3.18	393.33	2.62	$(167.53)
38	1.365	3-Apr-15	3.41	1393.91	3.21	448.33	2.90	$(184.15)
39	1.362	19-Feb-15	2.81	1272.12	2.84	476.67	2.29	$(251.61)
40	1.360	11-Mar-15	3.63	1515.94	3.83	451.00	3.28	$(212.24)
41	1.360	20-Mar-15	2.80	1231.87	2.94	426.00	2.67	$(164.95)
42	1.318	8-Mar-15	3.23	1408.14	3.37	380.33	3.11	$(137.52)
43	1.288	26-Mar-15	2.83	1201.77	2.86	381.67	2.38	$(195.62)
44	1.287	8-May-15	2.83	1078.97	2.80	356.67	2.22	$(190.35)
45	1.238	30-Mar-15	2.99	1249.27	3.04	426.33	3.30	$(153.48)
46	1.225	30-Mar-15	2.98	1250.48	3.09	434.00	2.99	$(217.93)
47	1.215	1-May-15	3.27	1271.44	3.23	464.33	3.91	$(136.31)
48	1.213	7-May-15	2.98	1136.98	2.78	340.33	2.33	$(195.62)
49	1.003	12-Apr-15	3.24	1310.50	3.22	436.33	3.24	$(322.85)
Average bottom 5 herds	**1.179**	**15-Apr-15**	**3.091**	**1,243.733**	**3.070**	**420.267**	**3.156**	**$(205.24)**
Overall average - pens of three	**1.559**	**27-Mar-15**	**3.187**	**1,334.462**	**3.291**	**462.687**	**2.855**	**$(107.10)**
Standard deviation		25.2	0.204	96.966	0.292	66.600	0.542	$79.11
number	49	49	49	49	49	49	49	

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

Growing and finishing feedlot performance of steers fed diets with rolled corn or rolled barley and medium- or low-fat dry distillers grains with solubles

Chanda L. Engel[1], Kendall C. Swanson[2] and Vern L. Anderson[1]

Feeding low- or medium-fat dried distillers grains with solubles (DDGS) at 26 percent of the diet dry matter to steers in growing and finishing diets appears to influence animal performance and carcass attributes similarly. When fed at similar diet dry-matter levels, rolled barley and rolled corn have similar effects on animal performance and carcass characteristics. Barley appears to result in similar feed efficiency with corn in the growing phase but showed improved feed efficiency in the finishing phase as a result of lower dry-matter intake and similar performance when compared with corn-based diets.

Summary

Crossbred steers (n = 154), with an initial body weight (BW) of 684 pounds, were used in a 189-day growing and finishing feedlot study evaluating the effects of corn or barley and two fat levels of dry distillers grains with solubles (DDGS). Steers were blocked by initial BW into four weight blocks and assigned randomly to one of 16 pens. Pens were assigned to one of four dietary treatments within weight blocks. Treatments were arranged as a 2 × 2 factorial with grain type (dry rolled corn or dry rolled barley) as one factor and fat content of DDGS (med-fat, 9.6 percent fat or low-fat, 5.8 percent fat) as the other factor. No grain type (corn or barley) by DDGS fat level (9.6 or 5.8 percent fat) interactions were detected ($P \geq 0.29$). Initial and final BW, average daily gain (ADG), dry-matter intake (DMI) and gain:feed (G:F; pounds BW gain/pound of feed consumed) were similar ($P \geq 0.11$) for low- and med-fat DDGS for the growing and finishing phases. Dressing percent, hot carcass weight (HCW), yield grade, longissimus muscle (LM) area, marbling score and back fat (BF) did not differ between DDGS treatments ($P \geq 0.18$). Steers fed corn- and barley-based diets had similar initial and final growing ($P \geq 0.16$) and finishing ($P \geq 0.17$) BW and ADG. Growing DMI was similar ($P = 0.37$) for corn and barley grain, resulting in similar G:F in the growing phase ($P = 0.26$). However, cattle on the corn finishing diets had greater ($P = 0.02$) DMI than barley, resulting in a tendency ($P = 0.08$) for barley to be more efficient than corn during the finishing phase. Overall, barley-fed steers had greater ($P = 0.002$) G:F than corn-fed steers. The carcass parameters dressing percent, HCW, yield grade, LM area, marbling score and BF were all similar ($P \geq 0.09$) for barley- and corn-fed cattle. Low-fat and medium-fat DDGS can be fed with corn and barley grain at similar levels without affecting animal performance. Additionally, rolled corn and rolled barley are comparable grain sources for growing and finishing feedlot steers.

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Introduction

Corn distillers grain (DG) is produced at multiple ethanol plants in North Dakota. Primarily three moisture levels of corn distillers grain products are available: dry (about 90 to 95 percent dry matter, DDGS), modified (49 to 52 percent dry mater, MDGS) or wet (less than 48 percent dry matter, WDGS). The DDGS product is the most shelf stable and transportable due to the lower moisture content.

The current process for ethanol plants involves a step to remove corn oil (fat) from DG during ethanol production. Ethanol plants remove corn oil from DG for higher-value biodiesel and feed markets. Some plants remove a greater proportion of oil than others, resulting in fat levels of DG ranging from 4 to 10 percent, depending on the plant process.

Fat is high in energy, thus oil removal may alter the nutrient density of the resulting distillers grain feedstuff. While certain nutrients such as protein are slightly increased, the main concern is a reduction in energy value related to fat removal and its effect on animal performance.

A portion of the distillers grains produced in North Dakota is fed in the state, but the majority is exported to other locations in the U.S., Canada and other international locations. Typically, feedlot diets in the U.S. include corn grain as the primary grain source. However, in Canada and at times in North Dakota, barley

is the primary grain source. Barley is higher in protein and fiber and lower in starch than corn; however, corn starch may be less digestible unless it is steam-flaked (Gibb and McAllister, 2003).

Concern has developed among nutritionists and feedlot managers that the variation in fat levels in the current distillers grains products on the market could affect animal performance when corn or barley is fed as the primary grain source. The objective of this study was to evaluate the effects on animal performance and carcass characteristics of feedlot cattle fed diets with moderate- or low-fat DDGS with rolled corn or rolled barley grain.

Experimental Procedures

All trial procedures were approved by the NDSU Animal Care and Use Committee. Crossbred steers (n = 154), with an initial BW of 684 pounds, were used in a 189-day feedlot study evaluating the effects of corn or barley and two fat levels of DDGS. The study, conducted at the NDSU Carrington Research Extension Center, included a 57-day growing phase (day 0 to day 57) and an approximately 132-day finishing phase (day 58 to end).

The heavy block (four pens) was marketed at day 180 and the remaining three blocks (12 pens) were marketed on day 194. Steers were consigned by North Dakota producers through the Dakota Feeder Calf Show producer feedout program.

Steers were implanted with 120 milligrams (mg) of trenbolone acetate and 24 mg of estradiol (Revalor S, Merck Animal Health) on day 0 and day 85. Upon arrival, steers were blocked by initial BW into four weight blocks and assigned randomly to one of 16 pens.

Pens were assigned to one of four dietary treatments within block in the 2 x 2 factorial design. Grain type (dry rolled corn or dry rolled barley), as one factor, was fed at 30 and 51 percent of the diet DM for the growing and finishing diets, respectively. Two fat levels of DDGS (med-fat, 9.6 percent fat or low-fat, 5.8 percent fat) were included as the other factor and fed at 26 percent diet DM in the growing and finishing diets.

Growing diets included 19 percent grass hay, 22 percent corn silage, and 3 percent vitamin and mineral supplement with an ionophore (DM basis). Finishing diets included 20 percent corn silage, and 3 percent supplement vitamin and mineral supplement with an ionophore (DM basis; Table 1 and 2).

Steers were weighed on day 0 and every 28 days until harvest. Steers were marketed at a commercial abattoir (Tyson Fresh Meats, Dakota City, Neb.). Hot carcass weights were obtained at harvest.

The following carcass attributes were evaluated by a trained grader after a 24-hour chill: 12th rib-fat depth; rib-eye area; kidney, pelvic and heart fat (KPH); marbling score; and U.S. Department of Agriculture

Table 1. Growing diets for steers fed two fat levels of dry distillers grains (DDGS) and corn or barley.

	Medium-fat DDGS		Low-fat DDGS	
Ingredient, % Dry Matter	Barley	Corn	Barley	Corn
Barley	30.2	–	30.3	–
Corn	–	30.8	–	30.7
DDGS, low-fat	–	–	25.6	25.5
DDGS, med-fat	25.7	25.6	–	–
Corn silage	22.1	21.9	22.0	21.8
Grass hay	18.6	18.4	18.5	18.4
Supplement	3.4	3.3	3.7	3.7
Diet dry matter, %	76.0	76.5	76.2	76.5
Crude protein, %	15.3	14.2	15.2	14.2
NEg, Mcal/lb.	49.1	51.8	47.5	50.1
Fat, %	4.1	4.6	3.1	3.6

Table 2. Finishing rations for steers fed two fat levels of dry distillers grains (DDGS) and corn or barley.

	Medium-fat DDGS		Low-fat DDGS	
Ingredient, % Dry Matter	Barley	Corn	Barley	Corn
Barley	50.9	–	51.1	–
Corn	–	51.4	–	51.5
DDGS, low-fat	–	–	25.9	25.8
DDGS, med-fat	26.1	25.9	–	–
Corn silage	19.5	19.4	19.4	19.3
Grass hay	0.7	0.8	0.7	0.6
Supplement	2.8	2.6	2.9	2.8
Diet dry matter, %	76.8	77.5	77.1	77.5
Crude protein, %	16.3	14.5	16.3	14.5
NEg, Mcal/lb.	56.5	60.9	55.0	59.3
Fat, %	4.2	5.0	3.2	4.0

yield grade. Performance and carcass characteristics were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.) and pen was the experimental unit.

Results and Discussion

No grain type (corn or barley) by DDGS fat level (9.6 or 5.8 percent fat) interactions were detected ($P \geq 0.29$); steers fed corn and barley responded to dietary treatments similarly across the two fat levels of DDGS fed at 26 percent of the diet dry matter, thus data is presented as main effects of DDGS fat level or grain type.

Initial and final body weight (BW) for the growing ($P \geq 0.18$) and finishing phases ($P \geq 0.11$) were similar for low- and med-fat DDGS (Table 3). Similarly, ADG, DMI and gain:feed (G:F; pounds BW gain/pound of feed consumed) were similar for growing ($P \geq 0.19$) and finishing ($P \geq 0.17$) phases for low- and med-fat DDGS. This is consistent with results observed in a previous feedlot study evaluating high- (12 percent fat), medium- (8 percent fat) and low- (4.5 percent fat) fat DDGS fed at 20 percent of the diet dry matter for finishing steers (Anderson and Engel, 2014).

In contrast, research conducted at Agriculture and Agri-food Canada, Lethbridge Research Centre, found that feeding growing feedlot diets to steers with 60 percent corn silage and 24.3 or 15 percent barley with 10 or 20 percent low- or medium-fat DDGS resulted in higher dry-matter intake and increased average daily gain for low-fat DDGS diets, compared with the medium-fat DDGS treatments (Ribeiro et al., 2016).

In the finishing phase of the Lethbridge study, barley replaced DDGS and levels were decreased to 5 and 10 percent for low- and medium-fat DDGS. The steers fed medium-fat DDGS in the finishing phase displayed improved feed efficiency conversion, compared with low-fat DDGS.

In a metabolism trial with diets similar to the current trial, Keomanivong et al. (2015) found that diets with low-fat DDGS had increased ruminal amylase activity. Additionally, this increased amylase activity was observed to be greater in diets with barley, compared with corn.

In a comparison of low-fat and traditional (high-fat) DDGS replacing corn in feedlot rations, Ceconi et al. (2012) observed lower rumen ammonia-nitrogen and greater volatile fatty acid concentrations in low-fat DDGS diets, compared with high-fat DDGS. The metabolism data from these studies (Keomanivong et. al., 2015 and Ceconi et. al., 2012) indicate that low-fat DDGS may enhance or higher-fat DDGS may suppress ruminal microorganism growth and activity.

In the current study, dressing percent, hot carcass weight, yield grade, longissimus muscle area,

Table 3. Growing and finishing performance of steers fed diets with two fat levels of dry distillers grains (DDGS) and corn or barley.

	DDGS		Grain			*P*-Value		Interaction
	Low-fat	Medium-fat	Barley	Corn	SEM	Grain	DDGs	Grain x DDGS
No. pens, n	8	8	8	8	–	–	–	–
Initial weight	683	690	690	682	3.38	0.16	0.18	0.70
Weight-d57[1]	860	870	873	857	7.96	0.17	0.43	0.37
Final weight[2]	1,398	1,419	1,413	1,393	12.86	0.30	0.11	0.40
ADG, d0-57	3.1	3.2	3.2	3.1	0.12	0.37	0.80	0.39
ADG, d58-end	4.0	4.1	4.1	4.1	0.07	0.80	0.33	0.42
ADG, d0-End	3.8	3.8	3.8	3.8	0.06	0.76	0.36	0.29
DMI, d 0-57	17.3	18.6	17.8	18.2	0.65	0.65	0.19	0.50
DMI, d58-end	22.1	23.0	21.7	23.4	0.42	0.02	0.17	0.35
DMI, d0-End	20.7	21.7	20.5	21.8	0.40	0.05	0.12	0.32
Feed:Gain, d0-57	5.6	5.9	5.5	5.9	0.18	0.15	0.29	0.69
Feed:Gain, d58-End	5.5	5.6	5.3	5.7	0.10	0.07	0.26	0.72
Feed:Gain, d0-End	5.5	5.7	5.4	5.8	0.08	0.002	0.20	0.85
Gain:Feed, d0-57	0.182	0.172	0.182	0.172	0.006	0.26	0.26	0.73
Gain:Feed, d58-End	0.184	0.180	0.187	0.177	0.003	0.08	0.25	0.73
Gain:Feed, d0-End	0.183	0.178	0.185	0.175	0.003	0.002	0.19	0.76

[1]The growing diet was fed from day 0 to day 57.
[2]Finishing ration was fed from day 58 to d 180 for four heavy pens and day 194 for 12 remaining pens.

marbling score and back fat did not differ among DDGS treatments ($P \geq 0.18$; Table 4). Anderson and Engel (2014) observed similar results for carcass characteristics in feedlot diets with three fat levels of distillers, with the exception of yield grade and marbling score.

Marbling score increased with increasing fat levels in DDGS and USDA yield grade was greater for high-fat but similar between medium- and low-fat DDGS diets. Similarly, Ribeiro et al. (2016) found carcass quality and liver abscesses were unaffected by type of DDGS and inclusion level.

In the current study, dietary fat levels ranged from 3.1 to 4.6 percent for the growing diets and 3.2 to 5 percent for the finishing diets (Table 1 and 2). Total dietary fat was 1 percent greater in the medium-fat DDGS diets, compared with the low-fat DDGS diets, when compared within the same grain type diets. Corn grain diets were slightly higher in total fat than the barley diets.

Steers fed corn- and barley-based diets had similar BW at trial initiation ($P = 0.16$), at the end of the growing phase ($P = 0.17$) and at trial completion ($P = 0.30$). Growing and finishing phase ADG was similar ($P \geq 0.37$) between grain sources. Growing DMI was similar ($P = 0.65$) for corn and barley grain (Table 3). However, cattle on the corn finishing diets had greater ($P = 0.02$) DMI than barley, resulting in similar ($P = 0.26$) growing phase G:F but had a tendency ($P = 0.08$) for barley to be more efficient than corn in the finishing phase.

Overall, barley-fed steers had greater ($P = 0.002$) G:F than corn-fed steers. Anderson and Ilse (2012) observed that as barley replaced corn at 0, 33, 67 and 100 percent of the diet for finishing steers, a linear decrease in feed intake, similar overall gains and a linear improvement in feed efficiency. Pritchard and Robbins (1991) substituted rolled barley for 0, 25, 50, 75 or 100 percent whole shelled corn in finishing diets. Increasing barley substitution resulted in decreased ADG and DMI but did not affect feed conversion.

We expected that as DMI decreased, ADG also would decrease. However, the lack of difference in feed conversion would support the idea that the energy value of barley may be underestimated (Owens et. al., 1997) and the energy value of corn may be overestimated (Zinn et al., 2002).

While corn is generally higher in starch than barley, differences in the kernel structure and starch matrix arrangement between these grains likely account for the differences in performance. The starch and protein fractions of barley are more digestible than they are in corn (Gibb and McAllister, 2003). The carcass parameters for dressing percent, HCW, yield grade, LM area, marbling score and BF were all similar ($P \geq 0.09$) for barley- and corn-fed cattle (Table 4).

Feeding low- or med-fat DDGS at 26 percent of the diet dry matter in the growing and finishing phases appears to influence animal performance and carcass attributes similarly. When fed at similar diet dry-matter levels, rolled barley and rolled corn have similar effects on animal performance and carcass characteristics. Additionally, barley appears to result in similar feed efficiency with corn in the growing phase but may improve feed efficiency, compared with corn in the finishing phase.

Table 4. Carcass performance for steers fed growing and finishing diets with two fat levels of dry distillers grains (DDGS) and corn or barley.

	DDGS		Grain			*P*-Value		Interaction
	Low-fat	Medium-fat	Barley	Corn	SEM	Grain	DDGs	Grain x DDGS
No. Pens, n	8	8	8	8	–	–	–	–
Shrunk dressing percent	63.6	63.2	63.0	63.9	0.004	0.09	0.46	0.88
Hot carcass weight, lb.	838	853	846	846	7.2	1.00	0.18	0.41
Yield grade[1]	3.1	3.1	3.1	3.2	0.12	0.47	0.85	0.73
Longissimus muscle area, sq in.	13.6	13.5	13.6	13.5	0.18	0.55	0.94	0.09
Marbling score[2]	455	475	451	478	10.15	0.10	0.19	0.29
Back fat, in.	0.54	0.53	0.52	0.55	0.02	0.38	0.84	0.50

[1]Yield grade is composite calculation of fat to lean yield in a carcass based on a relationship of hot carcass weight, rib-eye area, fat thickness and KPH; low values = lean carcasses.

[2]USDA Quality grades based on scores of 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700+ = prime

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The influence of grain source and dried corn distillers grains plus solubles oil concentration on finishing cattle performance and feeding behavior

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The objective of this experiment was to determine the effect of grain type (corn vs. barley) and oil concentration of dried corn distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on finishing performance, feeding behavior and carcass characteristics. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not influence finishing performance, feeding behavior or carcass measurements and that feeding barley-based diets resulted in decreased dry-matter intake and improved gain efficiency.

Summary

Eighty-one steers (944 ± 7.7 pounds of body weight) were used to determine the effect of grain type (corn vs. barley) and oil concentration of dried corn distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on finishing performance, feeding behavior and carcass characteristics. Steers were allotted by body weight to three pens. Within each pen, steers were assigned randomly to one of four dietary treatments (n = six or seven steers per treatment): 1) corn and moderate-fat DDGS, 2) corn and low-fat DDGS, 3) barley and moderate-fat DDGS and 4) barley and low-fat DDGS. Intake and feeding behavior traits were calculated from data generated via the Insentec feeding system. Steers were slaughtered with an average body weight of 1,473 ± 9.7 pounds and were marketed in two groups at 119 (n = 40) and 155 (n = 41) days. Final body weight and average daily gain were not affected ($P \geq 0.68$) by grain type or DDGS oil concentration. Dry-matter intake decreased ($P = 0.002$) and gain:feed increased ($P = 0.01$) in steers fed barley-based diets. Daily visits to the feeder decreased ($P = 0.05$), but time eating per visit increased ($P = 0.03$) in steers fed barley-based diets,

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compared with those fed corn-based diets. We found no effect ($P \geq 0.26$) of treatment on carcass traits: hot carcass weight; marbling; rib-eye area; 12th rib fat; and kidney, pelvic and heart fat. These data indicate steers fed barley-based diets had improved gain efficiency, having a greater gain:feed than steers fed corn-based diets. Oil concentration of DDGS had no effect on finishing performance. Steers fed barley-based diets spent more time eating per visit but visited the bunk less per day than those steers fed corn-based diets, which could account for the lower dry-matter intake in steers fed barley diets. Carcass traits were not affected by either grain type or oil concentration of DDGS. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not influence finishing performance, feeding behavior or carcass measurements, and that feeding barley-based diets resulted in decreased dry-matter intake and improved gain efficiency.

Introduction

Feed costs represent the largest direct cost in beef production. Utilizing different grain types can influence feed efficiency. Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein et al., 2008) and may influence growth performance differently, depending on grain source and processing.

The ethanol industry is evolving and changing its production practices. This has resulted in changes in the nutrient composition of the final coproduct available as a feedstuff.

Decreasing fat in the diet has been shown to decrease average daily gain in finishing steers (Zinn, 1989). However, increasing oil concentration in the diet also can have a negative effect on digestibility of nonlipid energy sources (Jenkins, 1993), so DDGS with a lower oil concentration actually could provide beneficial affects to ruminants.

Therefore, research is needed to determine what affect DDGS oil concentration has on finishing cattle performance, feeding behavior and carcass quality when commonly fed feed grains are fed. We hypothesize that grain type and DDGS oil concentration will influence finishing performance and feeding behavior.

Our objectives were to determine the effects of grain source (corn vs. barley) and DDGS oil concentration (4.5 vs. 7.9 percent DM) on finishing performance, feeding behavior and carcass quality.

Experimental Procedures

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Eighty-one steers (944 ± 7.7 pounds of body weight) predominately of Angus, Simmental and Shorthorn breeding were used in a 2 x 2 factorial arrangement of treatments (grain type [rolled corn vs. barley] and DDGS oil concentration [moderate = 7.9 percent vs. low = 4.5 percent]; Tables 1 and 2).

The steers were allotted into three pens (light, medium and heavy pens; n = 27 per pen) and housed at the NDSU Beef Cattle Research Complex. Within each pen, steers were assigned randomly to one of four experimental treatment diets (n = six or seven steers per treatment within pen; n = 20 or 21 per treatment): 1) corn with moderate-fat DDGS, 2) corn with low-fat DDGS, 3) barley with moderate-fat DDGS, and 4) barley with low-fat DDGS.

Diets were formulated to meet or exceed recommendations for dietary intake protein (DIP), metabolizable protein (MP), vitamins and minerals (NRC, 1996). Diets were offered for ad libitum intake. Steers were adapted to experimental diets by transitioning to the final diet during a 21-day period. Intake

Table 1. Diet composition.

	Treatment			
	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Rolled corn	50	50	-	-
Barley	-	-	50	50
DDGS	25	25	25	25
Corn silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	-	-
Salt	0.05	0.05	0.05	0.05
Vitamin premix[1]	0.01	0.01	0.01	0.01
Mineral premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground corn	2.71	2.71	2.86	2.86

[1]Contained 48,510 kilo International Units per kilogram (kIU/kg) vitamin A and 4,630.5 kIU/kg vitamin D.
[2]Contained 3.62 percent calcium, 2.56 percent copper,16 percent zinc, 6.5 percent iron, 4 percent manganese, 1.050 milligrams per kilogram (mg/kg) iodine and 250 mg/kg cobalt.
[3]Contained 176.4 grams (g) monensin/kg premix.
[4]Contained 88.2 g tylosin/kg premix.

Table 2. Analyzed nutrient concentration of diets (DM basis).

Dietary Component, % of DM	Treatment			
	Rolled Corn		Rolled Barley	
	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid detergent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

and feeding behavior traits were calculated from data generated via the Insentec feeding system.

Steers were slaughtered with an average body weight of 1,473 ± 9.7 pounds and were marketed in two groups at 119 (n = 40) and 155 (n = 41) days. Data were analyzed as a completely randomized block (days to slaughter) design using the generalized linear means mixed procedure of SAS with a 2 x 2 factorial arrangement of treatments. Data were considered significant when $P \leq 0.05$ and a tendency was considered when $0.05 < P \leq 0.10$.

Results and Discussion

Initial and final body weight did not differ between grain types or DDGS oil concentration (Table 3). We found no difference in average daily gain between grain types or DDGS oil concentration. Dry-matter intake decreased ($P = 0.002$) in steers fed barley, as compared with corn; however, we found no differences in dry-matter intake between DDGS oil concentrations. Barley-fed steers had increased ($P = 0.01$) gain:feed, compared with corn-fed steers, and we found no differences between DDGS oil concentrations.

No differences were observed in hot carcass weight; marbling score; rib-eye area; 12th rib fat; or kidney, pelvic and heart fat among steers fed different grain types or oil concentration of DDGS. We found a decrease ($P = 0.05$) in visits to the bunk per day in steers fed barley, compared with those fed corn, but no differences were found between DDGS oil concentrations (Table 4).

Time eating per visit increased ($P = 0.03$) in barley-fed steers. We observed a tendency ($P = 0.06$) for time eating per visit with DDGS oil concentrations to increase in low-oil-concentration DDGS. We found a tendency ($P = 0.09$) for a decrease in eating rate per visit for steers fed moderate-oil-concentration DDGS. We also observed a tendency ($P = 0.06$) for a decrease in eating rate per meal in barley-fed steers. No differences were found in eating rate per meal between oil concentrations of DDGS.

Research conflicts in regard to the effects on gain efficiency when different grain types are fed in finishing diets. These differences could be due to a number of variables, such as diet composition, grain source (field by field, state and region variety) or grain variety. Differences in dry-matter intake appear to be the driving influence behind the improved efficiency observed in this study.

Intake can be affected by roughage source and inclusion level in the diet and grain processing and, therefore, differences in each experiment's diets could affect intake. Our results were in agreement with the data suggesting that feeding barley improves gain efficiency, as compared with feeding corn.

Bremer et al. (2015) studied the effect of increasing distillers products with a reduced oil concentration on cattle performance to determine if the oil concentration affects average daily gain. Their results indicated an increase in average daily gain with increasing reduced-oil wet distillers grains plus solubles (7.9 percent fat) similar to normal-oil wet distillers grains plus solubles. Similar to our results, they also reported no differences in growth performance when feeding reduced-oil-concentration (7.9 percent fat) wet distillers grains plus solubles, compared with a normal wet distillers grains plus solubles (11.3 percent fat).

Steers fed barley-based diets spent more time eating per visit but visited the bunk less per day than those steers fed corn-based diets, which could account for the lower dry-matter intake in steers fed barley diets.

Steers fed moderate-oil-concentration DDGS tended to spend less time at the bunk per visit, which could be associated with changes in ruminal fermentation and digestion. More research is needed to better understand the effects that changes in feeding behavior induced by feeding different feeds have on growth performance.

In conclusion, utilizing barley, in comparison with corn, in finishing cattle diets decreased dry-matter intake, increased gain:feed and altered feeding behavior in cattle consuming a 90 percent concentrate diet without affecting carcass mass or quality. Utilizing a lower-oil-concentration DDGS did not significantly impact performance or carcass quality.

We found a tendency for oil concentration of DDGS to alter

feeding behavior; however, this did not seem to influence performance. Therefore, utilizing DDGS with a lower oil concentration in finishing diets likely will not greatly affect performance or carcass quality of finishing cattle.

Acknowledgments

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Table 3. Effects of grain source and oil level of dried distillers grains plus solubles on feeding behavior in finishing cattle.

	Treatment							
	Rolled Corn		Rolled Barley					
Item	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-fat DDGS	SEM[a]	Grain	DDGS	Grain*DDGS
Initial weight, lb.	937	939	952	937	15.6	0.74	0.66	0.57
Final weight, lb.	1,464	1,482	1,479	1,462	19.4	0.89	0.94	0.34
Average daily gain, lb./day	3.95	4.06	4.01	3.97	0.088	0.79	0.68	0.41
Dry matter intake, lb.	26.7	26.2	24.9	24.9	0.49	0.002	0.85	0.75
Gain:feed	0.149	0.154	0.161	0.159	0.0034	0.01	0.62	0.24
Hot carcass weight, lb.	904	908	897	897	13.9	0.52	0.82	0.85
Marbling score[b]	508	477	475	483	26.8	0.62	0.67	0.46
Rib-eye area, in.^{2}	13.7	14.2	13.8	13.6	0.05	0.55	0.59	0.26
12th rib fat, in.	0.539	0.500	0.504	0.528	0.0164	0.96	0.86	0.45
Kidney, pelvic, and heart fat, %	1.84	1.82	1.83	1.79	0.042	0.56	0.53	0.84

[a]Standard error of the mean (n = 20).
[b]400 to 499 = small, 500 – 599 = modest.

Table4. Effects of grain source and oil level of dried distillers grains plus solubles on feeding behavior in finishing cattle.

	Treatment							
	Rolled Corn		Rolled Barley					
Item	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-fat DDGS	SEM[a]	Grain	DDGS	Grain*DDGS
Events, per day								
Visits	27.1	28.6	23.1	26.2	1.6	0.05	0.16	0.60
Meals	7.35	7.62	7.61	7.55	0.257	0.71	0.68	0.53
Time eating, min.								
Per visit	3.46	3.18	4.21	3.55	0.248	0.03	0.06	0.44
Per meal	12.67	11.30	11.68	11.88	0.561	0.71	0.29	0.17
Eating rate, lb.								
Per visit	1.03	0.99	0.20	1.00	0.069	0.17	0.09	0.20
Per meal	3.73	3.53	3.37	3.35	0.146	0.06	0.42	0.53
Per min	0.300	0.313	0.298	0.287	0.0104	0.17	0.95	0.25

[a]Standard error of the mean (n = 20).

Effect of grain type and dried distillers grain with solubles oil concentration on site of digestion

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The objective of this experiment was to determine the effects of grain type (corn vs. barley) and oil concentration of dried distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent ether extract) on site of digestion. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not have an influence on site of digestion of nonlipid nutrients in finishing cattle.

Summary

Eight Holstein steers (1,579 ± 137 pounds) were used in a 4 x 4 Latin Square design consisting of four periods and four dietary treatments, with two steers assigned per treatment per period to determine the impact of grain type (corn vs. barley) and DDGS oil concentration (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on intake and total-tract digestibility. Apparent ruminal dry-matter and intestinal digestibility as a percentage of intake decreased ($P \leq 0.03$) in steers fed corn-based diets. We found no difference in total-tract dry-matter digestibility between grain types. No effects on dry-matter intake or digestibility were observed between steers fed low- and moderate-oil concentrations of DDGS. Starch intake was greater ($P = 0.01$) in steers fed corn-based diets, and total-tract starch digestibility was greater ($P = 0.01$) in steers fed barley-based diets. We found no effects on intake or digestibility of starch between low- and moderate-oil concentrations of DDGS. Intake of total lipids increased ($P < 0.001$) in steers fed corn diets as well as in steers fed diets with moderate oil of DDGS. Apparent ruminal lipid digestibility increased ($P = 0.02$) in steers fed moderate-oil DDGS, while intestinal lipid digestibility as a percent of intake was increased ($P = 0.04$) in steers fed low-oil DDGS. No differences were found in lipid apparent ruminal digestibility or lipid intestinal digestibility between grain types. Total-tract lipid digestibility was increased ($P < 0.001$) in steers fed moderate-oil DDGS. In summary, utilizing barley, as compared with corn, in finishing diets increases total-tract starch digestion, and decreasing the oil concentration of DDGS had no effect on site of digestion or total-tract digestibility of dry matter, crude protein and starch of the diets, although lipid digestibility was greater in steers fed moderate-fat DDGS. Therefore, utilizing low-oil DDGS in finishing diets may not affect digestibility of nonlipid nutrients in finishing cattle.

Introduction

Feed costs represent the largest expense in beef production. Grain type, specifically feeding barley vs. corn, can result in differences in digestibility and performance (Gozho and Mutsvangwa, 2008). Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein et al., 2008) and may influence growth performance differently, depending on grain source and processing.

The beef cattle National Research Council (NRC, 1996) reports DDGS having 11 percent ether extract on a dry-matter basis. This concentration has changed, however, as the ethanol industry has evolved and extracts more oil from the corn, resulting in DDGS with a lower oil content of approximately 4 to 5 percent. This raises the question of what happens to the digestibility of this low-oil DDGS product.

We hypothesized that grain type and DDGS oil concentration would have an effect on site of digestion. Our objectives were to determine the effect of grain type and DDGS oil concentration on ruminal, intestinal and total-tract digestibility.

Experimental Procedures

All animal care and handling procedures were approved by the NDSU Animal Care and Use Committee. Eight Holstein steers (1,579 ± 137 pounds) were used in a 4 x 4 Latin Square design consisting of four periods and four dietary treatments, with two steers assigned per treatment per period to determine the impact of grain type (corn vs. barley) and DDGS oil concentration (DDGS; moderate = 7.9 percent vs. low = 4.5 percent; Tables 1 and 2) on intake and total tract digestibility.

Steers were housed in individual tie stalls in a temperature-controlled environment at the North Dakota State University Animal

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Nutrition and Physiology Center. Dietary treatments were offered to ensure ad libitum intake and 6 percent feed refusal daily. Treatments were 1) corn with moderate-fat DDGS, 2) corn with low-fat DDGS, 3) barley with moderate-fat DDGS and 4) barley with low-fat DDGS.

Steers were adapted from a high-forage diet to a high-concentrate diet during a 21-day period. Then steers were adapted to their respective treatments during a seven-day period followed by a seven-day sample (feed, feed refusals, feces, and duodenal and ileal digesta) collection period. Finally, a 10-day transition period occurred in which steers were transitioned to their next treatment diet.

Data were analyzed as a replicated 4 x 4 Latin Square, with a 2 x 2 factorial arrangement of treatments using generalized least square means mixed procedure in SAS. A *P*-value of less than or equal to 0.05 was considered a significant difference, while a *P*-value of greater than 0.05 but less than 0.10 was considered a tendency.

Table 1. Dietary composition.

	Corn		Barley	
Dietary Component, % of dry matter	**Low-fat DDGS**	**Moderate-fat DDGS**	**Low-fat DDGS**	**Moderate-fat DDGS**
Rolled corn	50	50	–	–
Rolled barley	–	–	50	50
DDGS	25	25	25	25
Corn silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	–	–
Salt	0.05	0.05	0.05	0.05
Vitamin premix[1]	0.01	0.01	0.01	0.01
Mineral premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground corn	2.46	2.46	2.61	2.61
Chromium oxide	0.25	0.25	0.25	0.25

[1]Contained 48,510 kilo International Units per kilogram (kIIU/kg) vitamin A and 4,630.5 kIU/kg vitamin D.
[2]Contained 3.62 percent calcium, 2.56 percent copper,16 percent zinc, 6.5 percent iron, 4 percent manganese, 1.050 milligrams per kilogram (mg/kg) iodine and 250 mg/kg cobalt.
[3]Contained 176.4 grams (g) monensin/kg premix.
[4]Contained 88.2 g tylosin/kg premix.

Table 2. Analyzed nutrient concentration of diets.

	Rolled Corn		Rolled Barley	
Dietary Component, % of dry matter	**Low-fat DDGS**	**Moderate-fat DDGS**	**Low-fat DDGS**	**Moderate-fat DDGS**
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid detergent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

Results and Discussion

We found no differences in dry-matter intake between grain types (Table 3). Apparent ruminal dry-matter digestibility decreased ($P = 0.02$) in steers fed corn-based diets. Intestinal dry-matter digestibility as a percent of intake decreased ($P < 0.03$) in steers fed barley-based diets.

We observed no difference in total-tract dry-matter digestibility between grain types. No effects on dry-matter intake or digestibility were observed between steers fed low- or moderate-oil concentrations of DDGS. We also found no differences in crude protein intake between grain types.

We observed a tendency for apparent ruminal crude protein digestibility (percent of intake) to decrease ($P = 0.06$) in steers fed corn-based diets. We found a tendency ($P = 0.09$) for intestinal crude protein digestibility as a percent of intake to decrease in steers fed barley-based diets.

No differences were found in total-tract crude protein digestibility between grain types. No effects were found on crude protein intake or digestibility between steers fed low- or moderate-oil concentrations of DDGS.

Starch intake was greater ($P = 0.01$) in steers fed corn-based diets than in steers fed barley-based diets. Apparent ruminal starch digestibility and intestinal digestibility as a percent of intake did not differ between grain types. Total-tract starch digestibility decreased ($P = 0.01$) in corn-based diets.

We found no effects on intake or digestibility of starch between low- and moderate-oil concentrations of DDGS. Intake of total lipids increased ($P < 0.001$) in steers fed

Table 3. Effects of grain source and oil level of dried distillers grains plus solubles on nutrient intake and site of digestion.

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-Fat DDGS	*P*-value SEM	Grain	DDGS	Grain*DDGS
Intake, lb.								
Dry matter	33.3	31.5	32.4	32.6	1.34	0.99	0.46	0.37
Crude protein	4.94	4.83	4.87	4.85	0.218	0.89	0.64	0.76
Starch	17.9	16.1	14.9	15.0	0.767	0.01	0.28	0.21
Lipid	1.35	1.69	0.96	1.47	0.050	<0.001	<0.001	0.03
Digestiblity, % of intake								
Apparent ruminal								
Dry matter	46.2	43.1	51.7	53.7	3.22	0.02	0.85	0.37
Crude protein	-18.6	-19.4	-1.15	-7.2	9.32	0.06	0.60	0.67
Starch	88.3	93.3	90.9	91.8	1.8	0.78	0.11	0.26
Lipid	-58.8	-45.3	-75.1	-22.5	14.24	0.82	0.02	0.13
Intestinal								
Dry matter	33.2	35.6	26.7	25.8	3.16	0.01	0.78	0.53
Crude protein	96.6	96.8	80	87.4	9.32	0.09	0.55	0.55
Starch	7.99	3.21	7.58	7.01	1.803	0.36	0.14	0.24
Lipid	140	130	152	107	13.7	0.68	0.04	0.15
Total Tract								
Dry matter	79.5	78.7	78.6	79.1	0.94	0.78	0.86	0.45
Crude protein	78.7	77.6	78.8	79.8	1.08	0.3	0.94	0.33
Starch	96.6	96.9	98.3	98.8	0.7	0.01	0.49	0.93
Lipid	81.1	85.5	77.5	84.4	1.32	0.07	<0.001	0.25

[a]Standard error of the mean (n = 8).

corn diets as well as in steers fed diets with moderate oil of DDGS. Apparent ruminal lipid digestibility increased ($P = 0.02$) in steers fed moderate oil DDGS, while intestinal lipid digestibility as a percent of intake was increased ($P = 0.04$) in steers fed low-oil DDGS.

No differences were found in lipid apparent ruminal digestibility or lipid intestinal digestibility between grain types. Total-tract lipid digestibility was increased ($P < 0.001$) in steers fed moderate-oil DDGS and tended ($P = 0.07$) to increase in steers fed corn-based diets.

Little is known about how the oil concentrations of DDGS affect the site of digestion in finishing cattle. Jolly-Breithaupt et al. (2015) reported a decrease in total-tract digestibility of fat in de-oiled condensed distillers solubles vs. normal condensed distillers solubles, similar to what we observed in our study.

This might indicate that the animal utilizes more of the lipid from the moderate-oil DDGS than the low-oil DDGS, which supports the theory that the lipids in the lower-oil-concentration products may not be as digestible. This theory needs to be studied further to know the full effects and implications that can be associated with feeding ethanol coproducts with lower-oil concentrations.

In conclusion, utilizing barley, as compared with corn, in finishing diets increases total tract starch digestion, which may increase the amount of volatile fatty acids and glucose available to the animal and potentially provide more energy to the animal, resulting in improved growth performance.

Also, decreasing the oil concentration of DDGS had no effect on the site of digestion or total-tract digestibility of dry matter, crude protein or starch of the diets. Therefore, utilizing low-oil DDGS in finishing diets may not affect digestibility of nonlipid nutrients in finishing cattle.

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The influence of dry-rolled corn particle size and dried corn distillers grains plus solubles inclusion levels on rumen pH, ammonia and VFA concentration, total in vitro ruminal gas production and enteric methane emission

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The objectives of this study were to determine the influence of dry-rolled corn particle size and dried distillers grains with solubles (DDGS) inclusion level on ruminal pH, ammonia (NH3) and volatile fatty acid (VFA) concentrations and in vitro ruminal gas production and methane (CH4) emission. No differences in rumen pH were seen among treatments. Rumen ammonia was greater in steers receiving 20 percent DDGS, while steers fed fine-rolled corn had greater concentrations of butyric acid than steers fed coarse-rolled treatments. Total gas production and methane concentration were unaffected by treatment.

Summary

Eight cannulated Holstein steers (1,159 ± 8 pounds) were used in a 4 x 4 Latin square design to examine the impact of coarse (2.5 millimeter [mm]) vs. fine-rolled corn (1.7 mm) and 20 vs. 40 percent DDGS inclusion on ruminal pH, ammonia and VFA concentrations, in vitro ruminal gas production and enteric methane emission. Steers were housed in individual tie stalls (3.3 by 7.2 feet) in a temperature-controlled environment at the NDSU Animal Nutrition and Physiology Center. Dietary treatments (Table 1) were offered for ad libitum intake and consisted of 1) 65 percent coarse-rolled corn and 20 percent DDGS, 2) 45 percent coarse-rolled corn and 40 percent DDGS, 3) 65 percent fine-rolled corn and 20 percent DDGS and 4) 45 percent fine-rolled corn and 40 percent DDGS. Steers were provided experimental diets for 14 days (seven days of diet adaptation and seven days of data collection). Results indicate no differences among dietary treatments in overall rumen pH. The concentration of NH_3 was greater (P = 0.02) in cattle consuming 20 percent DDGS. Butyric acid concentration was greater (P = 0.02) in cattle fed fine-rolled corn, while no other VFAs differed among treatments. No differences were observed in the amount and rate of total gas produced or concentration of methane emitted.

Introduction

Ethanol is a commonly produced alternative fuel that largely is manufactured using corn grown in the Midwestern U.S. The production of ethanol also supplies a byproduct known as dried corn distillers grains plus solubles (DDGS), which provides a valuable feed source for ruminants. Ensuring the amount of corn grown to produce ethanol also allows much of the crop to be fed to cattle, which has proven to be extremely beneficial in regards to animal efficiency and environmental sustainability.

Methane is a greenhouse gas produced during enteric fermentation of feed in ruminants and can be influenced by feed intake, type of carbohydrate in the diet, feed processing methods and changes in ruminal microflora. The high levels of starch found in corn-based rations have been shown to be beneficial to the environment because cattle fed these diets produce less methane due to reduced hydrogen production in the rumen. In addition, a greater feed efficiency provides a shorter time to market, allowing less opportunity of methane emission to occur (Swanson et al., 2014).

Unfortunately, in regard to distillers grains and methane production, variable results have been observed. For example, distillers grains contain greater concentrations of fat and fiber. The fat found in these byproducts may reduce or eliminate protozoa as well as methanogenic bacteria in the rumen, helping mitigate CH4 emissions by altering the hydrogen sink through bio-hydrogenation via propionate production (Massé et al., 2014). Fiber, however, is concentrated nearly three-fold during ethanol production and possesses greater methanogenic potential than that of starch (Behlke et al., 2008).

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While a diet containing corn and DDGS offers a desirable nutrient profile, careful consideration must be taken when formulating such rations. Corn distillers grains commonly are mixed with cattle rations in ranges from 10 to 50 percent (dry-matter [DM] basis), depending on the goal of supplementation. When used as a protein source, 10 to 15 percent inclusion usually is the most desirable, while an addition of 20 to 30 percent is more common when used as an energy source, with approximately 40 to 50 percent generally the upper limit (Klopfenstein et al., 2008).

The available information on particle size reduction of rolled corn is limited, but Loe et al. (2006) reported an increase in intake when offering finely vs. coarsely rolled corn. Grain particle size, level of rumen carbohydrate fermentation and level of neutral detergent fiber (NDF) also will impact rumen pH and may cause acidosis. With this in mind, developing feeding strategies is important to determine the optimum corn processing method and DDGS inclusion rates to obtain the greatest benefit from each ration.

Experimental Procedures

All procedures involving animals were approved by the NDSU Animal Care and Use Committee. Eight cannulated Holstein steers (1,159 ± 8 pounds) were used in a 4 x 4 Latin square-designed experiment to examine the impact of dry-rolled corn processing and DDGS inclusion rate on ruminal pH, ammonia concentration, VFA profile, ruminal gas production and in vitro enteric methane emission in cattle.

Steers were housed in individual stalls in a temperature-controlled environment at the NDSU Animal Nutrition and Physiology Center. Dietary treatments (Table 1) were offered to ensure ad libitum intake and approximately 6 percent feed refusal daily. Treatments consisted of 1) coarse-rolled (2.5 millimeters [mm]) and 20 percent DDGS, 2) coarse-rolled corn and 40 percent DDGS, 3) fine-rolled corn (1.7 mm) and 20 percent DDGS and 4) fine-rolled corn and 40 percent DDGS.

Diets were formulated to meet or exceed National Research Council (NRC) recommendations for degradable intake protein (DIP), metabolizable protein (MP), vitamins and minerals (NRC, 1996). Before the initiation of the experiment, steers were adapted to a high-grain diet during a period of 21 days. A preliminary period of seven days on the animals' respective treatment preceded seven days of sample collection for each period. This was followed by a three-day rest period in which steers were offered an intermediate diet to allow all animals to return to a basal level.

Ruminal pH was determined using a wireless pH sensor (Kahne Ltd., Auckland, New Zealand), with measurements taken every five minutes from days 3 to 5 of the collection period. Sensors were calibrated with 7 and 4 pH solutions before each period and were inserted manually into the rumen and placed in the liquid phase of the ventral sac.

Ammonia and VFA concentrations were quantified using a subsample of approximately 200 milliliters (mL) of rumen fluid collected from days 3 to 5 (at 2 a.m., 8 a.m., 2 p.m. and 8 p.m. on day 3; 4 a.m., 10 a.m., 4 p.m. and 10 p.m.

Table 1. Dietary composition and analyzed nutrient concentration of diets (DM basis).

	Coarse-rolled corn		Fine-rolled corn	
Dietary component, % of DM	20% DDGS	40% DDGS	20% DDGS	40% DDGS
Coarse-rolled corn	65.0	45.0	–	–
Fine-rolled corn	–	–	65.0	45.0
Dried corn distillers grains with solubles	20.0	40.0	20.0	40.0
Grass-legume hay	5.0	5.0	5.0	5.0
Corn silage	5.0	5.0	5.0	5.0
Limestone	1.56	1.90	1.56	1.90
Urea	0.85	–	0.85	–
Salt	0.20	0.20	0.20	0.20
Vitamin premix	0.01	0.01	0.01	0.01
Trace mineral premix	0.05	0.05	0.05	0.05
Rumensin/Tylan premix	0.03	0.03	0.03	0.03
Fine-ground corn	2.05	2.56	2.05	2.56
Chromium oxide	0.25	0.25	0.25	0.25
Feed Analysis				
Dry matter, % of as fed	82.2	82.9	82.4	83.6
Organic matter, % of DM	94.9	93.7	95.1	93.8
Crude protein, % of DM	16.3	17.9	15.9	17.4
Neutral detergent fiber, % of DM	27.1	30.2	24.5	30.5
Acid detergent fiber, % of DM	9.02	11.1	8.47	11.0
Fat, % of DM	4.45	4.92	3.77	4.86
Calcium, % of DM	0.794	0.929	0.757	1.00
Phosphorus, % of DM	0.408	0.537	0.409	0.538

on day 4; and 6 a.m., noon, 6 p.m. and midnight on day 5 to represent every other hour in a 24-hour cycle.

After collection, subsamples were taken to the lab and stored frozen (minus 20 C) until the end of the collection period, at which point they were thawed, equally composited and used for ammonia and VFA analysis.

Gas production was determined using Ankom's gas pressure flasks, wireless system and analysis software (Gas Pressure Monitor, Ankom Technology Corp., Macedon, N.Y.). After the addition of ruminal fluid and buffer, the vials were flushed with carbon dioxide. The flasks then were screwed tightly to the pressure monitor caps and placed in an oscillating water bath (Northwest Scientific Incorporated) at 39 C for 24 hours, with the oscillation set at 125 revolutions per minute.

Data obtained from this system were converted from pressure units to volume units (mL) using the formula reported by López et al. (2007). Gas production was examined on days 1 and 7 of the collection period for approximately 24 hours.

Data were analyzed as a 2 × 2 factorial using the Mixed procedure of SAS (SAS Inst. Inc., Cary, N.C.). The model included the effects of animal, period, degree of dry-roll processing (coarse vs. fine), DDGS inclusion (20 vs. 40 percent DDGS) and the interaction between the degree of dry-roll processing × DDGS inclusion rate. Statistical significance was declared at $P \leq 0.05$.

Results and Discussion

No differences were observed in ruminal pH among dietary treatments ($P > 0.05$). Rumen NH3 was increased ($P = 0.02$) in diets containing 20 percent DDGS. Urea was added to rations with 20 percent DDGS to meet the NRC's DIP requirement. This urea likely was rapidly hydrolyzed to ammonia by bacterial urease. Volatile fatty acids were generally unaffected by dietary treatment; however, the level of butyric acid was greater ($P = 0.02$) in cattle consuming fine-rolled corn (Table 2).

In vitro gas production and enteric methane emission were not different among treatments ($P \geq 0.44$; Table 3). Acetate has been shown to increase methane production, while propionate has the opposite effect (Moss et al., 2000). As no changes to the acetate:propionate ratio were found in the current study, we were not surprised that methane concentrations did not differ between the variable rations.

Dietary treatments did not affect rumen pH or VFA concentration in a way that would affect gas production or enteric methane emission significantly. This would indicate that the digestive tracts of the cattle tested were not strongly influenced by the degree of corn processing or inclusion rate of DDGS.

Table 2. Ruminal pH and VFA profiles of steers fed coarse- vs. fine-rolled corn with 20 vs. 40 percent dried distillers grains with solubles.

	Coarse-rolled corn		Fine-rolled corn			*P*-Values			
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	Distiller's	Corn * Distiller's	Hour
Rumen pH	5.96	5.68	5.88	5.70	0.134	0.85	0.12	0.72	<0.001
Minimum	5.31	5.04	5.22	5.10	0.197	0.94	0.32	0.68	-
Maximum	6.69	6.77	7.04	6.78	0.214	0.44	0.69	0.49	-
Time < 5.5, h/d	3.02	11.1	4.66	5.82	2.125	0.40	0.07	0.14	-
Rumen NH_3, mM	13.3	10.4	13.4	9.8	13.31	0.87	0.02	0.80	<0.001
Total VFA, mM	184	183	197	198	9.7	0.14	0.99	0.91	<0.001
				VFA, mol/100 mol					
Acetic	33.1	34.1	32.0	32.7	1.44	0.41	0.56	0.92	0.18
Propionic	22.0	24.7	25.2	22.2	2.19	0.87	0.96	0.20	<0.001
Isobutyric	2.79	2.77	2.48	2.58	0.159	0.12	0.82	0.73	<0.001
Butyric	17.4	15.3	19.6	21.4	1.68	0.02	0.93	0.24	0.45
Isovaleric	16.5	14.7	11.9	10.9	2.07	0.06	0.50	0.84	<0.001
Valeric	8.24	8.51	8.83	10.2	0.642	0.10	0.23	0.42	0.05
Acetate:Propionate	1.65	1.52	1.39	1.70	3.4	0.84	0.66	0.28	0.001

[a]Data are presented as least square means per treatment ± SEM, n = 8

Table 3. Gas production and methane emission of steers fed coarse- vs. fine-rolled corn with 20 vs. 40 percent dried distillers grains with solubles.

	Coarse-rolled corn		Fine-rolled corn			*P*-Values		
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	Corn * Distiller's	Distiller's
Gas production, mLs								
A	195	176	183	198	30.5	0.86	0.96	0.56
C	0.075	0.063	0.082	0.094	0.0234	0.38	0.10	0.55
d	0.019	0.128	-0.068	-0.132	0.1013	0.09	0.82	0.38
L	1.19	1.07	1.65	0.804	0.2890	0.71	0.08	0.17
Methane, % of gas	10.8	12.1	11.5	12.6	12.64	0.68	0.44	0.94

[a]Data are presented as least square means per treatment ± SEM, n = 4 per treatment. A = asymptote, C = rate, d = degradation rate, L = Lag

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Effects of maternal nutrition on fructose and expression of the fructose transporter *GLUT5* in bovine tissues and fluids from days 16 to 50 of gestation

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The objectives of this study were to determine the effects of maternal nutritional status on fructose concentration in maternal and fetal fluids and the mRNA expression of the fructose transporter GLUT5 in maternal and fetal tissues on days 16, 34, and 50 of gestation. The expression of GLUT5 was not influenced by maternal nutritional status; however, the concentration of fructose in amniotic fluids was influenced by day of gestation and maternal nutritional status.

Summary

We tested the hypothesis that the concentration of fructose in maternal and fetal fluids, and expression of *GLUT5* in utero-placental tissues, would be influenced by day of gestation and maternal nutritional status. Angus-cross heifers (n = 46, about 15 months of age; average initial body weight [BW] = 716 pounds) were estrus synchronized, bred via artificial insemination (AI) and ovariohysterectomized on day 16, 34, or 50 of their respective gestations (n = 6 to 9/day). Some heifers (n = 6) were not bred to serve as nonpregnant (NP) controls and were ovariohysterectomized on day 16 of the synchronized estrous cycle. Immediately after AI, heifers were assigned randomly to one of two treatment groups: Control (CON) received 100 percent of the National Research Council (NRC, 2000) requirements to gain 1 pound per heifer daily, and restricted (RES) received only 60 percent of the CON diet. Tissues collected included: caruncular tissue from the uterine horn ipsilateral to the corpus luteum (PC), from the uterine horn contralateral to the corpus luteum (NPC), inter-caruncular tissue from the uterine horn ipsilateral to the corpus luteum (PIC) and from the uterine horn contralateral to the corpus luteum (NPIC), as well as chorioallantoic tissue (FM). Fluids collected included: maternal serum, histotroph collected from horn ipsilateral to the corpus luteum (P histotroph) and from the horn contralateral to the corpus luteum (NP histotroph), allantoic fluid and amniotic fluid. Fetal membranes, allantoic fluid and amniotic fluid were not collected in NP heifers due to the lack of the presence of fetal tissues and fluids in NP animals. Serum fructose concentrations were greater ($P < 0.01$) in nonpregnant heifers, compared with pregnant heifers. Concentrations of fructose in P histotroph and NP histotroph were greater ($P < 0.01$) on day 50, compared with days 16 and 34. Amniotic fluid was influenced by a day × treatment interaction, with day 34 RES being greater ($P = 0.04$) than day 50 CON and RES heifers. Expression of *GLUT5* was greater on day 34 in PC ($P = 0.02$) and NPC ($P < 0.01$). In FM, day 16 was greater ($P = 0.04$), compared with days 34 and 50 of gestation. These results indicate that the expression of *GLUT5* is not influenced by maternal nutritional status; however, concentrations of fructose in amniotic fluids are influenced by maternal nutritional status and day of gestation.

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Introduction

First-service AI rates in beef cows are approximately 90 percent (Bridges et al., 2013); however, by day 30, only 50 to 60 percent are viable embryos in beef cows. Furthermore, fetal growth is vulnerable to maternal dietary nutrient deficiencies during the first trimester of gestation (Wu et al., 2004).

Currently, fetal undernutrition occurs in grazing livestock worldwide (Wu et al., 2004). Early in gestation, trans-placental exchange has yet to be established; therefore, nutrients must be transported to the conceptus via nutrient transporters in the uterus and developing placenta, such as the fructose transporter *GLUT5*.

Fructose is the most abundant hexose sugar in fetal blood and fetal fluids of ungulates (Kim et al., 2012), and maternal undernutrition has been implicated in altered fructose transport (Zhang et al., 2015). Having an understanding of how maternal nutrition affects the mRNA expression and supply of fructose to the conceptus could lead to future research that may directly influence the flux of fructose from

the maternal to fetal systems in early gestation.

This research utilized a newly developed technique to ovariohysterectomize cattle without slaughter to allow for an accurate analysis of fetal growth and development, as well as utero-placental tissues and fluids on days 16, 34 and 50 of early gestation in beef heifers.

In this study, we tested the hypothesis that the concentration of fructose in maternal and fetal fluids, along with the relative mRNA expression of *GLUT5* in maternal and fetal tissues, would be influenced by day of gestation and maternal nutritional status.

Experimental Procedures

All animal procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee (IACUC numbers A14053 and A16049). Crossbred Angus heifers (n = 49, about 15 months of age; average initial BW = 716 pounds) were exposed to the 5-day CO-Synch + CIDR estrus synchronization protocol. Six heifers were not inseminated to serve as nonpregnant controls, but received an ovariohysterectomy on day 16 of the subsequent synchronized estrous cycle. The remaining heifers (n = six to nine/day of gestation/treatment) were bred by AI to a common sire at 12 hours after observed estrus and ovariohysterectomized at days 16, 34, and 50 of gestation.

Immediately following the ovariohysterectomy, maternal caruncular (PC) and inter-caruncular tissue (PIC) were collected from the uterine horn ipsilateral to the corpus luteum, along with caruncular (NPC) and inter-caruncular tissue (NPIC) collected from the uterine horn contralateral to the corpus luteum. Also, fetal membranes (chorioallantois) were obtained.

Fetal membranes were collected only on days 16, 34, and 50 of gestation due to nonpregnant controls not having fetal membranes. All tissues were frozen immediately in liquid nitrogen-cooled isopentane and stored at minus 112 F.

Serum samples were obtained via jugular venipuncture on the day of ovariohysterectomy, and blood constituents were separated by centrifugation and stored at minus 20 F. Histotroph was obtained from the uterine horn ipsilateral to the corpus luteum (P histotroph) and from the uterine horn contralateral to the corpus luteum (NP histotroph) for pregnant and NP heifers.

Allantoic and amniotic fluids were collected on days 34 and 50 of gestation due to the limited presence of fetal fluids on day 16. Histotroph, allantoic and amniotic were snap-frozen in liquid nitrogen-cooled isopentane and stored at minus 20 F immediately after being obtained.

Fructose concentrations among fluid samples were determined by utilizing a colorimetric assay kit. Expression of *GLUT5* was determined by first isolating and purifying RNA from collected tissue samples, followed by real-time quantitative PCR (qPCR) to determine differences in mRNA expression of the fructose transporter in each tissue relative to a NP endometrium sample.

Results and Discussion

Concentrations of fructose in maternal serum were greater ($P < 0.01$) in NP heifers, compared with pregnant heifers (Table 1). In P histotroph, fructose concentrations were greater ($P < 0.01$) on day 50, compared with days 16 and 34 (1.34, 0.18, and 0.63 millimolar [mM], respectively; SEM = 0.22).

Fructose concentrations also were greater ($P < 0.01$) on day 34 + 50, when compared with day 16 (Table 1). In NP histotroph, day 50 (0.97 mM) was greater ($P = 0.01$) than days 16 and 34 (0.10, and 0.36 mM, respectively; SEM = 0.20).

Additionally, fructose concentrations were greater ($P = 0.02$) in NP histotroph on days 34 + 50, compared with day 16 (Table 1). Fructose concentrations in amniotic fluid were influenced by a day × treatment interaction, where day 34 RES (3.60 mM) was greater ($P = 0.04$) than the day 50 CON and RES treatments (2.57, and 1.55 mM, respectively; SEM = 0.29). Furthermore, day 34 and 50 CON (3.30 and 2.57 mM, respectively) were greater than day 50 RES (1.55 mM; SEM = 0.29).

In PC, a main effect of day was observed; day 34 was greater (44.40-fold greater than NP; $P = 0.02$; Table 2) than day 16 and day 34 (4.79 and 6.49-fold greater than NP, respectively; SEM = 10.88).

In NPC, the expression of *GLUT5* was greater ($P < 0.01$) on days 34 and 50, compared with day 16 (44.19, 36.60 and 3.22-fold greater than NP, respectively; Table 2). Furthermore, the relative expression of *GLUT5* in pregnant heifers was greater ($P = 0.02$), compared with NP heifers.

A main effect of day was observed in FM where day 16 was greater (P = 0.04) than day 50 (80.17 and 27.39, respectively; SEM = 13.82; Table 2). Also, day 16 was greater, compared with day 34 + 50 ($P = 0.03$). The results show that as pregnancy advances, fructose and mRNA expression of *GLUT5* changes significantly among various tissues and fluids measured in this study.

The low fructose concentration found in maternal serum is expected because fructose is not a main physiological fuel for the dam. The cause of the NP heifers having a greater fructose concentration in serum samples could be due to fructose being utilized by the conceptus. The greater mRNA expression of *GLUT5* in pregnant heifers, compared with NP heifers in NPC, may

be explained by the conceptus's increasing need of fructose, which is partially supplied by maternal blood concentrations.

The consistent concentration of fructose in P histotroph and NP histotroph may be explained by the availability of fructose for transport into the uterine lumen. Fructose concentrations were found to be less than 1 mM in maternal circulation; therefore the total available fructose to be transported to the conceptus from the maternal system is low.

The placenta is a site of the conversion of glucose to fructose (Kim et al., 2012), which plays a role in the consistently high fructose concentration and the increase in fructose concentration found in fetal fluids compared with maternal fluids. This conversion of glucose to fructose indicates the essentiality of fructose for the growth and development of the conceptus. Furthermore, this consistently high concentration could be explained by the conceptus's hypoxic environment.

Vascularization of the fetal membranes is limited up to day 35 of gestation, which results in an oxygen-poor environment for the conceptus due to a lack of a transport of oxygen via a shared blood supply. Glucose thrives in a hyperoxic environment, while fructose thrives in a hypoxic environment.

This information is emphasized by our observed results in fetal fluids and FM. Fructose concentration decreased from day 34 to 50 (numerically in allantoic), while relative ex-

Table 1: Fructose concentrations mM in Serum (maternal serum), P histotroph (histotroph from the horn ipsilateral to the corpus luteum), NP histotroph (histotroph from the horn contralateral to the corpus luteum), Allantoic (allantoic fluid) and Amniotic (amniotic fluid) on days 16, 34 and 50 of gestation.

									P - values[2]					
				Day of Gestation[1]					NP vs. P	16 vs. 34 + 50	34 vs. 50			Day × Trt
Fluid[3]	Trt[4]		NP	16	34	50	Trt[5]	SEM[6]				Day	Trt	
Serum	CON		0.13	0.08	0.075	0.071	0.07	0.016	< 0.01	0.79	0.92	0.97	0.35	0.82
	RES		–	0.08	0.085	0.094	0.09							
		Day[7]		0.08	0.080	0.083								
P Histotroph	CON		0.14	0.12	0.58	1.03	0.58	0.310	0.09	< 0.01	0.03	< 0.01	0.27	0.65
	RES		–	0.23	0.69	1.64	0.86							
		Day		0.18[h]	0.63[h]	1.34[g]								
NP Histotroph	CON		0.01	0.11	0.45	0.67	0.41	0.277	0.13	0.02	0.02	0.01	0.58	0.33
	RES		–	0.08	0.26	1.27	0.54							
		Day		0.10[h]	0.36[h]	0.97[g]								
Allantoic	CON		–	–	5.53	5.07	5.30	0.76	–	–	0.95	0.90	0.44	0.64
	RES		–	–	4.56	4.83	4.69							
		Day		–	5.04	4.95								
Amniotic	CON		–	–	3.30[ab]	2.57[b]	2.94	0.29	–	–	–	< 0.01	0.21	0.04
	RES		–	–	3.56[a]	1.55[c]	2.55							
		Day		–	3.43	2.06								

[1]Number of days after AI.

[2]Probability values for the effect of day, treatment and day × treatment on the concentration of fructose. Contrast statements comparing pregnant vs. nonpregnant concentration (NP vs. P), day pre-implantation vs. day post-implantation (day 16 vs. 34 + 50) and day post-attachment comparison (34 vs. 50).

[3]Fluids evaluated for fructose concentrations mM include maternal serum (Serum), histotroph flushed from the horn ipsilateral to the corpus luteum (P histotroph), histotroph flushed from the horn contralateral to the corpus luteum (NP histotroph), allantoic fluid (Allantoic) and amniotic fluid (Amniotic).

[4]CON = Heifers fed a TMR that meets 100 percent of NRC requirements to gain 0.45 kg daily. RES = Heifer restricted to 60 percent of CON diet.

[5]Mean fructose concentration of treatment groups across day of gestation within fluid.

[6]Average SEM for day × treatment interaction. Day 16 CON n = 7, day 16 RES n = 7, day 34 CON n = 6, day 34 RES n = 9, day 50 CON n = 7, day 50 RES n = 7.

[7]Mean fructose concentration across treatment within day of gestation.

[a-c]Means within fluid without common superscript differ in day × treatment ($P \leq 0.05$).

[g-h]Means within row without common superscript differ in main effect of day ($P \leq 0.05$).

pression of *GLUT5* decreased from day 16 to 50, indicating a decreased need of fructose transport.

These decreases could be due to vascularization intensifying after day 35, resulting in an increase in oxygen for the conceptus's environment, thereby decreasing the concentration of fructose (3.43 to 2.06 mM in amniotic fluid from day 34 to 50, respectively) and increasing the need of glucose (results from our lab not shown; 1.46 to 1.68 mM glucose in amniotic fluid from day 34 to 50, respectively).

In amniotic fluid, fructose concentrations differed between day 34 RES and day 50 CON and RES, as well as between day 50 CON and RES. We interpret these data to imply that a compensatory mechanism may be in action when examining the greater fructose concentration found in day 34 RES, compared with day 50 CON and RES.

Organogenesis takes place throughout the first 50 days of gestation, with most of the fetal organs having significantly developed by day 50. At this time, the conceptus could have a greater need of fructose. Therefore, a compensatory mechanism may have been in action, resulting in a greater amount of fructose being made available to the conceptus for day 34 RES to maintain a viable pregnancy.

Table 2: Relative mRNA expression of GLUT5 in PC (pregnant caruncle), PIC (pregnant inter-caruncle), NPC (non-pregnant caruncle), NPIC (non-pregnant inter-caruncle) and FM (fetal membranes from days 16, 34, and 50 of gestation as a fold change in relation to nonpregnant heifer samples set to 1.

									P - values[2]					
				Day of Gestation[1]					NP vs. P	16 vs. 34 + 50	34 vs. 50	Day	Trt	Day × Trt
Tissue[3]	Trt[4]		NP	16	34	50	Trt[5]	SEM[6]						
PC	CON		6.61	22.06	9.07	12.58	15.33	0.24	0.06	< 0.01	0.02	0.35	0.20	
	RES		2.98	66.74	3.91	24.54								
		Day[7]	4.79[h]	44.40[g]	6.49[h]									
PIC	CON		1.46	3.60	6.11	3.72	2.36	0.36	0.58	0.97	0.85	0.66	0.31	
	RES		3.59	3.82	1.20	2.87								
		Day	2.52	3.71	3.66									
NPC	CON		4.24	36.44	53.54	31.41	10.39	0.02	< 0.01	0.36	< 0.01	0.43	0.07	
	RES		2.21	51.93	19.66	24.60								
		Day	3.22[h]	44.19[g]	36.60[g]									
NPIC	CON		25.23	38.42	49.57	37.74	16.90	0.17	0.46	0.82	0.74	0.13	0.57	
	RES		14.29	27.02	6.99	16.10								
		Day	19.76	32.72	28.28									
FM	CON		59.78	43.59	33.40	45.59	19.54	–	0.03	0.30	0.04	0.52	0.44	
	RES		100.57	46.63	21.38	56.19								
		Day	80.17[g]	45.11[gh]	27.39[h]									

[1]Number of days after AI.

[2]Probability values for the effect of day, treatment and day × treatment on the mRNA expression of *GLUT5*. Contrast statements comparing pregnant vs. nonpregnant expression (NP vs. P), day pre-implantation vs. day post-implantation (day 16 vs. 34 + 50), and day post-attachment comparison (34 vs. 50).

[3]Tissues evaluated for mRNA expression of *GLUT5* include caruncular tissue collected from the uterine horn ipsilateral to the corpus luteum (PC), caruncular tissue collected from the uterine horn contralateral to the corpus luteum (NPC), inter-caruncular tissues collected from the uterine horn ipsilateral to the corpus luteum (PIC), inter-caruncular tissue collected from the uterine horn contralateral to the corpus luteum (NPIC), and chorioallantois (FM).

[4]CON = Heifers fed a TMR that meets 100 percent of NRC requirements to gain 0.45 kg daily. RES = Heifer estricted to 60 percent of CON diet.

[5]Mean *GLUT5* mRNA expression of treatment groups across day of gestation within tissue.

[6]Average SEM for day × treatment interaction. Day 16 CON n = 7, day 16 RES n = 7, day 34 CON n = 6, day 34 RES n = 9, day 50 CON n = 7, day 50 RES n = 7.

[7]Mean *GLUT5* mRNA expression across treatment within day of gestation.

[a-c]Means within tissue without a common superscript differ in day × treatment ($P \leq 0.05$).

[g-h]Means within row without a common superscript differ in main effect of day ($P \leq 0.05$).

When examining the greater concentrations found in day 50 CON, compared with day 50 RES, we interpret these data to imply that the conceptus could have a lower need of fructose at this time, which is supported by the decrease in fructose concentration observed from day 34 to 50 in amniotic fluid and the increased placental development and vascularization on day 34, compared with day 50.

This potential decreased need of fructose may have resulted in the lack of the aforementioned compensatory mechanism. Therefore, the greater concentration of fructose found in day 50 CON could be explained by the day 50 CON receiving 100 percent of NRC requirements, while the day 50 RES received only 60 percent of requirements.

In PC and NPC, relative *GLUT5* mRNA expression was greater on days 34 and 50, compared with day 16. We interpret these data to imply that the increase could be due to the critical period for maternal recognition (days 15 to 16) already passing (Senger, 2012), resulting in an increase in expression to compensate for the nutritional needs of the developing conceptus.

The FM had high mRNA expression of *GLUT5* relative to NP. We interpret this data to imply that the conversion of glucose to fructose may have an impact on the mRNA expression of *GLUT5* in FM.

When examining the main effect of day seen in FM, the fold change relative to NP decreases from 80.17 at day 16 to 27.39-fold greater than NP by day 50. We interpret these data to imply that sugars such as fructose are highly important in supplying energy for the elongation of the conceptus on days 12 to15 to ensure maternal recognition of pregnancy to occur by days 15 to 16 (Senger, 2012).

In conclusion, these data partially support our hypothesis that day of gestation and maternal nutritional status would impact mRNA expression of *GLUT5* in utero-placental tissues and fructose concentration among maternal and fetal fluids. In partially keeping with our hypothesis, we found that day of gestation, but not a 40 percent global nutrient restriction, affects the relative expression of *GLUT5* in PC, NPC and FM.

In addition, day of gestation, and not a 40 percent global nutrient restriction, affects fructose concentration in histotroph. Furthermore, maternal nutritional status and day of gestation affect fructose concentration in amniotic fluid.

With the establishment of these data, future research can be aimed at increasing efficiency of maternal and fetal nutrition. Specifically, providing improvements to the dam's nutrition at certain points of gestation allows the conceptus to receive an appropriate amount of fructose throughout early gestation, which it needs for proper growth and development. Applications such as this may result in increased reproductive efficiency and, ultimately, aid in supporting the increasing need of food by the growing world population.

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Effects of pre-breeding administration of injectable trace mineral supplements on subsequent reproductive performance in beef herds

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The objective of this study was to evaluate the effects of injectable trace mineral supplements administered 30 days before the start of the breeding season on reproductive performance when natural-service breeding was used. Results indicate that pregnancy rate and calving distribution were not changed when an injectable trace mineral supplement was used.

Summary

One thousand three hundred eleven commercial beef cows originating from four herds in North Dakota were stratified within herd by days postpartum, then randomly assigned to receive one of two treatments: 1) Cows received no additional treatments prior to bull turnout (CON; n = 638) or 2) Cows were administered an injectable trace mineral supplementation (60, 10 and 15 milligrams per milliliter (mg/mL) of zinc, manganese and copper as disodium EDTA chelates, and 5 mg/mL of selenium as sodium selenite) subcutaneously on day minus 30 relative to bull turnout (TM; n = 673). On the day of mineral administration, blood samples were collected immediately prior to mineral injection via jugular venipuncture in 10-mL Vacutainer tubes (BD Worldwide, Franklin Lakes, N.J.). Samples were analyzed for baseline mineral status on a subset (10 randomly selected females) of cows within each herd. Total mixed rations also were collected for the animals still in confinement prior to pasture/bull turnout. Water samples were collected from all available water sources for each herd. Herd bulls were turned out to a common pasture and remained there for the duration of the producer-defined breeding season. The presence of a viable fetus was determined at least 45 days after the conclusion of the breeding season. At parturition, birth date was recorded. We found no difference ($P = 0.41$) in the proportion of females that became pregnant between treatments. Weaning weights of calves on the side of cows receiving treatments also were similar ($P = 0.90$). At calving, date of birth in the calving season was not different ($P = 0.99$) for those calves born from TM cows or control cows. When evaluating the distribution of calves born in the calving season by 21-day increments, the proportion of calves born in the first 21, 22-42 or more than 42 days of the calving season were similar ($P = 0.40$) between groups.

Introduction

Reproductive performance and overall herd health are vital to a successful and profitable cow herd. Deficiencies of trace minerals can lead to anemia, immune suppression, decreased ovulation, irregular estrous cycles, fetal malformations and abortions because these minerals are vital to fetal development and nutrient transfer (Hostetler et al., 2003). Increased reproductive failure and potential for animal death could result in decreased profitability for cattle producers.

Mineral supplementation, as well as the mineral composition of forages and individual animal intake, is highly variable. Palatability, individual requirements, mineral content of available water sources, season of the year and individual animal intake are all factors that must be considered (McDowell, 1996). Injectable trace mineral products are available and may be used for a more targeted supplement. However, injectable products are not blanket nutrients or broad spectrum, but contain only a few trace minerals.

Injectable supplementation advantages include the targeted delivery of known trace mineral elements and the ability to distribute those minerals when previous management delivery was not a viable option due to terrain or environment (rough country, pastures that routinely flood, etc.; Arthington et al., 2014). Administering injectable trace mineral supplements 30 days before breeding resulted in a greater proportion of females becoming pregnant to artificial insemination (AI), compared with females not receiving supplements (Mundell et al., 2012).

The objective of this study was to evaluate the effects of injectable trace mineral supplements administered 30 days before the start of the breeding season on reproductive performance when natural-service breeding was used.

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Experimental Procedures

One thousand three hundred eleven commercial beef cows originating from four herds in North Dakota were stratified within herd by days postpartum, then randomly assigned to receive one of two treatments: 1) Cows received no additional treatments prior to bull turnout (CON; n = 638) or 2) Cows were administered an injectable trace mineral supplementation (6 mL of MultiMin; 60, 10 and 15 mg/mL of zinc, manganese and copper as disodium EDTA chelates; and 5 mg/mL of selenium as sodium selenite) subcutaneously on day minus 30 relative to bull turnout (TM; n = 673). The TM treatment cow will receive a single injection prior to breeding, as opposed to the label recommendations of an injection prior to calving and prior to breeding for mature females.

On the day of mineral administration, blood samples were collected immediately prior to mineral injection via jugular venipuncture in 10-mL Vacutainer tubes (BD Worldwide, Franklin Lakes, N.J.). Serum samples were analyzed for baseline mineral status on a subset (10 randomly selected females) of cows within each herd. Samples were analyzed for concentrations of cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se) and zinc (Zn).

Total mixed rations also were collected for those animals still in confinement prior to pasture/bull turnout. Water samples were collected from all available water sources for each herd. Feed and water samples were analyzed for toxic levels of the minerals (Table 1 and 2, respectively). Blood samples were averaged for each herd and are presented in Table 3.

Cows within each herd and treatment were housed in common pastures and exposed to common management. Natural-service bulls were turned out to all cows 30 days after treatment administration and remained with the cows for the duration of the producer-defined breeding season. Transrectal ultrasonography or rectal palpation was used to determine the presence of a viable fetus at least 45 days after the end of the breeding season by a herd veterinarian.

Weaning weights were collected at the time of weaning for the year of administration. At the time of calving, birth date and calf sex were recorded. Cows continued to be managed on similar pastures throughout the grazing season and through the wintering period.

The MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) was used to analyze all continuous data (calf birth date and calf weaning weights). The GENMOD procedure of SAS was used to analyze the binomial data (pregnancy rate calving

Table 1. Mineral composition of feed samples[1].

		Herd		
Mineral	Max. Levels[2]	1	3	4
Copper	10	4.2	20.5	6.1
Iron	50	225	965	917
Manganese	1200	63.1	134.9	71.5
Molybdenum	-	3	< 1.0	1
Phosphorus	1,700-2,200	1,928	2,747	1,685
Selenium	0.1	< 10.0	< 10.0	< 10.0
Sulfur	1,500	1,095	2,210	1,568
Zinc	30	10.5	53.2	20.7

[1]Mineral values given in parts per million.
[2]Maximum tolerable levels based on 1996 Beef Cattle National Research Council (NRC). Levels given for lactating cows.

Table 2. Mineral composition of water samples[1].

		Herd								
Mineral	Max. Levels[2]	1a	1b	2a	2b	2c	2d	2e	3	4
Copper	10	< 1.3	< 1.3	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	0.031	< 0.025
Iron	50	< 0.30	< 0.30	0.716	0.44	0.193	0.649	0.125	1.404	3.429
Manganese	0.12	< 0.05	< 0.085	0.108	0.064	0.094	0.418	< 0.025	0.716	0.051
Molybdenum	–	–	–	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Phosphorus	1,700-2,000	< 10.0	< 10.0	< 0.50	0.6	0.7	0.9	< 0.5	< 0.50	< 0.50
Selenium	0.1	< 0.050	< 0.050	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Sulfur	1,500	< 250.0	< 250.0	186.3	464.3	284.5	62.1	267.8	78.4	271.2
Zinc	30	< 5.0	< 5.0	0.059	0.075	0.118	0.069	0.108	0.29	0.091

[1]Mineral values given in parts per million.
[2]Maximum levels based on 1996 Beef Cattle NRC. Levels given for lactating cows.

distribution). Each model included the effect of treatment (control or injectable trace mineral supplementation).

When analyzing the effects of days postpartum (DPP) and body condition score (BCS), categories were created to determine differences in groups of data and included in the model. For DPP, cows were at or less than 60, 61 to70, 71 to 80 or greater than 80 based on the time between their last calving and current breeding date. For BCS, cows were less than 4, 4, 5 or greater than 5 based on their condition at the time of treatment administration. Significance was declared at $P \leq 0.05$.

Results and Discussion

Prior to treatment administration, free-choice mineral was available for all cows or was included in a total mixed ration (TMR). Tables 1 and 2 illustrate the feed and water analysis for each herd. Blood samples (Table 3) were averaged for each herd.

Selenium and manganese levels were high in some females, while copper and zinc were lower than adequate. While ranges exist, what is important to note is that ranges can be variable based on the type of sample and the laboratory conducting the analyses.

The current study was conducted to evaluate the effect of an injectable trace mineral supplement on reproduction of commercial beef herds in North Dakota. The injectable trace mineral supplement was administered at one of the label-recommended time points, 30 days prior to breeding. A similar (P = 0.36) proportion of cows became pregnant by the end of the producer-defined breeding season between treatments (TM: 92 percent and CON: 93 percent).

We found an effect (P = 0.05) of days postpartum (DPP) on the attainment of pregnancy, which followed a predictable trend (at or less than 60: 88 percent and greater than 80: 99 percent) All other groups were similar (P = 0.10) between treatments (61 to 70, 71 to 80). Differences in cow body condition scores were highly variable but did not affect (P = 0.83) the proportion of cows that became pregnant in the breeding season.

Calves suckling cows at the time of treatment administration were weighed at the time of weaning. Weights of calves at this time were recorded to determine if the injectable trace mineral supplement may have had an effect on nutrition of the dam and, therefore, the weight of the calf at her side.

Weights of calves from dams administered the injectable trace mineral supplement were not different (P = 0.90) than of calves born from dams in the control group (622.8 ± 4.4 pounds and 631.3 ± 4.6 pounds, respectively). The proportion of females that weaned a calf also was similar (P = 0.55) between treatment

Table 3. Mineral composition of blood samples[1].

Mineral	Serum Levels[3]	Herd[2] 1	2	3	4
Cobalt	> 0.0001	0.00019	0.00021	0.00079	0.00047
Copper	0.6-0.8	0.61	0.51	0.67	0.57
Iron	110-180	124.5	148.88	158.22	162.10
Manganese	0.0015-0.0025	0.00505	0.00289	0.00688	0.00078
Molybdenum	0.004-0.1	0.02332	0.03159	0.00652	0.01244
Selenium	0.07-0.1	0.1015	0.127	0.10756	0.125
Zinc	0.9-2	0.73	0.94	0.93	0.86

[1]Mineral values given in parts per million.
[2]Serum levels are presented as averages for each herd. Eight to 10 animals were sampled from each herd.
[3]Serum levels based on Michigan State University Diagnostic Center for Population and Animal Health. Levels are determined to be adequate if within listed ranges.

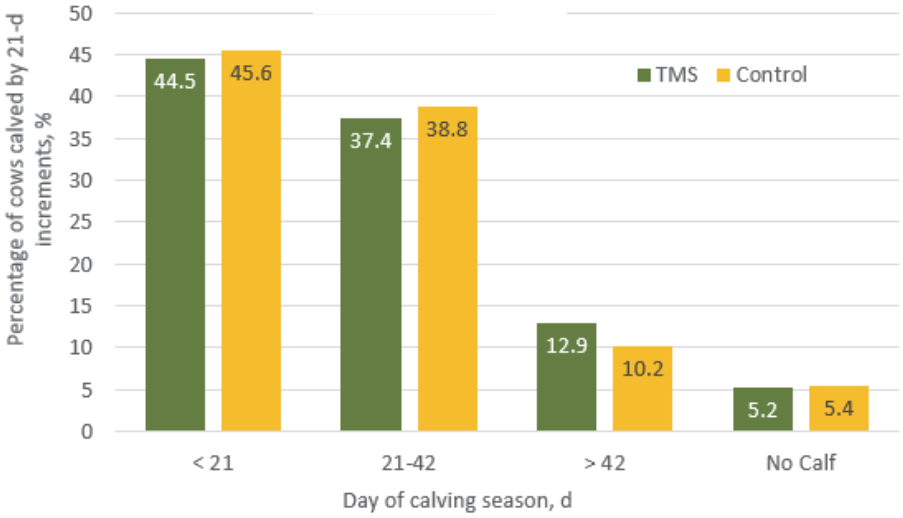

Figure 1. Effect of injectable trace mineral supplemention on the distribution of calving.

groups (CON: 92 percent and TM: 92 percent).

At parturition, birth dates and sex were recorded. Date of birth in the calving season was not different ($P = 0.99$) for calves born from dams administered the injectable trace mineral supplementation, compared with calves born from control dams (25.7 ± 0.75 pounds and 24.6 ± 0.72 pounds, respectively). In addition, we found no difference ($P > 0.40$) in the distribution of calving when the calving season was divided into 21-day increments (Figure 1).

The incorporation of an injectable trace mineral supplement administered 30 days prior to bull turnout did not affect pregnancy attainment, weaning weights of calves or calving distribution. Although reproduction was not affected by treatments in this study, what is important to note is that overall pregnancy rates and calving were very good across herds.

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The effects of nutrient restriction on interferon-tau and pregnancy-specific protein-B mRNA during the establishment of pregnancy in beef heifers

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The objectives of this project were to elucidate the effects of maternal nutrient restriction on PSP-B and IFN-τ in placental formation, placental function and establishment of pregnancy. PSP-B and IFN-τ were expressed differentially during early gestation and may be important to the establishment of pregnancy.

Summary

We hypothesize that pregnancy-specific protein-B (PSP-B) and interferon-τ (INF-τ) will be expressed differentially during early pregnancy (days 16 to 50) and will be influenced by plane of maternal nutrition. Commercial Angus crossbred heifers (n = 49; about 16 months of age; body weight [BW] = 713 ± 62 pounds) were maintained on a total mixed ration (TMR) and supplemented with dried distillers grains with solubles. All heifers were subject to 5-day CO-Synch + CIDR estrus synchronization protocol and artificial insemination (AI) to a single Angus sire (day of breeding = day 0). On the day of breeding, heifers were assigned randomly to dietary treatments. One-half were assigned to the control diet (CON) targeted to gain .45 kg/day and the remaining half were assigned to a restricted diet (RES) and received 60 percent of control diets. Heifers were subjected to ovariohysterectomy on days 16, 34 and 50 of gestation. Utero-placental tissues were obtained from the uterine horn ipsilateral (P) and contralateral (NP) to the corpora lutea (CL) and separated into maternal caruncle (CAR); maternal endometrium, inter-caruncle (ICAR); and fetal membrane (FM) After being collected, all tissues were snap-frozen in liquid nitrogen-cooled 2-Methylbutane and stored at minus 80 C. *Pregnancy-specific protein-B* increased ($P < 0.01$) by 18,000-fold as gestation progressed in P-CAR. *Pregnancy-specific protein-B* was increased ($P < 0.01$) on days 34 and 50 (337.3 and 203.2 ± 60.9, respectively), compared with day 16 (10.4 ± 60.9). We found no interactions between stage of gestation and nutritional treatment for PSP-B (P = 0.22). In conclusion, maternal nutri-

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ent restriction only influenced *INF-τ*, but *PSP-B* and *INF-τ* were expressed differentially in maternal and fetal tissues at critical time points during the first 50 days of gestation in beef heifers.

Introduction

Placental development is closely related to fetal growth and is sensitive to maternal nutrient supply from the earliest stages of pregnancy (Reynolds and Redmer, 2001) by facilitating the transfer of nutrient, gas and waste (Ramsey, 1982). Inadequate maternal nutrient supply leads to poor placental development, resulting in compromised fetal growth (Caton and Hess, 2010).

Twenty-one members of the pregnancy-associated glycoprotein (PAG) family have been discovered to date (Green et al., 2000). The assortment of PAG present may provide a multitude of binding sites and perform a variety of functions at and during the formation of the feto-maternal interface (Green et al., 1998).

The binucleated cells and modern PAGs seem to interact extensively with maternal connective tissue that develops during placental villi formation (Wooding et al., 2005). However, the exact functions of both types of PAG remain to be elucidated.

Researchers have speculated that PAGs may be involved in proteolytic activation of growth factors and other molecules specific to pregnancy, protection of fetal tissues from maternal immune response, transport of hormones between fetal and maternal tissues, and cell-to-cell fusion (Wooding et al., 2005). Therefore, we hypothesize that *pregnancy-specific protein-B (PSP-B)* and *interferon-τ (INF-τ)* will be expressed differentially during early pregnancy (days 16 to 50) and will be influenced by plane of maternal nutrition.

Experimental Procedures

All animal procedures were conducted with approval from the Institutional Animal Care and Use Committee at North Dakota State University (A16049). Commercial Angus crossbred heifers (n = 49; about 16 months of age; BW = 713 ± 62 pounds) were transported 142 miles from the Central Grasslands Research Extension Center (Streeter, N.D.) to the Animal Nutrition and Physiology Center (North Dakota State University, Fargo, N.D.).

The heifers were housed in pens, with six heifers per pen, and individually fed daily in an electronic head gate facility (American Calan; Northwood, N.H.) at 8 a.m. Heifers were maintained on a total mixed ration (TMR) (48.4 percent dry matter [DM], 5.3 percent crude protein [CP], 29.4 percent neutral detergent fiber [NDF], 6.8 percent ash), supplemented with dried distillers grains with solubles (87.5 percent DM, 31.3 percent CP, 53.4 percent NDF, 8.2 percent ash), and granted ad libitum access to water.

All heifers were subjected to 5-day CO-Synch + CIDR estrus synchronization protocol and artificial insemination (AI) to a single Angus sire (day of breeding = day 0). On the day of breeding, heifers were assigned randomly to dietary treatments. One-half were assigned to control diet (CON) targeted to gain .45 kg/day and the remaining half were assigned to the restricted diet (RES) and received 60 percent of control diets.

Heifers were subjected to ovariohysterectomy on days 16, 34 and 50, as previously described, McLean et al., (2016). Thus, experimental design for the pregnancy analysis was a 2 × 3 factorial design. Nonbred, nonpregnant control heifers (NP; n = 6) were ovariohysterectomized on day 16 of the luteal cycle following the synchronization cycle. The NP heifers and heifers that were ovariohysterectomized on days 16, 34 and 50 and fed the CON diet were used in a CRD to address comparisons of pregnancy status and establishment.

Pregnancy was confirmed via trans-rectal ultrasonography day 28 and again on the day of surgery (day beyond 28). During surgery, the left and right uterine arteries, left and right spiral arteries and the cervix were ligated and then the uterus was removed.

Uterine contents were held in place with a 24-centimeter (cm) Crafoord Coarctation Clamp (Integra-Miltex; Plainsboro, N.J.) placed just cranial to the cervical ligatures during and after removal from the body cavity. Following surgery, heifers were kept in individual pens during recovery and stitches were removed 14 days after surgery (McLean et al., 2016), then the animals were returned to the control diets.

Immediately upon removal from the body cavity, tissues were trimmed of excess broad ligament, fat and nonreproductive tissues. Gravid uterus, individual and total ovarian, and CL weights were taken, as well as CL measurements for CL area before fixation, freezing and storage. Utero-placental tissues were obtained from the uterine horn ipsilateral (containing the embryo) to the CL (pregnant uterine horn), maternal caruncle (P-CAR) and maternal endometrium, inter-caruncle, (P-ICAR).

Tissues were obtained in the uterine horn contralateral (opposite the embryo) to the CL (non-pregnant horn), maternal caruncle (NP-CAR) and maternal endometrium, inter-caruncle, (NP-ICAR). Fetal membranes (FM) were collected on days 16, 34 and 50. After being collected, all tissues were snap-frozen in liquid nitrogen-cooled isopentane (Sigma-Aldrich; St. Louis, Mo.) and stored at minus 80 C.

Gene expression was analyzed for threshold cycle using a 7500 Fast

Real-Time PCR System (Applied Biosystems, Grand Island, N.Y.) with SYBR Green Master Mix (Bio-Rad Laboratories, Hercules, Calif.). Gene expression for maternal tissues was calculated using the ΔΔCT method, with *β-actin* as the reference gene and the average of NP expression as the control (set to 1) within each tissue.

Fetal membrane gene expression was calculated using the ΔΔCT method, with *β-actin* as the reference gene and of the ΔCT for uterine endometrium of each individual gene as the control (set to 1) within each tissue.

Statistical analyses for gene expression of *PSP-B* and *INF-τ* were conducted as a 2 × 3 factorial with individual heifer as the experimental unit via the GLM procedure of SAS version 9.4 (SAS Inst. Inc., Cary, N.Y.) to test for a stage of gestation × nutritional plane interaction or the main effects of nutritional plane and stage of gestation. Means were separated using the LSMEANS statement of SAS with differences determined at a *P*-values ≤ 0.05.

Results and Discussion

Factors that influence fetal and placental growth and development include maternal plane of nutrition, number of fetuses, maternal parity and age, maternal and fetal genotype, and maternal stress (Reynolds et al., 2010). The long-term effects of restricted nutrient intake during early gestation may be associated with impaired placental development or poor contact during the establishment of the feto-maternal interface, resulting in intrauterine growth retardation (Zhang et al., 2015).

The pregnancy-associated glycoproteins (PAGs) have been found only in binucleate trophoblast cells (Wooding et al., 2005). *Pregnancy-specific protein-B* increased ($P < 0.01$) by 18,000-fold as gestation progressed in P-CAR (Figure 1A).

In P-ICAR, the expression of *pregnancy-specific protein-B* was increased ($P < 0.01$; Figure 1B) on days 34 and 50, compared with day 16. In NP-CAR, the expression of pregnancy-specific protein-B increased ($P < 0.01$) by 317-fold as gestation progressed in NP-CAR (Figure 1C). The expression of *PSP-B* was increased ($P = 0.02$) on days 34 and 50, compared with day 16, in NP-ICAR (data not shown).

The PAGs seem to interact extensively with maternal connective tissue that develops during placental villi formation (Wooding et al., 2005). Researchers have theorized that PAGs may be involved in proteolytic activation of growth factors and other molecules specific to pregnancy, protection of fetal tissues from maternal immune response, transport of hormones between fetal and maternal tissues, and cell to cell fusion (Wooding et al., 2005).

The increase in expression of PSP-B in our data supports functions for cell-to-cell fusion and transport of hormones at the feto-maternal interface. The interaction of maternal caruncles and fetal cotyledons is the most intimate contact between maternal and fetal tissues and could add to the evidence to support

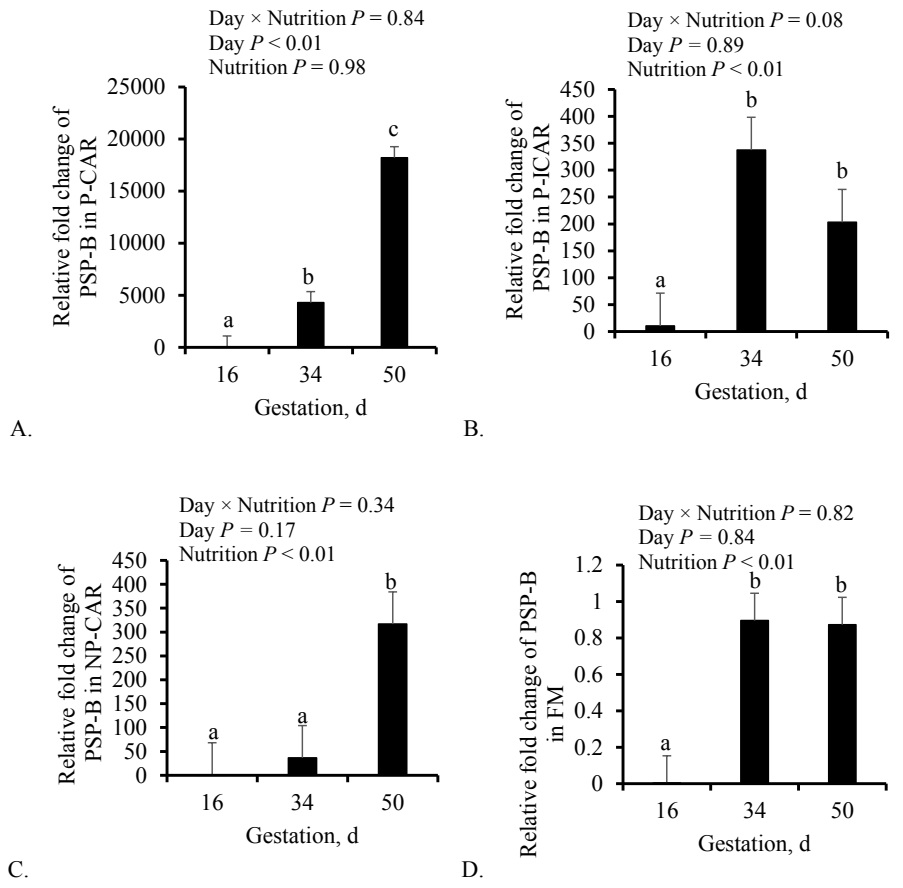

Figure 1. Expression of PSP-B in utero-placental tissues during early gestation. A) pregnant uterine horn caruncle (P-CAR) B) pregnant uterine horn endometrium (P-ICAR) C. non-pregnant uterine horn caruncle (NP-CAR) D. expression in fetal membranes. Data presented as a $2^{-\Delta\Delta CT}$ fold change normalized to *β-Actin* and the average of NP.

[a,b]Means without a common superscript differ ($P < 0.05$)

a role in immune protection and further implicate PSP-B in cell-to-cell fusion functions. The secretion of *INF-τ* from the trophoblast is widely accepted as the ruminant signal for pregnancy recognition secreted from the trophoblast (Spencer et al., 2007). Nutritional treatment also influenced *INF-τ* mRNA expression, with RES heifers having decreased (P = 0.05) *INF-τ* expression, compared with CON feed heifers (Figure 2A).

In NP-ICAR, the nutritional plane tended (P = 0.09) to influence INF-τ expression, with greater expression in CON heifers, compared with RES heifers (data not shown). In FM, *INF-τ* had an interaction of stage of gestation × nutritional plane (P < 0.01). Fetal membranes on day 16 were greater than all other days, and RES heifers were greater, compared with CON heifers (Figure 2B).

Fetal membrane expression of *INF-τ* had an interaction between stage and nutritional plane on day 16 that was greater than all other days, and RES heifers were greater, compared with CON heifers. The expression of *INF-τ* in P-CAR was influenced by nutritional treatment and *INF-τ* expression in FM was increased in RES heifers more during the time of maternal recognition (about day 16), compared with CON heifers. This may be a compensatory mechanism to try to establish pregnancy successfully in a slower-growing embryo.

In conclusion, 50 day of 40 percent nutrient restriction may not be severe or long enough of a restriction to influence most expression PSP-B or *INF-τ* in utero-placental tissues. Our previous data and this work confirmed differential expression of PSP-B and *INF-τ* in maternal and fetal tissues during the first 50 days of gestation.

These differences in expression are at critical time points during the establishment of pregnancy, specifically maternal recognition (day 16), completion of fetal adhesion (day 34) and rapid placental development (day 50). While exact functions during early gestation remain to be elucidated for PSP-B and *INF-τ*, they appear to complete vital steps for the successful establishment of pregnancy in beef heifers.

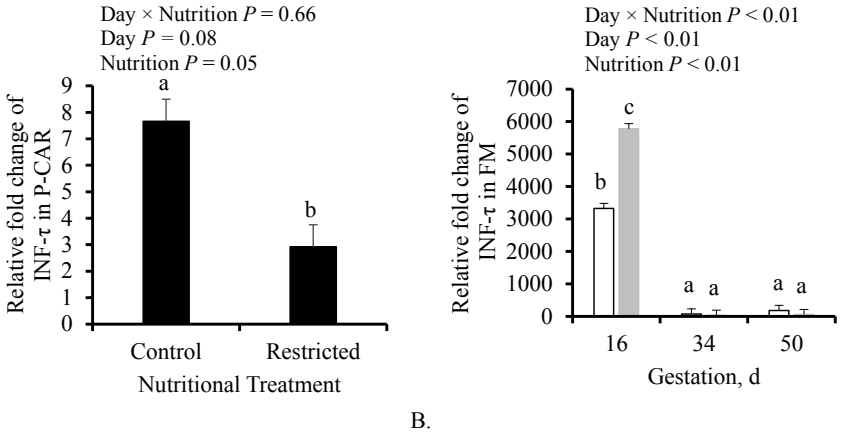

Figure 2. The effects of nutrient restriction and day of gestation on IFN-τ expression in utero-placental tissues B) the effects of nutritional plane on mRNA of IFN-τ in pregnant uterine caruncle (P-CAR). and B) IFN-τ in fetal membranes (FM) where white bars outlined in black represent control heifers and gray bars represent restricted heifers Data presented as a $2^{-\Delta\Delta CT}$ fold change normalized to *β-Actin* and the average of NP.

[a, b]Means without a common superscript differ (P < 0.05)

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The effects of nutrient restriction on expression of endogenous retroviruses mRNA during the establishment of pregnancy in beef heifers

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The objectives of this project were to elucidate the effects of maternal nutrient restriction on endogenous retroviral genes in placental formation, placental function and establishment of pregnancy. Syncytin-Rum1 and BERV-K1 were expressed differentially during early gestation and may be important to the establishment of pregnancy.

Summary

We hypothesize that endogenous retrovirus envelope genes will be expressed differentially during early pregnancy (days 16 to 50) and will be influenced by plane of maternal nutrition. Commercial Angus crossbred heifers (n = 49; about 16 months of age; body weight [BW] = 713 ± 62 pounds) were maintained on a total mixed ration (TMR) and supplemented with dried distillers grains with solubles. All heifers were subjected to 5-day CO-Synch + CIDR estrus synchronization protocol and artificial insemination (AI) to a single Angus sire (day of breeding = day 0). On the day of breeding, heifers were assigned randomly to dietary treatments. One-half were assigned to control diet (CON) targeted to gain .45 kg/day and the remaining half were assigned to a restricted diet (RES) and received 60 percent of control diets. Heifers were subjected to ovariohysterectomy on days 16, 34 and 50 of gestation. Utero-placental tissues were obtained from the uterine horn ipsilateral (P) and contralateral (NP) to the corpora lutea (CL) and separated into maternal caruncle (CAR); maternal endometrium, inter-caruncle (ICAR); and fetal membrane (FM), After being collected, all tissues were snap-frozen in liquid nitrogen-cooled isopentane and stored at minus 80 C. Expression of *syncytin-Rum1* was greater ($P = 0.01$) on day 16, with a 14.14 ± 2.06-fold increase, compared with a 5.11 ± 2.06-fold increase on day 34 and a 7.75 ± 2.06-fold increase of expression on day 50 in P-ICAR. The effect of plane of nutrition on *BERV-K1* was dependent on the stage of gestation ($P = 0.03$) in NP-CAR. Heifers on the CON diet had expression that decreased from days 16 to 34 and reached max levels on day 50, with a 116.3 ± 22.5 increase, whereas RES heifer expression was not different throughout early gestation. We found no interactions between stage of gestation and nutritional treatment for *syncytin-Rum1* ($P > 0.22$). In conclusion, maternal nutrient restriction only influenced *BERV-K1*, but *syncytin-Rum1* and *BERV-K1* were expressed differentially in maternal and fetal tissues at critical time points during the first 50 days of gestation in beef heifers.

Introduction

Placental development is closely related to fetal growth and is sensitive to maternal nutrient supply from the earliest stages of pregnancy (Reynolds and Redmer, 2001) by facilitating the transfer of nutrient, gas and waste (Ramsey, 1982). Inadequate maternal nutrient supply leads to poor placental development, resulting in compromised fetal growth (Caton and Hess, 2010). The syncytiotrophoblast and syncytium will function as the feto-maternal interface to exchange nutrients, produce hormones and protect the conceptus from the maternal immune responses.

Syncytium formation is initiated by endogenous retroviral elements (ERV) that have been incorporated into the host genome. A significant portion of the genome in made up of ERV.

The Bovidae genome contains 24 ERV families, depending on the species (Garcia-Etxebarria and Jugo, 2013). The envelope proteins of *syncytin-Rum1* and *BERV-K1* are expressed differentially during early gestation and have been implicated as nutrient sensors (Sharif et al., 2013). Thus, expression may be influenced by the maternal plane of nutrition during early gestation.

Therefore, we hypothesize that endogenous retrovirus envelope genes will be expressed differentially during early pregnancy (days 16 to 50) and will be influenced by plane of maternal nutrition.

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Experimental Procedures

All animal procedures were conducted with approval from the Institutional Animal Care and Use Committee at North Dakota State University (A16049). Commercial Angus crossbred heifers (n = 49; about 16 months of age; BW = 713 ± 62 pounds) were transported 142 miles from the Central Grasslands Research Extension Center (Streeter, N.D.) to the Animal Nutrition and Physiology Center (North Dakota State University, Fargo, N.D.).

The heifers were housed in pens, with six heifers per pen, and individually fed daily in an electronic head gate facility (American Calan; Northwood, N.H.) at 8 a.m. Heifers were maintained on a TMR (48.4 percent dry matter [DM], 5.3 percent crude protein [CP], 29.4 percent neutral detergent fiber [NDF], 6.8 percent ash), supplemented with dried distillers grains with solubles (87.5 percent DM, 31.3 percent CP, 53.4 percent NDF, 8.2 percent ash), and granted ad libitum access to water.

All heifers were subjected to 5-day CO-Synch + CIDR estrus synchronization protocol and AI to a single Angus sire (day of breeding = day 0; Bridges et al., 2008). On the day of breeding, heifers were assigned randomly to dietary treatments.

One half were assigned to a control diet (CON) targeted to gain .45 kg/day and the remaining half were assigned to a restricted diet (RES) and received 60 percent of control diets.

Heifers were subjected to ovariohysterectomy on days 16, 34 and 50, as previously described, McLean et al., (2016a). Thus, experimental design for the pregnancy analysis was a 2 × 3 factorial design. Nonbred, nonpregnant control heifers (NP; n = 6) were ovariohysterectomized on day 16 of the luteal cycle following the synchronization cycle. The NP heifers and heifers that were ovariohysterectomized on days 16, 34 and 50 and fed the CON diet were used in a CRD to address comparisons of pregnancy status and establishment.

Pregnancy was confirmed via trans-rectal ultrasonography on day 28 and again on the day of surgery (day beyond 28). During surgery, the left and right uterine arteries, left and right spiral arteries and the cervix were ligated and then the uterus was removed.

Uterine contents were held in place with a 24-centimeter (cm) Crafoord Coarctation Clamp (Integra-Miltex; Plainsboro, N.J.) placed just cranial to the cervical ligatures during and after removal from the body cavity. Following surgery, heifers were kept in individual pens during recovery and stitches were removed 14 days after surgery (McLean et al., 2016a), then the animals were returned to the control diets.

Immediately upon removal from the body cavity, tissues were trimmed of excess broad ligament, fat and nonreproductive tissues. Gravid uterus, individual and total ovarian, and CL weights were taken, as well as CL measurements for CL area before fixation, freezing and storage.

Utero-placental tissues were obtained from the uterine horn ipsilateral (containing the embryo) to the CL (pregnant uterine horn), maternal caruncle (P-CAR) and maternal endometrium, inter-caruncle, (P-ICAR).

Tissues were obtained in the uterine horn contralateral (opposite the embryo) to the CL (nonpregnant horn), maternal caruncle (NP-CAR) and maternal endometrium, inter-caruncle, (NP-ICAR). Fetal membranes (FM) were collected on days 16, 34 and 50. After being collected, all tissues were snap-frozen in liquid nitrogen-cooled isopentane and stored at minus 80 C.

Gene expression was analyzed for threshold cycle using a 7500 Fast Real-Time PCR System (Applied Biosystems, Grand Island, N.Y.) with SYBR Green Master Mix (Bio-Rad Laboratories, Hercules, Calif.). Gene expression for maternal tissues was calculated using the ΔΔCT method, with *β-actin* as the reference gene and the average of NP expression as the control (set to 1) within each tissue.

Fetal membrane gene expression was calculated using the ΔΔCT method, with *β-actin* as the reference gene and of the ΔCT for uterine endometrium of each individual gene as the control (set to 1) within each tissue.

Statistical analyses for gene expression of *syncytin-Rum1* and *BERV-K1* were conducted as a 2 × 3 factorial with individual heifer as the experimental unit via the GLM procedure of SAS version 9.4 (SAS Inst. Inc., Cary, N.Y.) to test for a stage of gestation × nutritional plane interaction or the main effects of nutritional plane and stage of gestation. Means were separated using the LSMEANS statement of SAS with differences determined at a *P*-values ≤ 0.05.

Results and Discussion

Factors that influence fetal and placental growth and development include maternal plane of nutrition, number of fetuses, maternal parity and age, maternal and fetal genotype, and maternal stress (Reynolds et al., 2010). The long-term effects of restricted nutrient intake during early gestation may be associated with impaired placental development or poor contact during the establishment of the feto-maternal interface, resulting in intrauterine growth retardation (Zhang et al., 2015).

In P-CAR, we found no interactions between the stage of gestation and nutritional treatment for *syncy-*

tin-Rum1 or *BERV-K1* ($P > 0.49$), so the main effects of day of gestation and nutritional treatment will be presented. Expression of syncytin-Rum1 tended ($P = 0.10$) to be greater at day 50 (17.7 ± 3.8), compared with days 16 and 34 (6.9 and 7.9 ± 3.9, respectively; data not shown).

In P-ICAR, we found no interactions between plane of nutrition and day of gestation or any effects of nutritional treatment for either gene expression ($P > 0.12$). Expression of *syncytin-Rum1* was greater ($P = 0.01$) on day 16, compared with day 34 and day 50 (Figure 1A). Expression of *syncytin-Rum1* increased ($P = 0.03$) in FM at day 50, compared with days 16 and 34 (Figure 1B).

In NP-CAR, neither stage nor nutritional treatment influenced *syncytin-Rum1* ($P > 0.11$). We found a plane of nutrition × stage of gestation ($P = 0.03$) on *BERV-K1* expression. Heifers on the CON diet had expression that decreased from days 16 to 34 and increased on day 50; whereas, RES heifer expression was not different throughout early gestation (Figure 2A).

Sharif et al. (2013) reported that, in the developing placenta, ERV likely function as nutrient sensors that may be turned on during periods of hypomethylation, which occurs very early in gestation. *BERV-K1* has been reported to have greater fusogenic capabilities than *BERVE-A* or *syncytinRum-1* (Nakaya et al., 2013). This may explain why *BERVE-K1* was increased in the normal placental cytotrophoblast cell line (NPC) as the placental development spreads into the contralateral uterine horn, which may indicate a greater role in cell-to-cell fusion and the formation of syncytial plaques.

Thus, the function of *BERVE-K1* may be similar to *syncytin-A*, which altered trophoblast stem cell (TSC) fusion, causing inefficient placental transport, decreased vascularity and growth retardation, ultimately terminating gestation between days 11.5 and 13.5 of gestation (Dupressoir et al., 2009). The stage of gestation and plane of nutrition did not influence *syncytin-Rum1* or *BERV-K1* ($P > 0.14$). The mRNA expression levels of *BERV-K1* in FM increased ($P < 0.01$) at day 34, compared with day 16, and then decreased to day 50; however, day 50 was greater ($P < 0.01$) than day 16 (Figure 2B).

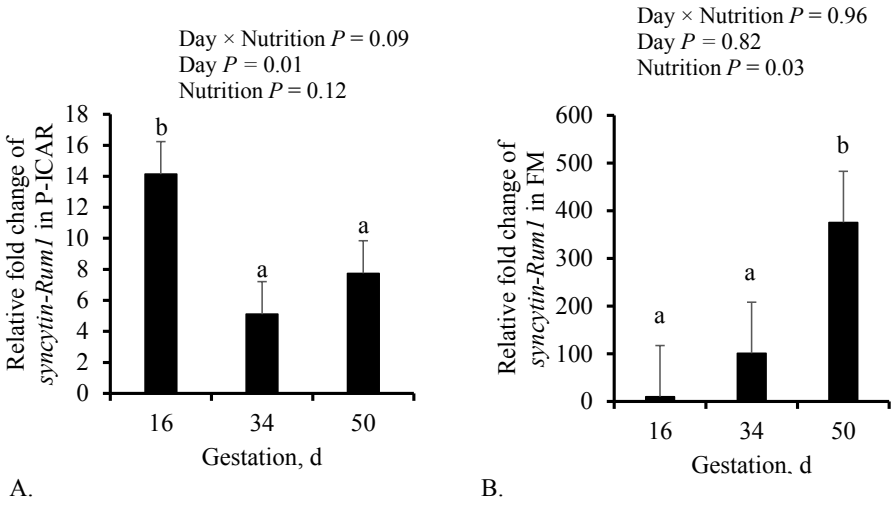

Figure 1. Expression of *syncytin-Rum1* in pregnant uterine horn endometrium (P-ICAR) and fetal membranes during the establishment of pregnancy in beef heifers: A) *syncytin-Rum1* in P-ICAR and B) Expression of *BERV-K1* in FM. Data presented as a 2^-ΔΔCT fold change normalized to *β-Actin* and the average of NP.

[a,b]Means without a common superscript differ ($P < 0.05$)

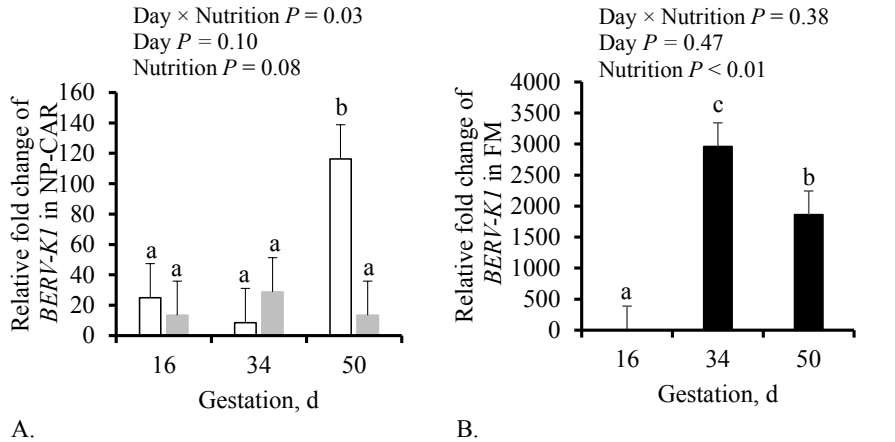

Figure 2. Expression of *BERV-K1* in caruncles of the contralateral uterine horn to the conceptus (NP-CAR) and fetal membranes (FM) during the establishment of pregnancy in beef heifers: A) Expression of *BERV-K1* in NP-CAR where white bars outlined in black represent control heifers and gray bars represent restricted heifers and B) Expression of *BERV-K1* in FM. Data presented as a 2^-ΔΔCT fold change normalized to *β-Actin* and the average of NP.

[a,b,c]Means without a common superscript differ ($P < 0.05$)

As in rodents and humans, our data has determined that cattle have at least two ERV, *syncytin-Rum1* and *BERV-K1*, that are expressed differentially in reproductive tissues during the establishment of pregnancy. However, in contrast to previous findings (Cornelis et al., 2013), these data indicated that maternal tissues do express mRNA for ERV and at times have increased mRNA expression. This is in agreement with previous data from our laboratory (McLean et al., 2016b).

While differing expression levels are intriguing, the limited knowledge of function and pathways in which ERV are influencing the formation of the placenta and fetus and the establishment of pregnancy hinder the elucidation of the importance of ERV during early gestation.

In conclusion, 50 days of 40 percent nutrient restriction may not be severe or long enough of a restriction to influence ERV expression in utero-placental tissues. Our previous data and this work confirmed differential expression of *syncytin-Rum1* and *BERV-K1* in maternal and fetal tissues during the first 50 days of gestation. These differences in expression are at critical time points during the establishment of pregnancy, specifically, maternal recognition (day 16), completion of fetal adhesion (day 34) and rapid placental development (day 50).While exact functions during early gestation remain to be elucidated, ERV may complete vital steps for the successful establishment of pregnancy in beef heifers.

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A meta-analysis of the relationship of maternal weight and fetal sex on uterine blood flow and maternal heart rate in beef cows from mid to late gestation

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Uterine blood flow plays a critical role in the development of the conceptus, allowing for the maternal-fetal exchange of nutrients, hormones, and wastes. This analysis found that cows carrying bull calves have higher uterine blood flow than those carrying heifer calves which could be contributing to heavier birth weights. Additionally, heavier cows tended to have greater uterine blood flow throughout mid-to late-pregnancy, accompanied by higher heart rates.

Summary

Our objective was to examine the relationships among maternal body weight (BW), fetal sex, uterine blood flow and maternal heart rate in beef cows during mid to late gestation. Four studies were used in the analyses, with blood flow measurements taken via Doppler ultrasonography on four days of gestation from 108 beef cows, which resulted in 333 total observations. Fetal sex, maternal BW class (100-pound increments) and BW class by fetal sex interactions were analyzed with generalized least squares (mixed procedure of SAS) with repeated measures. Day of gestation was included as a covariate, and treatment was nested within study. Linear, quadratic and cubic orthogonal contrasts were tested. Cows carrying bull calves (n = 82) had greater (P = 0.03) uterine blood flow from days 100 to 250 of gestation, compared with cows carrying heifer calves (n = 26; 4.9 vs. 4.1 ± 0.3 gallons/minute [gal/min]). As maternal BW increased, uterine blood flow tended (P = 0.09) to increase linearly. Maternal heart rate also increased linearly (P = 0.02) as maternal BW increased. Fetal sex did not impact maternal heart rate (P = 0.13). In conclusion, the increase in uterine blood flow for male progeny may be contributing to heavier birth weights when compared with their female counterparts. Also, increasing maternal weight may be associated with increased uterine blood flow and heart rate. The reason bull calves are heavier than heifer calves at birth may be due to the male's ability to increase uterine blood flow.

Introduction

Little is known about the physiological role of fetal sex or maternal body weight on total uterine blood flow and maternal heart rate. Sex-specific differences in uterine blood flow have been observed at 120 days of gestation in beef heifers fed a protein-restricted diet, with heifers carrying male progeny experiencing higher uterine blood flow (Hernandez-Medrano et al., 2015). Those sex-specific blood flow differences could not be detected after day 120 of pregnancy or independent of maternal diet.

The objective of this analysis was to examine the relationships among maternal BW, fetal sex, uterine blood flow and maternal heart rate in beef cows during mid to late gestation. We hypothesized that heavier cows would have greater uterine blood flow and heart rates, and cows carrying bull calves would have greater total uterine blood flow.

Experimental Procedures

A total of 108 multiparous Angus or Angus x Continental cows from four independent studies were included in the analysis. Uterine blood flow changes were tracked from day 100 to day 250 of pregnancy through transrectal Doppler ultrasonography measurements of the uterine artery with the ALOKA 3500 ultrasound.

A 7.5 MHz finger probe was inserted into the rectum and the bifurcation of the external and internal iliac arteries were identified. Placement of the probe was immediately posterior to the first branch of the external iliac artery, measuring the descending uterine artery.

Three cardiac cycle waveform profiles from two to three ultrasound measurements were collected of the uterine arteries ipsilateral (I; same horn) and contralateral (C; opposite horn) to the conceptus, with an average of all measurements accounting for one observation (n = 333; I + C = Total).

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Fetal sex was confirmed at parturition (bull, n= 82; heifer, n=26). Fetal sex, BW class (100-pound increments), and BW class by fetal sex interactions were analyzed using generalized least squares with the mixed procedure of SAS with cow as the repeated measure. Day of gestation was included as a covariate and treatment was nested within study.

Linear, quadratic and cubic orthogonal contrasts for BW class also were tested. A P-value ≤ 0.05 was considered significant and a P-value of ≤ 0.09 was considered a tendency.

Results and Discussion

As illustrated by Figure 1, cows carrying bull calves had greater (P = 0.03) uterine blood flow from days 100 to 250 of gestation, compared with cows carrying heifer calves (4.99 vs. 4.1 ± 0.3 gal/min). Additionally, we found no interaction (P = 0.20) between maternal BW class and the sex of the progeny.

Figure 2 shows that fetal sex did not impact maternal heart rate (P = 0.13) and no maternal BW class or fetal sex interactions influenced maternal heart rate (P = 0.21). One possible explanation for this phenomenon is that the male fetus produces some factor to increase maternal blood flow by expanding the maternal arteries without impacting heart rate.

Linear, quadratic and cubic contrasts (Figure 3) were examined to determine the relationship between maternal BW and uterine blood flow. Uterine arterial blood flow tended (P = 0.09) to increase linearly at a rate of 1.6 quarts per 100 pounds as maternal BW increased, thus heavier cows experienced greater uterine blood flow independent of the day of gestation.

The relationship between maternal heart rate and maternal BW also was analyzed with linear, quadratic and cubic contrasts (Figure 4). As maternal BW increased, maternal heart rate also increased linearly (P = 0.03) at a rate of 1.4 beats per min per 100 pounds of BW.

As expected, heavier cows have increased uterine blood flows and heart rates. Additionally, fetal sex contributes to total uterine blood flow; cows carrying bull calves displayed greater total uterine arterial blood flow. One probable cause for increased bull weights at birth could be the male fetus's ability to increase local factors in the uterus or pla-

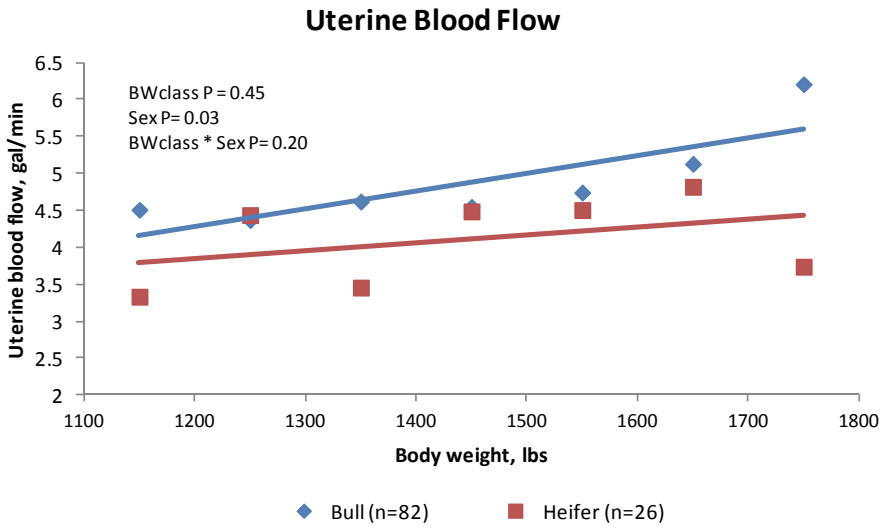

Figure 1. Effects of maternal BW class and fetal sex on uterine blood flow (milliliters/minute).

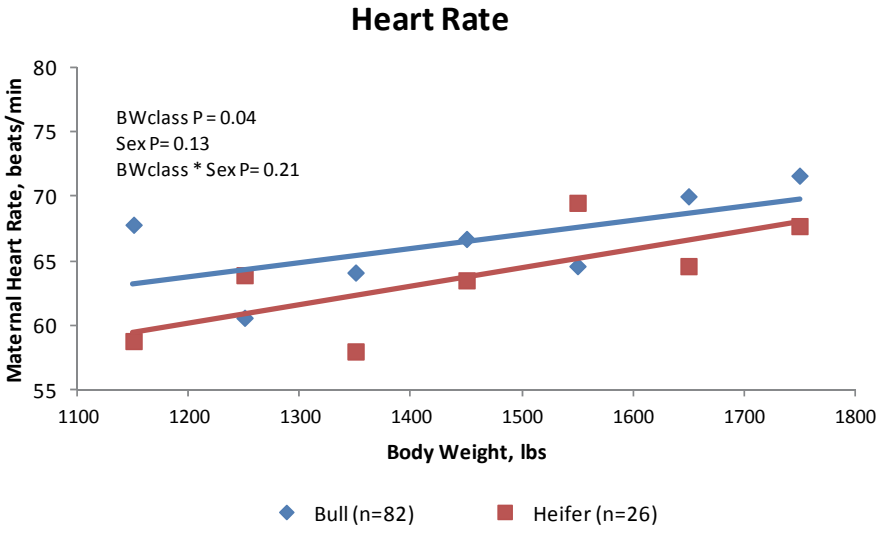

Figure 2. Effects of maternal BW class and fetal sex on maternal heart rate, beats/minute.

centa that drive uterine blood flow throughout mid to late gestation.

Because fetal sex did not increase the maternal heart rate, this gives further evidence that bull calves may be causing the release of some factor that increases uterine blood flow.

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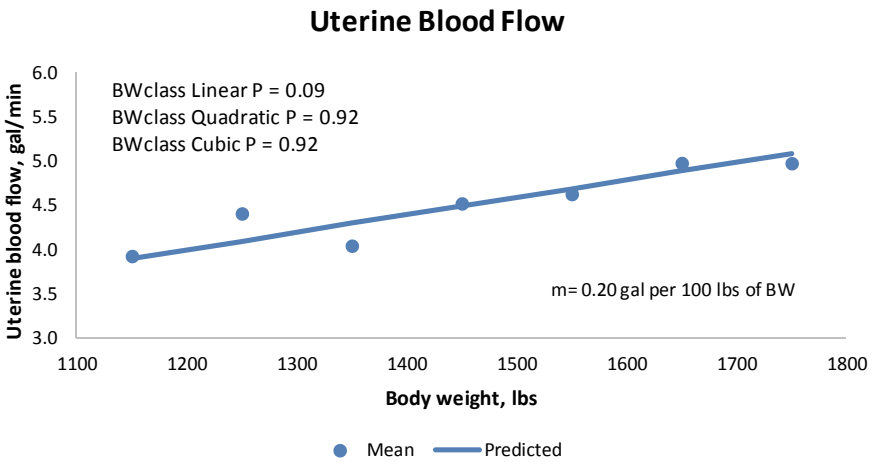

Figure 3. Effects of maternal BW class on uterine blood flow (gallons/minute).

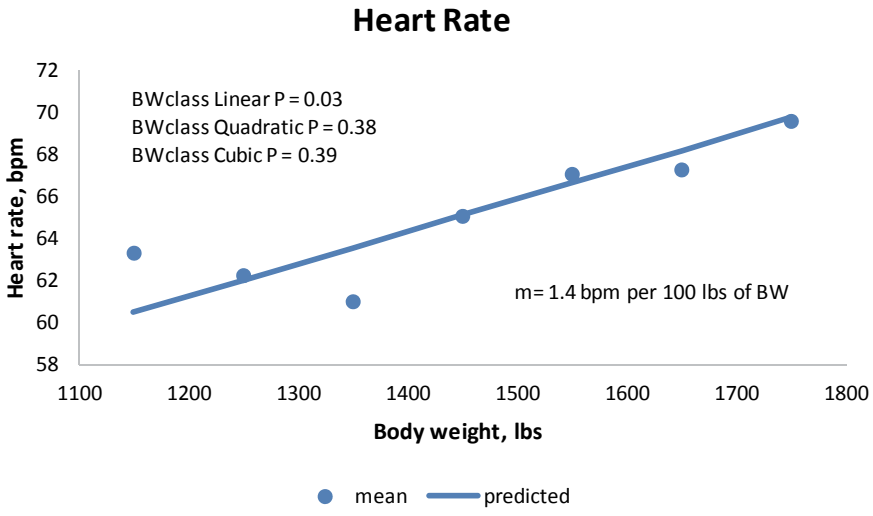

Figure 4. Effects of maternal BW class on maternal heart rate, beats/minute.

Effects of breeding system of origin (natural service or artificial insemination) on pregnancy rates, distribution of calving and calf weaning weights of commercial beef cow herds in North Dakota

Mellissa. R. Crosswhite[1], Danielle. N. Black[1], Tammi. L. Neville[1], Sarah. R. Underdahl[1] and Carl. R. Dahlen[1]

The objective of this study was to examine the pregnancy rates, calving distribution and calf weaning weights of commercial beef cows bred by artificial insemination (AI) or natural-service breeding systems. Cows exposed to AI calved earlier in the breeding season, compared with cows exposed only to natural service. Furthermore, calves born to AI-exposed cows were heavier at weaning, compared with calves born from cows exposed only to natural service.

Summary

The objectives of this study were to compare pregnancy rates, calving distribution and calf weaning weights of commercial beef cows exposed to two different breeding systems. North Dakota county Extension agents were recruited by researchers for the involvement and selection of producers in their areas. The producers recruited (n = 10) never had implemented estrus synchronization and AI into their reproductive management plan. Within each herd, cows were assigned randomly to one of two breeding system treatments: 1) only exposed to natural-service herd bulls (NS; n = 1,122) or 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls (TAI, fixed-time artificial insemination; n = 1,284). Production, performance and profit outcomes were evaluated within/across herds for each breeding system. Females exposed to TAI were exposed to a 7-d CO-Synch + CIDR protocol with fixed-time AI at 60 to 66 hours after CIDR removal. Cleanup bulls were placed in breeding pastures one day after AI and remained with females until the end of the producer-defined breeding season. The presence of a viable fetus was determined at least 45 days after the conclusion of the breeding season. At parturition, birth date was recorded. No differences ($P = 0.54$) were observed in the proportion of females pregnant at the end of the breeding season between NS (93.1 percent) and TAI (93.2 percent) treatments. Cows in the TAI treatment calved 7.8 days earlier ($P < 0.001$) in the calving season, compared with NS cows. A greater proportion ($P < 0.001$) of TAI cows (44.8 percent) gave birth in the first 21 days of the calving season, compared with NS cows (26 percent). From days 22 to 42, a greater proportion ($P < 0.001$) of NS cows (41.6 percent) gave birth, compared with TAI cows (28.2 percent), and a greater proportion of NS cows (23.7 percent) gave birth from day 42 to the end of the calving season, compared with TAI cows (17.2 percent). A treatment x calving group interaction was present for weaning weight. Greater ($P = 0.002$) weaning weights were observed for calves born from TAI cows in the first 21 days of the calving season (592.5 ± 4 pounds), compared with NS calves born in the first 21 days (566.7 ± 5.8 pounds), but weaning weights of calves born in the second 21 days and from day 42 to the end of the calving season were similar ($P = 0.17$) among treatments. Use of TAI in commercial beef herds increased the number of calves born earlier in the calving season and increased the weaning weights of calves.

Introduction

Estrous synchronization and artificial insemination (AI) are management techniques available for the advancement of herd genetics by the selection of highly proven sires without the overhead cost of the equivalent of a natural-service sire. Estrous synchronization and AI create the opportunity for potential benefits, including shortening the breeding and calving seasons, increasing the number of early births resulting in older and heavier calves at weaning (Odde, 1990; Rodgers et al., 2012). However, less than 8 percent of the beef industry utilizes AI, citing labor and time as major contributors (NAHMS, 2009).

Our previous research has highlighted the fact that incorporating AI into a management scheme resulted in older, heavier calves at weaning, compared with a breeding system that relied solely on natural-service breeding (Steichen et al., 2013). In addition, a North Dakota survey determined that more than

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51 percent of producers staying in the beef industry for at least the next 10 years were likely to utilize AI on their operations (Schook et al., 2014).

With an increase in potential adoption of AI in North Dakota, the objectives of this study were to compare the effects of artificial insemination and natural-service breeding systems on pregnancy rates, calving distribution and calf weaning weights of commercial beef cow-calf operations never previously utilizing TAI on their herds.

Experimental Procedures

Two thousand three hundred ninety-nine crossbred commercial cows originating from 10 commercial beef herds in North Dakota were used to compare pregnancy rates, calving distribution and calf weaning weights of beef cows exposed to two different breeding systems. North Dakota county Extension agents were selected for their involvement and identification of commercial cattle producers in their respective areas.

The producers recruited never had implemented estrous synchronization or AI into their management plans. Each herd was managed according to predefined producer management techniques with the addition of the new breeding system.

Within each herd, females were stratified by days postpartum and randomly assigned to one of two treatments: 1) only exposed to natural-service herd bulls (natural service; NS; n = 1,114) and 2) exposed to ovulation synchronization and fixed-time AI followed by natural-service bulls (timed AI; TAI, n = 1,285).

To achieve a common breeding date, all TAI females were exposed to ovulation synchronization (7-d CO-Synch + CIDR for cows and heifers; Lamb et al., 2006, Larson et al., 2006, respectively) consisting of inserting a controlled internal drug-releasing insert (CIDR,1.38 grams (g) of Progesterone, Zoetis Inc., Florham, N.J.) and 100 micrograms (µg) of Gonadotrophin Releasing Hormone (GnRH) intramuscular (i.m.) (2 mL Factrel, Zoetis Inc.), followed in seven days by CIDR removal and 25 milligrams (mg) of PGF2α i.m. (5 mL Lutalyse, Zoetis Inc.), followed in 60 to 66 hours by 100 µg of GnRH i.m. and TAI.

At the time of the CIDR insertion, body condition scores (BCS) were recorded on all TAI females. Each producer was responsible for the selection of AI sires for the TAI treatment for their given herd.

Within each herd, females from both treatments were comingled on common pastures and managed together. Bulls were placed into breeding pastures at least one day after TAI. The presence of a viable fetus was determined by the herd veterinarian of each operation a minimum of 45 days after the conclusion of the producer-defined breeding season.

Birth date was recorded at parturition and individual weaning weights were collected at weaning. Calves born from cows exposed to TAI will be referred to as TAI-grouped calves and calves born from dams only exposed to NS will be referred to as NS-group calves.

The MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) was used to analyze all continuous data (calf birth date and calf weaning weights). For all analysis of calf data, treatments will be applied by dam treatment origin (cows exposed to TAI will calve TAI-grouped calves, etc.).

The GENMOD procedure of SAS was used to analyze the binomial data (pregnancy rate calving distribution). Each model included the effect of treatment (natural service or fixed-timed AI breeding systems) and ranch location. When analyzing the effects of days postpartum (DPP) and BCS, categories were created to determine differences in groups of data and included in the model.

For DPP, cows were less than or equal to 40, 41 to 70, 71 to 100 or more than 100 based on the time between their last calving and current breeding date. For BCS, cows were less than 4, 4, 5 or greater than 5 based on their condition at the time of treatment administration. Significance was declared at $P \leq 0.05$.

Results and Discussion

The current study was conducted to evaluate the impact of two different breeding systems, natural service and timed-AI, on commercial beef operations in North Dakota. Days postpartum were similar ($P = 0.97$) between treatments, with an average of 65 days, and the average BCS was 4.4 on a 1-to-9 scale. A similar proportion of cows became pregnant by the end of the producer-defined breeding season between treatments (93.2 percent; $P = 0.58$).

At the time of calving, birth date was recorded. Cows in the TAI group calved 7.7 days earlier ($P < 0.001$) than those in the NS group (27.1 and 34.8 days, respectively). Because pregnancy was determined at the end of the breeding season, pregnancy to AI is unknown. The proportion of cows calving in the first 21-day period of the calving season is not an exact measurement; however, it can be used as an indicator for cows becoming pregnant to TAI.

In addition, a greater ($P < 0.001$) proportion of cows in the TAI group calved in the first 21-day period of the calving season (Figure 1). When evaluating the second and third 21-day periods, a greater proportion ($P < 0.001$) of NS-bred females calved.

Finally, we found no difference ($P = 0.59$) in the proportion of cows

that did not calve. Similarly, Rodgers et al. (2012) and Steichen et al. (2013) reported that incorporating estrous synchronization and AI into herds shifted the calving date earlier in the calving season, with a greater proportion of females calving in the first 21-day period of the calving season.

Weaning weights of calves born from the two breeding systems were collected at each producer location. Greater ($P < 0.001$) weights were observed in calves born to dams in the TAI group, compared with the NS group (549.8 ± 3.5 pounds and 534 ± 3.7 pounds, respectively; Table 1).

A treatment x calving group interaction also was present for weaning weight. Greater ($P = 0.002$) weaning weights were observed for calves born from TAI cows in the first 21 days of the calving season (592.5 ± 4 pounds), compared with NS-born calves (566.7 ± 5.8 pounds).

For the second 21-day period, a treatment x calving group interaction also was present, where greater ($P = 0.05$) weaning weights were observed in NS-group calves when compared with calves born to TAI cows (542.7 ± 5.1 pounds and 527.3 ± 2.8 pounds, respectively). We found no differences ($P = 0.76$) in the weights of calves born on day 42 or later in the calving season.

The incorporation of estrous synchronization and AI did not affect the proportion of cows becoming pregnant; however, it did increase the number of calves born early in the calving season. In addition, calves born to dams in the TAI treatment were heavier at weaning. For these reasons, the use of estrous synchronization and AI could have potential benefits for producers. Subsequent analysis will determine if earlier calving and heavier weaning weights resulted in any differences in profit.

Acknowledgments

We thank all of our cooperating producers: T.J. Alme, Jim Enge, Aaron and Jodi Hintz, Jarvis and Katie Sorenson, Jerrid and Cami Janikowski, Justin and Sharnae Klein, Kent and Judy Oland, Dustin and Barbra Roise, Rodney and Karen Schmidt, and Chris and Nadine Tedford. In addition, we acknowledge the following current and former NDSU county agents and area Extension specialists - Jim Hennessey, Calli Thorne, Rick Schmidt, Raquel Dugan-Dibble, Brian Zimprich, Penny Nester, Andrea Bowman, Sarah Crimmins, Craig Askim and John Dhuyvetter - for their assistance with identifying producers and attending all meetings and working events.

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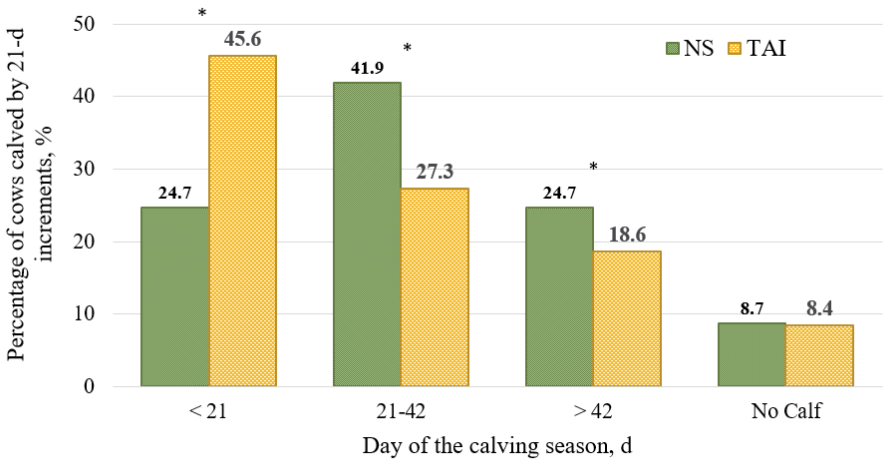

*Treatment differ within calving group ($P \leq 0.05$)

Figure 1. Effect of breeding system of origin on calving distribution.

Table 1. Effect of breeding system of origin on weaning weights of calves.

Item	Treatment[1]		*P* – value	
	NS	TAI	Treatment	Treatment x Calving Group
No. of calves	655	759	–	–
Weaning weights, lb.	534.0	549.8	<0.001	–
< 21	566.7	592.5	–	< 0.01
22-42	542.7	527.3	–	0.05
> 42	481.8	478.8	–	0.76

[1]Treatments: NS = Natural service only; TAI = Fixed-time AI bred with cleanup natural service

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Effects of maternal nutritional status on nutrient transporter expression in bovine utero-placental tissue on days 16 to 50 of gestation

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The objectives of this study were to determine the effect of a 40 percent global nutrient restriction on the messenger ribonucleic acid (mRNA) expression of nutrient transporters known for their roles in transporting arginine (CAT-1, CAT-2 and CAT-3) and glucose (GLUT1) across the uterine endometrium and fetal membranes to the fetus from days 16 to 50 of gestation. The results indicate that a 40 percent global nutrient restriction only affects mRNA expression of arginine transporter CAT-2 and not any other transporter investigated.

Summary

We hypothesized that maternal nutrition and day of gestation would impact mRNA expression of nutrient transporters *GLUT1, CAT-1, CAT-2* and *CAT-3* in beef heifers. Crossbred Angus heifers (n = 49) were synchronized, bred via artificial insemination (AI), assigned to nutritional treatment (CON = 100 percent of requirements for 1 pound/day of gain and RES = 60 percent of CON) and ovariohysterectomized on days 16, 34 or 50 of gestation (n = six to nine/day). Nonpregnant (NP) controls were not bred and ovariohysterectomized on day 16 of the synchronized estrous cycle (n = 6). The resulting arrangement of treatments was a 2 × 3 factorial + 1. Caruncle (CAR), intercaruncular endometrium (ICAR) and fetal membranes (FM) were obtained from the pregnant uterine horn immediately following ovariohysterectomy. For NP controls, only CAR and ICAR were obtained. The relative expression of the glucose transporter *GLUT1* and cationic amino acid transporters *CAT-1, CAT-2* and *CAT-3* was determined for each tissue utilizing NP-CAR and NP-ICAR tissue as the baseline. For FM, NP endometrium served as the baseline. We found no interaction of day and treatment in FM for any genes ($P \geq 0.05$). Expression of *GLUT1* and *CAT-1* showed a day effect, being greater ($P < 0.05$) in FM on days 34 and 50, compared with day 16. In CAR, we found no day × treatment interaction, and *CAT-3* expression tended ($P = 0.06$) to be greater in CON vs. RES heifers. Additionally, expression of *GLUT1, CAT-1* and *CAT-2* in CAR were greater ($P < 0.01$) on day 16, compared with days 34 and 50, day 34 compared with day 50, and days 16 and 34 compared with day 50, respectively. In ICAR, *CAT-2* showed a day ×

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treatment interaction, being greater ($P = 0.01$) on day 50 CON, compared with all other groups. Transporter *CAT-3* tended ($P = 0.09$) to be greater in day × treatment in ICAR on day 16 CON, compared with all other days and treatments. The expression of *GLUT1* was greater ($P < 0.01$) in ICAR on day 16 than all other days. Arginine transporter *CAT-1* was greater ($P < 0.01$) in ICAR on days 34 and 50, compared with day 16. These results partially support our hypothesis and indicate that day was a more influential factor for mRNA expression of utero-placental glucose and cationic amino acid transporters than maternal nutritional status in heifers during early pregnancy.

Introduction

Fetal growth is vulnerable to maternal dietary nutrient deficiencies during the first trimester of gestation (Wu et al., 2004). During the first 50 days of gestation, organogenesis is taking place. This time period of gestation is a critical developmental window with significant cellular and tissue differentiation. Nutritional influences may alter the mammalian phenotype through affecting gene regulatory mechanisms involved in DNA synthesis and replication, thus "imprinting" potential susceptibilities to chronic disease and metabolic issues into the genome (Waterland and Jirtle, 2004).

Currently, fetal undernutrition occurs in grazing livestock worldwide (Wu et al., 2004). Maternal undernutrition has been implicated in fetal growth restriction and altered placental growth, reduced amino acid and glucose transport, and increased apoptosis and autophagy, which overall can yield decreased fetal growth during gestation (Zhang et al., 2015).

Before the establishment of hemotrophic nutrition, the placenta is developing and the fetus begins to utilize increasing quantities of glucose and amino acids (Groebner et al., 2011). Thus, the expression of glucose and amino acid transporters in the utero-placenta becomes essential to the viability of the conceptus.

Therefore, we studied the utero-placental glucose transporter *GLUT1 (SLC2A1)*, which is present in most tissues throughout the body and is ubiquitous across species. The amino acid transporters investigated are *CAT-1, CAT-2* and *CAT-3* (*SLC7A1, SLC7A2* and *SLC7A3*), whose substrates are cationic amino acids such as arginine and lysine, which are directly linked to angiogenesis and cell proliferation.

In this experiment, we tested the hypothesis that mRNA for glucose and cationic amino acid transporters in utero-placental tissues would be expressed differentially due to day of gestation and maternal nutritional status.

Experimental Procedures

Protocols described herein were approved by the North Dakota State University Institutional Animal Care and Use Committee. Crossbred Angus heifers (n = 49, about 15 months of age; average initial body weight [BW] = 722 pounds) were exposed to the 5-d CO-Synch + CIDR estrus synchronization protocol. Six heifers were not inseminated to serve as nonpregnant (NP) controls but received ovariohysterectomy for tissue collections on day 16 of the synchronized estrous cycle. The remaining heifers (n = six to nine/day of gestation/treatment) were bred by AI to a common sire at 12 hours after observed estrus and ovariohysterectomized at days 16, 34 or 50 of gestation.

Heifers were housed at the NDSU Animal Nutrition and Physiology Center. Heifers were acclimated to individual bunk feeding for two weeks before the beginning of the trial.

Immediately following AI, heifers were assigned randomly to one of two treatment groups. Control heifers (CON) received 100 percent of National Research Council (NRC, 2000) requirements for 0.45 kilogram per day (kg/d) gain to reach 80 percent of mature BW at first calving. Restricted heifers (RES) were placed on a 40 percent global nutrient restriction, which was accomplished by reducing total diet delivery 60 percent of the control delivery.

The diet was delivered via total mixed ration (TMR) and consisted of grass hay (73.4 percent neutral detergent fiber [NDF], 8 percent crude [CP]), corn silage (55.6 percent NDF, 6.3 percent CP), alfalfa haylage, (48.9 percent NDF, 16.4 percent CP), grain supplement, (32.6 percent NDF, 24.1 percent CP) and dried distillers grains (53.4 percent NDF, 31.3 percent CP), on a dry-matter (DM) basis.

Immediately following ovariohysterectomy (McLean et al., 2016), utero-placental tissues (caruncle, CAR; intercaruncular endometrium, ICAR; fetal membrane [chorioallantois], FM; cotyledon, COT; intercotyledonary placenta ICOT; and amnion, AMN) were obtained from the uterine horn containing the conceptus, as previously described (Grazul-Bilska et al., 2010, 2011). Fetal membranes also were collected only from heifers that were bred due to a lack of FM in NP controls.

On day 50 of gestation, FM was split into COT and ICOT. Amnion was collected only on day 50. Once collected, all tissues were frozen in liquid nitrogen-cooled isopentane and stored at minus 112 F.

The RNA was extracted from each tissue and purified. The level of mRNA expression of each transporter within the tissue was established using polymerase chain reaction (PCR) to determine differences in mRNA expression of the transporters across days of early gestation.

Results and Discussion

The mRNA expression of glucose transporter *GLUT1* was greater ($P < 0.01$) in AMN, compared with COT and ICOT (0.67 vs. 0.24 and 0.29, respectively; Table 1). Arginine transporter *CAT-1* mRNA expression was greater ($P = 0.02$) in AMN when compared with COT and ICOT (0.30 vs. 0.22 and 0.17, respectively; Table 1).

Cationic amino acid transporter *CAT-2* mRNA expression was greater ($P = 0.05$) in AMN, compared with ICOT (3.27 vs. 0.82, respectively). The level of expression of *CAT-3* was greater ($P < 0.01$) in AMN, compared with COT and ICOT (7.64 vs. 0.73 and 2.75, respectively)

We found no day × treatment interaction or main effect of treatment for any gene in FM ($P > 0.05$). Expression of *GLUT1* was greater ($P = 0.04$) on day 50 of gestation, compared with day 16 (0.38 vs. 0.15, respectively; Table 2). Cationic amino acid transporter *CAT-1* expression was greater ($P < 0.01$) on days 34 and 50, compared with day 16 (0.23 and 0.22 vs. 0.05, respectively; Table 2). The mRNA expression of *CAT-2* tended to be greater ($P = 0.09$) on day 50 of gestation, compared with day 16.

We also found no day × treatment interaction ($P \geq 0.05$) on the mRNA expression of *GLUT1, CAT-1, CAT-2* or *CAT-3* in CAR. Expression of *CAT-3* showed a tendency ($P = 0.06$) to be greater across day of gestation in CON vs. RES (2.60 vs. 1.16; Table 3). Expression of *GLUT1* was greater ($P < 0.01$) on day 16 of gestation, compared with days 34 and 50 (2.89 vs. 0.85 and 1.14 respectively).

The mRNA expression of CAT-1 was greater ($P < 0.01$) on day 34, compared with days 16 and 50 (5.22 vs. 1.47 and 0.51 respectively; Table 3). Additionally, mRNA expression of *CAT-1* tended to be greater ($P = 0.09$) in the post-implantation (days 34 and 50) vs. implantation (day 16). Expression of cationic amino acid transporter *CAT-2* was greater ($P = 0.02$) on day 34, compared with day 16 of gestation (14.67 vs. 4.36, respectively). In addition, *CAT-2* mRNA expression showed a tendency ($P = 0.06$) to be greater in pregnant vs. NP heifers.

The expression of *CAT-2* showed a day × treatment interaction ($P = 0.01$) being greater, with day 50 CON heifers having greater expression, compared with days 16 and 50 RES and day 34 CON heifers (Table 4). The cationic amino acid transporter *CAT-3* tended ($P = 0.09$) to be greater in day 16 CON, compared with all other days and treatments.

The mRNA expression of *GLUT1* was greater ($P < 0.01$) on day 16 of gestation compared with day 34 (2.11 vs. 0.75). Arginine and Lysine transporter *CAT-1* was greater ($P < 0.01$) on days 34 and 50, compared with day 16 (14.62 and 11.13 vs. 0.58, respectively). Additionally, *CAT-1* mRNA expression was greater in ICAR ($P < 0.01$) in pregnant, compared with NP heifers (8.78 vs. 1, respectively).

Fertilization rates for first-service AI are approximately 90 percent in beef heifers (Bridges et al., 2013); however, by day 30 of gestation, only 50 to 60 percent of heifers maintain a viable pregnancy. Moreover, Thatcher et al., (1994) indicated that up to 40 percent of all embryonic loss occurs before day 40 of gestation in sheep and cattle.

Glucose and amino acids, specifically arginine, are crucial for proper energy metabolism and growth, and are key regulators of mTOR, which is linked to angiogenesis and cell proliferation, causing increased fetal growth and mitigating apoptosis (Tan and Miyamoto, 2016

The expression of all transporters investigated was greatest on day 50 in AMN, compared with COT and ICOT. Amniotic fluid contains the nutrient reserve from which the conceptus draws to meet its energetic and growth requirements prior to transplacental exchange. The reported data further demonstrate the increased emphasis on transport of nutrients across the AMN to provide nutrients to the conceptus.

Table 1. Relative expression of nutrient transporters *GLUT1, CAT-1, CAT-2* and *CAT-3* in AMN, COT and ICOT on day 50 of gestation using NP endometrium as a baseline value set to 1.

Gene[1]	AMN[2]	COT[3]	ICOT[4]	SEM[5]	P-value[6]
GLUT1	0.67[a]	0.24[b]	0.29[b]	0.07	< 0.01
CAT-1	0.30[a]	0.22[b]	0.17[b]	0.03	0.02
CAT-2	3.27[a]	1.42[ab]	0.82[b]	0.66	0.05
CAT-3	7.64[a]	0.73[b]	2.75[b]	1.38	< 0.01

[1]Gene = *GLUT1* – Glucose transporter solute carrier family 2 member 1. *CAT-1, CAT-2* and *CAT-3* – Cationic amino acid transporters of arginine and lysine, solute carrier family 7 member 1, 2 and 3.
[2]Amnion taken on day 50 of gestation.
[3]Cotyledons taken from fetal membranes on day 50 of gestation.
[4]Intercotyledonary tissue (fetal membrane tissue not including cotyledons; taken from fetal membranes on day 50 of gestation).
[5]Average SEM was used within gene; AMN n = 11, COT n = 14, ICOT n =14
[6]Probability values for the effect of tissue on level of expression of individual genes.
[a-b]Means within gene without a common superscript differ by tissue ($P \leq 0.05$).

Before the establishment of transplacental exchange, nutrient transporters are the only method of supplying nutrients to the conceptus. Therefore, evaluating the concentration of nutrients in the maternal and fetal fluids (serum, histotroph, and allantoic and amniotic fluids) is of interest to determine whether nutrient restriction during early gestation affects nutrient concentrations in maternal and fetal fluids or nutrient transport capacity, thereby altering the abundance of nutrients available for transport to the conceptus.

We interpret these data to imply that a 40 percent global maternal nutritional restriction may affect the mRNA expression of some *(CAT-2)* but not all utero-placental nutrient transporters investigated in this study. The effects of day of gestation on the mRNA expression of glucose and cationic amino acid transporters reflect the changing nutrient supply and demand curve necessary for proper conceptus growth. Moreover, additional knowledge in this area will facilitate increased efficiencies of beef cattle production and contribute to meeting the projected world food demands.

Acknowledgments

We thank the North Dakota State Board of Agricultural Research and Education and the U.S. Department of Agriculture's National Institute of Food and Agriculture and Agriculture and Food Research Initiative (2016-67016-24942) for research support. We also express appreciation to personnel at the NDSU Animal Nutrition and Physiology Center, NDSU Animal Science Nutrition Laboratory and Animal Science Reproductive Physiology Laboratory, and Animal Science graduate students Jordan Hieber and Evan Knutson for their assistance in completing this project.

Table 2. Level of expression of nutrient transporters *GLUT1*, *CAT-1*, *CAT-2* and *CAT-3* in fetal membranes (FM) due to CON and RES dietary treatments from days 16 to 50 of gestation in beef heifers using NP endometrium as a baseline value set to 1.

			Day of Gestation[2]					*P* – values[3]		
Gene[1]	Trt[4]		16	34	50	Trt[5]	SEM[6]	Day	Trt	Day × Trt
GLUT1	CON		0.11	0.25	0.38	0.25	0.08	0.04	0.70	0.90
	RES		0.19	0.27	0.38	0.28				
		Day[7]	0.15[h]	0.26[gh]	0.38[g]					
CAT-1	CON		0.04	0.22	0.22	0.16	0.17	< 0.01	0.70	0.99
	RES		0.05	0.24	0.23	0.17				
		Day	0.05[h]	0.23[g]	0.22[g]					
CAT-2	CON		0.42	0.84	1.97	1.08	0.66	0.09	0.87	0.82
	RES		0.24	1.16	1.57	0.99				
		Day	0.33	1.00	1.77					
CAT-3	CON		0.08	3.94	5.20	3.07	2.21	0.39	0.61	0.57
	RES		2.38	0.93	3.02	2.11				
		Day	1.23	2.43	4.11					

[1]Gene = *GLUT1* – Glucose transporter solute carrier family 2 member 1. *CAT-1, CAT-2* and *CAT-3* – Cationic amino acid transporters of arginine and lysine, solute carrier family 7 member 1, 2 and 3.

[2]Day of Gestation = number of days after AI. Each gene of interest expression value is reported as a fold change in relation to NP endometrium level of gene expression.

[3]Probability values for the effect of day, treatment and day × treatment on the level of expression of individual genes.

[4]CON = Heifers fed a diet that meets 100% of NRC requirements to gain 1 pound daily. RES = Heifers restricted to 60% of CON diet.

[5]Mean gene expression of treatment group across day of gestation within tissue and gene of interest.

[6]Average SEM used within gene. d 16 CON n = 7, d 16 RES n = 7, d 34 CON n = 6, d 34 RES n = 9, d 50 CON n = 7, d 50 RES n = 7

[7]Mean gene expression across treatment within day and gene of interest.

[a-c]Means within gene and tissue without a common superscript differ in day × treatment ($P \leq 0.05$).

[g-h]Means within row lacking common superscript differ in main effect of day ($P \leq 0.05$).

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Table 3. Level of expression of nutrient transporters *GLUT1*, *CAT-1*, *CAT-2* and *CAT-3* in caruncular CAR tissue due to CON and RES dietary treatments from d 16 to 50 of gestation and in non-pregnant (NP) controls set to 1.

								P - values[3]					
		Day of Gestation[2]					NP vs.	16 vs.	34 vs.			Day x
Gene[1]	Trt[4]	16	34	50	Trt[5]	SEM[6]	Preg	34 and 50	50	Day	Trt	Trt
GLUT1	CON	2.40	0.93	1.38	1.57	0.44	0.21	< 0.01	0.47	< 0.01	0.77	0.23
	RES	3.38	0.76	0.89	1.67							
	Day[7]	2.89[g]	0.85[h]	1.14[h]								
CAT-1	CON	1.08	5.24	0.53	2.28	1.03	0.21	0.09	< 0.01	< 0.01	0.78	0.90
	RES	1.85	5.20	0.49	2.51							
	Day	1.47h	5.22[g]	0.51[h]								
CAT-2	CON	5.76	14.37	7.98	9.37	3.63	0.06	0.02	0.04	0.02	0.77	0.89
	RES	2.95	14.97	7.58	8.50							
	Day	4.36[h]	14.67[g]	7.78[gh]								
CAT-3	CON	1.29	2.23	4.28	2.60	1.09	0.44	0.24	0.11	0.20	0.06	0.90
	RES	0.45	0.99	2.05	1.16							
	Day	0.87	1.61	3.16								

[1]Gene = *GLUT1* – Glucose transporter solute carrier family 2 member 1. *CAT-1, CAT-2, and CAT-3* – Cationic amino acid transporters of arginine and lysine, solute carrier family 7 member 1, 2, and 3.

[2]Day of Gestation = number of days after insemination. Each gene expression is given as a fold change in relation to NP level of expression set to 1.

[3]Probability values for effect of d, treatment, and day × treatment on level of expression of individual genes. Probability values for the contrast of mRNA level of expression of NP vs. Preg (all days of gestation), d 16 of gestation vs. d 34 and 50 of gestation, and d 34 vs. d 50 of gestation.

[4]CON = Heifers fed a diet that meets 100% of NRC requirements to gain 1 pound daily. RES = Heifers restricted to 60% of CON diet

[5]Mean level of expression of treatment group across day of gestation within tissue and gene of interest.

[6]Average SEM was used within gene. NP n = 6, d 16 CON n = 7, d 16 RES n = 7, d 34 CON n = 6, d 34 RES n = 9, d 50 CON n = 7, d 50 RES n = 7

[7]Mean level of expression across treatment within day and gene of interest.

[a-c]Means within gene and tissue without a common superscript differ in day × treatment ($P \leq 0.05$).

[g-h]Means within row without a common superscript differ in main effect of day ($P \leq 0.05$).

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Table 4. Level of expression of nutrient transporters *GLUT1*, *CAT-1*, *CAT-2* and *CAT-3* in intercaruncular ICAR tissue due to CON and RES dietary treatments from d 16 to 50 of gestation and in non-pregnant (NP) controls set to 1.

								P - values[3]					
			Day of Gestation[2]					NP vs.	16 vs.	34 vs.			Day x
Gene[1]	Trt[4]		16	34	50	Trt[5]	SEM[6]	Preg	34 and 50	50	Day	Trt	Trt
GLUT1	CON		2.44	0.63	1.77	1.61	0.39	0.43	< 0.01	0.10	< 0.01	0.26	0.42
	RES		1.77	0.87	1.08	1.24							
		Day[7]	2.11^{g}	0.75^{h}	1.43^{gh}								
CAT-1	CON		0.65	13.86	9.94	8.15	2.59	< 0.01	< 0.01	0.13	< 0.01	0.56	0.89
	RES		0.51	15.37	12.33	9.41							
		Day	0.58^{h}	14.62^{g}	11.13^{g}								
CAT-2	CON		6.83^{ab}	2.31^{c}	7.78a	5.64	1.43	0.04	0.88	0.56	0.22	0.68	0.01
	RES		3.10b^{c}	6.08^{abc}	3.17^{bc}	4.11							
		Day	4.97	4.19	5.48								
CAT-3	CON		9.69	1.55	5.53	5.59	1.89	0.09	0.12	0.27	0.13	0.45	0.09
	RES		3.87	4.25	5.05	4.39							
		Day	6.78	2.90	5.29								

[1]Gene = *GLUT1* – Glucose transporter solute carrier family 2 member 1. *CAT-1, CAT-2,* and *CAT-3* – Cationic amino acid transporters of arginine and lysine, solute carrier family 7 member 1, 2, and 3.

[2]Day of Gestation = number of days after insemination. Each gene expression is given as a fold change in relation to NP level of expression set to 1.

[3]Probability values for effect of d, treatment, and day × treatment on level of expression of individual genes. Probability values for the contrast of mRNA level of expression of NP vs. Preg (all days of gestation), d 16 of gestation vs. d 34 and 50 of gestation, and d 34 vs. d 50 of gestation.

[4]CON = Heifers fed a diet that meets 100% of NRC requirements to gain 1 pound daily. RES = Heifers restricted to 60% of CON diet.

[5]Mean level of expression of treatment group across day of gestation within tissue and gene of interest.

[6]Average SEM was used within gene. NP n = 6, d 16 CON n = 7, d 16 RES n = 7, d 34 CON n = 6, d 34 RES n = 9, d 50 CON n = 7, d 50 RES n = 7

[7]Mean level of expression across treatment within day and gene of interest.

[a-c]Means within gene and tissue without a common superscript differ in day × treatment ($P \leq 0.05$).

[g-h]Means within row without a common superscript differ in main effect of day ($P \leq 0.05$).

Effects of cold temperatures on feed intake in beef cows

Jessica R. Schneider[1], Marc L. Bauer[1], Kendall C. Swanson[1], Trent C. Gilbery[1], Sarah R. Underdahl[1] and Kimberly A. Vonnahme[1]

The objective of this study was to measure the response in intake by cows fed a forage-based diet to cold temperatures. Results indicate cows ate more as the temperature declined during months when they were acclimating to the cold temperature. When cows were acclimated to the cold temperature, intake changed little across temperatures. Cows ate more during warmer temperatures in February, which was the opposite of earlier months. This may not be completely due to temperature because cows were in late pregnancy at this time as well.

Summary

Forty-seven pregnant beef cows (1,453 pounds of body weight) were fed initially a diet (6.7 percent crude protein) of 45 percent grass hay, 45 percent wheat straw and 10 percent partially de-sugared molasses. One group was supplemented with dry-rolled corn at 0.3 percent of body weight, and the other was just fed the hay-based diet. All cows wore radio-frequency identification tags to monitor individual intake. Feed intake of cows was measured in November, December, January and February (115 to 224 days of gestation). Cows fed the control diet gained 1.0 pound/day and lost 0.2 body condition score units (9-point scale). Cows fed supplement gained 1.5 pounds/day and 0.2 score units. In November and December, intake increased due to temperatures getting colder ($P < 0.01$). In January, feed intake did not respond to temperature change ($P = 0.07$). In February, feed intake increased when the temperature warmed ($P < 0.01$). During January and February, the cows' response to colder temperatures was different than in November and December. We hypothesize these differences were because cows had longer to become acclimatized to colder temperatures, having thicker hair coats and higher metabolism rates.

Introduction

Temperatures have been shown to affect feed intake of beef cattle when they move toward extremes of heat or cold. Outside the range of 59 to 77 F, cattle try to maintain their critical temperatures by heating or cooling. Effects are more likely to be shown if the environmental changes are through time because daily intake is more variable as the result of many factors.

In temperatures below 59 F, intake will increase gradually to provide more heat to the animal's core. Above 77 F, the animal will reduce feed intake to reduce internal heat.

Acclimation to colder temperatures happens in a few ways. As days grow shorter, the coats of cattle will grow thicker, adding insulation, to keep the internal temperature steady. But while the coat is growing, feed intake will need to produce the extra heat. Once the coat is grown in and body temp stabilizes, intake will level off. We hypothesized that beef cows will increase their feed intake as temperatures become colder.

Experimental Procedures

Forty-seven pregnant beef cows (Angus cross) were housed at the NDSU Beef Cattle Research Complex and were part of an experiment measuring the effect of corn supplementation on blood flow to the uterus and development of the calf, including lifetime effects on growth, carcass and meat traits. The cow's starting average body weight was 1,453 pounds and average body condition score was 5.2 on a 9-point scale.

Cows were weighed monthly throughout the duration of the study. The starting diet (dry basis) consisted of 45 percent grass hay, 45 percent wheat straw and 10 percent partially de-sugared beet molasses. The diet contained 6.7 percent crude protein (CP), 67 percent neutral detergent fiber (NDF), 42 percent acid detergent fiber (ADF), 0.37 percent calcium (Ca) and 0.12 percent phosphorus (P).

After Dec. 2, the diet changed to 60 percent grass hay, 30 percent wheat straw and 10 percent partially de-sugared beet molasses. The new analysis was 7.0 percent CP, 65 percent NDF, 38 percent ADF, 0.33 percent Ca and 0.14 percent P. One group was supplemented with dry-rolled corn at 0.3 percent of body weight and the other was just fed the hay-based diet.

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All cows wore radio-frequency identification tags to monitor individual intake and feeding behavior. We are just reporting total intake for this study.

For the purpose of this study, feed intake was measured during November, December, January and February. During this period, cows were 115 to 224 days in gestation. This covers midgestation to about a month into late gestation, during which nutrient requirement changes would be minimal, allowing us to focus more on environmental effects on intake.

The data was statistically analyzed within months because cows acclimate to temperatures. Our initial analysis indicated different responses during the months (a time interaction).

Results and Discussion

Cows fed the control diet gained 1.0 pound/day and cows fed supplement gained 1.5 pounds/day. Also, cows fed the control diet lost 0.2 body condition score and supplemented cows gained 0.2 score units (9-point scale).

The daily average ambient temperature ranged from 16 to 52 F in November, 1 to 39 F in December, minus 13 to 32 F in January and 1 to 34 F in February. The daily average dew point ranged from 9 to 48 F in November, minus 6 to 34 F in December, minus 22 to 28 F in January and minus 8 to 30 F in February.

Intake changed quadratically with temperature ($P < 0.001$) and dew point ($P = 0.002$). With this dataset, temperature and dew point did not interactively affect intake ($P = 0.20$). Dew point is highly dependent on temperature, and cold air has very little moisture. Therefore, only temperature will be presented and discussed here; intake responded to dew point very similarly to the way it responded to temperature.

In November and December, the cows' intake increased due to temperatures getting colder ($P < 0.01$; Figure 1). These months showed results as expected; as temperatures fell, intake increased. In November, intake rose steadily as temperatures declined. In December, with the temperatures cooler than in November, the cows increased their intake more rapidly as temperature dropped. In January, their feed intake did not respond as much due to change in temperature ($P = 0.07$). A hypothesis for this is that they had become acclimated to the colder temperatures and maintained nutrition.

February once again showed changes in feed intake due to temperature ($P < 0.01$), but this time, intake increased with warmer temperatures. This change was less than the increase with colder temperatures in earlier months.

The best-fit line for February is inverted when compared with November and December lines. This inversion may be due to the cows' gestational period, which would be the third trimester. The cows' energy and nutrient requirements are rapidly increasing during this period. The inverse response also could be attributed to longer acclimatization and warming temperatures.

During January and February, the cows' response to colder temperatures was different than earlier months, with February being markedly different. One likely cause was cows had longer to become acclimatized to colder temperatures, having thicker hair coats and higher metabolism rates. February's change also may have been caused by physiological changes associated with pregnancy, as well because the cows are closer to parturition.

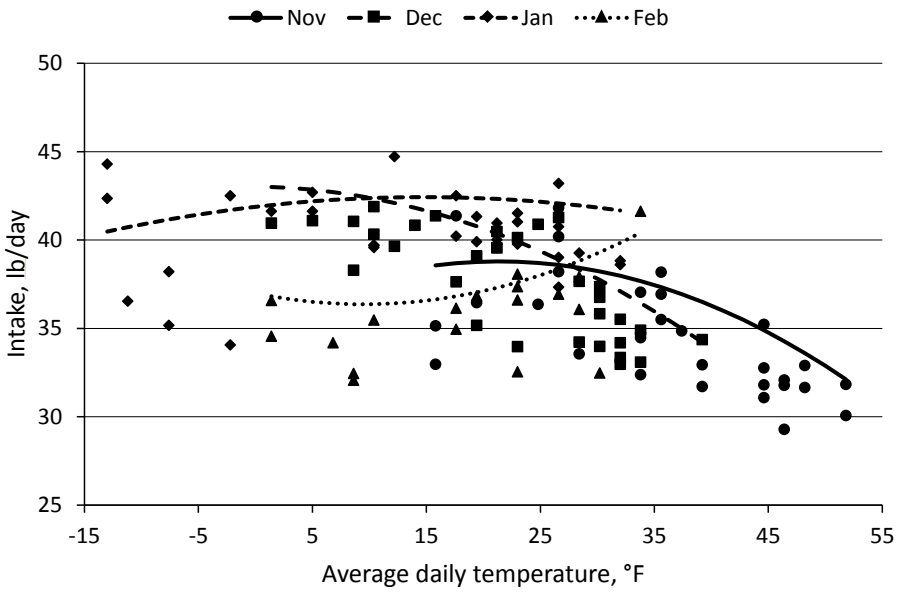

Figure 1: Daily intake based on average daily temperature

Frequency of supplement delivery to cows on corn residue

Michael Undi[1], Bryan W. Neville[1], Fara A. Brummer[1] and Stephanie M. Gross[1]

Methods of supplementing grazing cattle in winter should aim to reduce winter feed costs, which are the single highest annual cost in a cow-calf operation. This study examined the effect of daily, every third day and every sixth day supplement delivery on the performance of cows grazing corn residue. Supplements such as distillers dried grains with solubles (DDGS) can be fed every third day with no detrimental effects on animal performance.

Summary

This study was conducted to evaluate the effects of the frequency of delivering distillers dried grains with solubles (DDGS) as a supplement to cows grazing corn residue in the northern Great Plains. The 36-day study was conducted in the fall of 2015, with 80 first- and second-calf cows (1,146 ± 76 pounds body weight [BW]) in their second trimester. Ten cows were assigned to one of eight 10-acre paddocks of corn residue. Four treatments with two replications per treatment were: 1) grazing corn residue with no supplementation (control), 2) grazing corn residue plus DDGS delivered daily (daily), 3) grazing corn residue plus DDGS delivered every third day (3 d) and 4) grazing corn residue plus DDGS delivered every sixth day (6 d). The DDGS was fed at 0.35 percent BW per day. Body weight and body condition scores were recorded on two consecutive days at the beginning and end of the study. Gusty winds in excess of 60 mph prior to harvest resulted in approximately 890 pounds/acre of corn grain on the ground. Above-normal temperatures were encountered through the six-week course of the study. Average daily gain was greater ($P < 0.05$) following daily (3.5 ± 0.26 pounds) and every third day supplement delivery (3.6 ± 0.26 pounds) relative to control (2.7 ± 0.26 pounds) or every sixth day supplement delivery (2.6 ± 0.26 pounds). Body condition score change was greater ($P < 0.05$) following daily supplement delivery (0.7 ± 0.08) relative to every sixth day supplement delivery (0.4 ± 0.08). Results show that, under certain conditions such as mild weather and excessive grain drop, cows grazing corn residue may not require supplementation until later in the grazing season. Secondly, supplement can be fed every third day with no detrimental effects on animal performance.

Introduction

Corn residue, which includes dropped ears, leaves and husks, and stalks remaining after the corn harvest, is a readily available feed resource for winter grazing in corn-growing areas of North Dakota (Lardy, 2011), but the low protein and mineral contents of corn residue can lead to poor animal performance. Improving the nutrient supply to cows grazing corn residue can be accomplished by targeted supplementation that provides missing nutrients in corn residue.

For supplements such as distillers grains with solubles (DDGS) that can be fed in loose form, the most common practice is to feed the supplement daily. Producers are interested in supplement delivery methods that reduce labor costs, as is the case when delivering the supplement less frequently.

Reducing supplement delivery frequency can reduce labor and fuel costs, provided animals continue to consume feed and maintain good nutrient status (Schauer et al., 2005). Also, reducing the frequency of supplement delivery may improve forage utilization because animals spend less time at the feeding trough (Brundyn et al., 2005).

Several studies (Brundyn et al., 2005; Schauer et al., 2005; Loy et al., 2007; Canesin et al., 2014; Klein et al., 2014) have demonstrated the benefits of reducing the frequency of supplement delivery to grazing animals. These studies were conducted in warm-weather grazing situations.

Winters in North Dakota, characterized by cold temperatures, low wind chills and freezing rain, offer unique challenges that need to be taken into account when evaluating supplements for winter grazing. This study was conducted to evaluate the effect of frequency of supplement delivery to cows grazing corn residue on animal performance in a northern climate.

Experimental Procedures

Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee. This study was conducted in the fall of 2015 (Nov. 9 to Dec. 16) at

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the Central Grasslands Research Extension Center. Eighty second- and third-calf cows (1,146 ± 76 pounds BW) in their second trimester were assigned randomly to one of eight 10-acre paddocks (10 cows/paddock) and allowed to graze corn residue for 36 days.

Each paddock subsequently was assigned to receive one of four treatments (two paddocks/treatment): 1) grazing corn residue with no supplementation (control), 2) grazing corn residue plus DDGS delivered daily (daily), 3) grazing corn residue plus DDGS delivered every third day (3 d) and 4) grazing corn residue plus DDGS delivered every sixth day (6 d). Corn residue grazing was controlled using high-tensile electric wire, which allowed access to a quarter of the paddock at a time.

The amount of DDGS (30 percent crude protein; 73 percent total digestible nutrients) delivered as a supplement, 4 pounds/head/day, was based on chemical composition of corn residue samples collected randomly from paddocks and was determined using CowBytes (v 5.31; Alberta ARD, 2012). Cows had ad libitum access to water and a mineral lick.

Body weights and body condition scores were measured at the start and end of the study. The amount of corn left in the field (bushels/acre) postharvest was estimated in four paddocks by counting the number of ears in three different 100-foot strips in each paddock (Rasby et al., 2014).

Results and Discussion

The nutrient content of corn residue was generally poor (Table 1). Components with the highest nutrient content were the grain and leaf. The husk was low in protein but had a good energy profile, while the cob was poor in protein and energy.

We found that daily gains and body condition score (BCS) changes were positive for all cows, including those that were not supplemented. Daily or every third day supplement delivery resulted in greater (P = 0.02) daily gains relative to control and every sixth day supplement delivery (Table 2). Body condition score change was less (P = 0.04) following every sixth day supplement delivery relative to daily supplement delivery. We found no difference in BCS changes among control, daily and every third day supplement delivery.

The low nutrient content of corn residue fed shows that the initial premise of the study that cows grazing corn residue require supplementation was justified. Indeed, studies (Gustad et al., 2006; Warner et al., 2011) have shown beneficial effects of supplementing cattle grazing corn residue. We attributed positive daily gains and BCS changes in this study to nutrient content of corn residue, corn residue grazing management and environmental conditions.

The excessive amount of downed ears in this study was unexpected, with estimates before the start of the study indicating a minimum of 16 bushels of corn grain. Winds in excess of 60 mph, which occurred just before corn harvest, were responsible for most of this grain.

Compared with other components of the corn plant, the grain has a high nutrient content, with adequate protein and energy (Table 1) to meet nutrient requirements of overwintering cows. Cattle prefer downed ears, as well as leaf and husk material, and cows will start

Table 1. Composition (DM basis) of corn residue.

		Component				
	Whole[1]	Grain	Leaf	Husk	Cob	Stalk
CP, %	3.0	9.4	7.1	2.6	2.4	2.8
TDN, %	57	89	56	60	17	55
NDF, %	75.1	8.7	68.3	80.3	83.2	71.6
ADF, %	44.8	2.4	45.5	40.6	43.0	46.4
Ca, %	0.1	0.04	0.9	0.1	0.05	0.1
P, %	0.05	0.3	0.09	0.04	0.05	0.07
K, %	0.6	0.3	0.2	0.4	0.4	1.7
Mg, %	0.2	0.1	0.4	0.2	0.09	0.1
S, %	0.04	0.1	0.1	0.04	0.03	0.04

[1]Includes all components except grain.

Table 2. Effect of supplement delivery frequency on cow performance.

		Delivery frequency				
	Control[1]	Daily	3 d	6 d	SE	*P*-value
Initial BW, lb.	1,158	1,142	1,164	1,135	17.6	0.63
Final BW, lb.	1,255	1,267	1,293	1,229	19.4	0.15
ADG, lb./day	2.7[b]	3.5[a]	3.6[a]	2.6[b]	0.26	0.02
Initial BCS	4.7	4.6	4.8	4.9	0.073	0.06
Final BCS	5.3	5.3	5.4	5.3	0.075	0.57
BCS change	0.5[ab]	0.7[a]	0.6[ab]	0.4[b]	0.078	0.04

[1]Grazing corn residue with no supplementation.
[ab]Means in the same row followed by a different letter differ (P < 0.05).

with downed ears upon getting into a field, then clean up leaves and husks before moving on to cobs and, finally, to stalks (Lardy, 2011).

Movement of the electric fence in this study may have been too frequent and did not allow cows to graze the corn residue down to stalks. As a result, the nutrient profile of consumed feed was probably greater than the analyzed nutrient profile of whole-corn residue shown in Table 1.

The fall of 2015 had greater than normal temperatures. Normal high and low temperatures are 38 F and 19 F for November and 27 F and 6 F for December, respectively. Average maximum and minimum temperatures during our study were 43 F and 19 F for November and 27 F and 14 F for December, respectively. This trend in temperature was consistent throughout the grazing period (Figure 1).

Based on these yearly temperature differences, planned supplementation strategies may have provided more energy and protein than was required to meet animal needs. The amount of DDGS fed in this study was designed to meet nutrient shortfalls expected from feeding corn residue during the cooler part of the year in the northern Great Plains.

Results suggest that under certain conditions such as mild weather and excessive grain drop, supplementation may not be required until later in the grazing season. Secondly, with excessive grain drop, grain intake should be limited by delaying access to new corn residue areas until cows are forced to graze other residue components. Further, when necessary, DDGS can be fed as a supplement every third day to reduce winter labor costs, with no detrimental effects on animal performance.

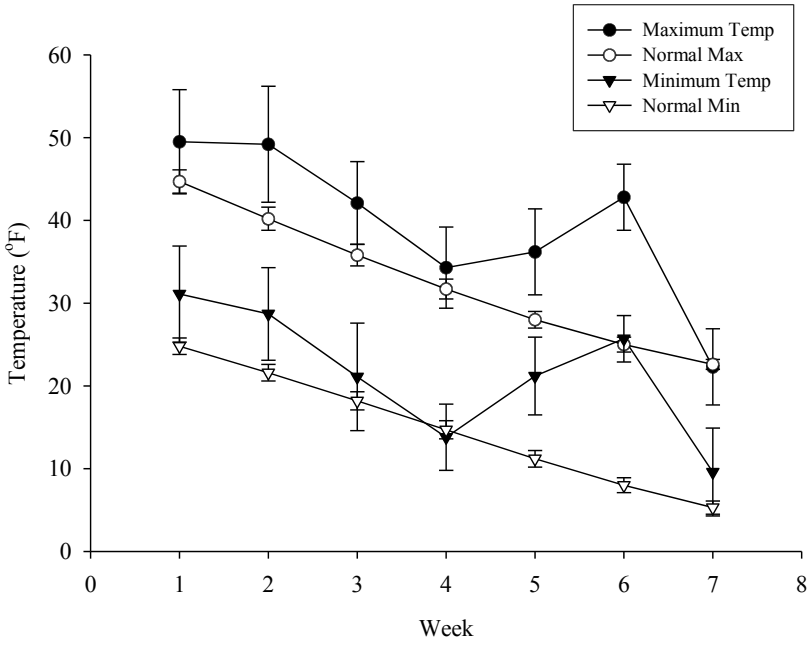

Figure 1. Weekly temperatures (mean ± SD) for November and December 2015 at CGREC.

Week 1 = Mean temperature for Nov. 1 to 7, etc. Data source: North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu

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Quality of hay from road right of ways in North Dakota

Miranda A. Meehan[1], Kevin K. Sedivec[2], Fara Brummer[3] and Carl R. Dahlen[1]

Hay harvested from forages growing in road ditches commonly is used as feed for beef cattle, yet little is documented regarding the nutrient content of ditch hay, the amount of ditch hay harvested or the intended use of ditch hay in North Dakota. Extension agents collected 182 ditch hay samples from 36 counties across North Dakota, and samples were analyzed to reveal factors contributing to variation in nutrient quality and recommendations for balancing quality and quantity of forage harvested. The results of this project revealed factors influencing ditch hay quality and management practices that can be implemented to improve hay quality, while reinforcing the importance of testing forage quality.

Summary

Extension agents engaged producers in 36 counties throughout North Dakota to collect a total of 182 samples of hay harvested from road rights of way (ditch hay). Samples were classified based on the county where the hay was produced, and the cutting date, whether the hay was rained on, type of binding material used, target species for feeding the hay, and whether the hay was going to be fed on the ground, in a hay feeder or as part of a total mixed ration (TMR) were reported. Each hay sample was analyzed for concentrations of dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro organic matter digestibility (IVOMD), calcium (Ca) and phosphorus (P). Samples were bound with plastic twine (40.6 percent), net wrap (40 percent) or sisal twine (19.4 percent). Producers primarily planned to feed ditch hay to cattle (about 90 percent), with the remaining hay produced for horses, sheep and bison. Producers intended to feed bales using a bale feeder (63.9 percent), directly onto the ground (36.8 percent) or with a TMR (11.6 percent). The mean nutrient content value for samples was 91.4 percent DM, 10.8 percent ash, 8.5 percent CP, 65.1 percent NDF, 52 percent total digestible nutrients (TDN), 0.61 percent Ca and 0.2 percent P. Crude protein content was impacted by the cutting day ($P < 0.01$), with forage harvested early in the year having greater concentrations, compared with those harvested later in the year. Rain during the interval from cutting to baling reduced the TDN content by 2 percentage points ($P = 0.01$). Results highlight the variability observed in ditch hay nutrient content and reinforce the importance of testing individual feeds to ensure appropriate delivery of nutrients to different classes of livestock.

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Introduction

Hay from road ditches commonly is harvested and used as feed for beef cattle and other livestock. In some cases, the forages being harvested from ditches are very high quality, while in others, the hay is harvested well after dedicated hay fields, and optimizing quality may not be a top priority.

In addition, different types of roads (federal, state, county, township, etc.) may have specific regulations about the time of year forages must be cut and/or removed from the ditches. These and other factors may influence hay quality. Little is known about the nutrient content of ditch hay, the amount of ditch hay harvested or the intended use of ditch hay in North Dakota.

Experimental Procedures

A total of 182 hay samples were collected from road rights of way and hay lots in 36 counties across North Dakota (Figure 1). Samples were collected from July 15 through Oct. 31, 2015. County Extension agents were critical to the success of this effort, with agents from 29 counties volunteering to aid in collecting and characterizing samples.

Hay samples were composed of hay collected from five or more bales from each sampling location. Samples were collected using a Penn State Forage Probe. Samples were classified based on the county where hay was produced, cutting date, whether hay was rained on, type of binding material used, type of plant species present in the hay and type of road adjacent to the ditches

Additional information regarding the miles of ditch hay baled by

producers, percentage of hay inventory represented by ditch hay, target species for feeding the hay, and whether hay was going to be fed on the ground, in a hay feeder or as part of a total mixed ration also was collected.

Each hay sample was analyzed for concentrations of dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), in vitro organic matter digestibility (IVOMD), calcium (Ca) and phosphorus (P). Following analysis, individual reports of the nutrient content of sampled hay, along with appropriate feeding recommendations, were distributed to participating producers.

Means and standard errors of nutrient content of samples were determined. A general linear model (GLM) and single factor univariate analysis of variance using PROC GLM SAS (Ver. 9.2, SAS 2002) was used to determine the impacts of cutting date, rain, road type and region on nutrient content. Mean separations test was performed using the LSMEANS procedure with the Tukey adjustment.

Results and Discussion

Plastic twine (40.6 percent) and net wrap (40 percent) were the bale binding materials most often used, with a smaller proportion of bales being bound with sisal twine (19.4 percent). A majority of the hay sampled was going to be fed to cattle (about 90 percent), with the remaining proportion split among horses, sheep and bison. The feeding method indicated most often was using a bale feeder (63.9 percent), followed by feeding on the ground (36.8 percent) and feeding with a TMR (11.6 percent).

Variability also was observed in the analyzed nutrient content of the forages (Table 1). Some samples tested were extremely high quality, whereas the quality of other samples was poor.

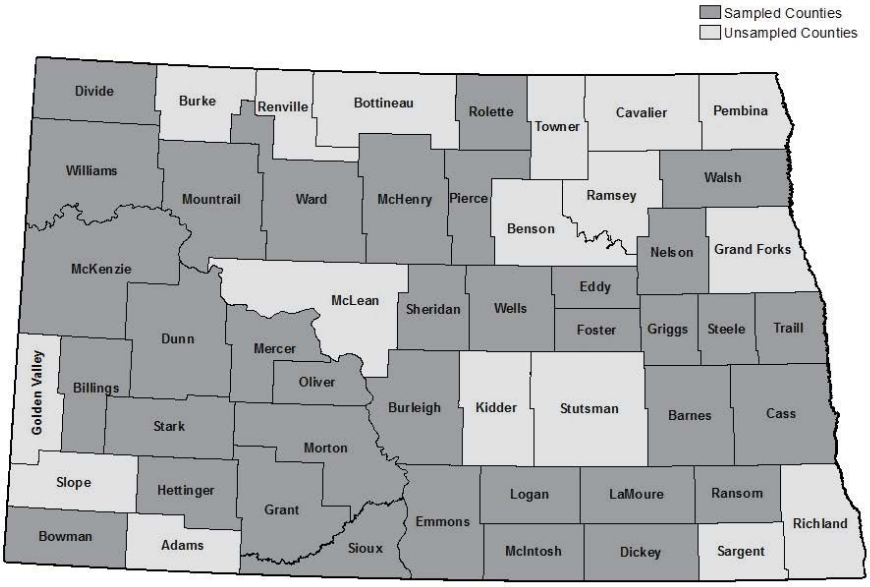

Figure 1. Location of North Dakota counties from which road right-of-way hay samples were collected in 2015.

Table 1. Nutrient content of ditch hay samples.

Item	Average	Minimum	Maximum
Dry matter (DM)	91.4	83.7	95.6
Ash	10.8	6.8	37.0
Crude protein (CP)	8.5	5.9	17.0
Neutral det. fiber (NDF)	65.1	35.2	53.6
Total dig. nutrients (TDN)	52.0	34.8	58.5
Calcium (Ca)	0.61	0.28	1.44
Phosphorus (P)	0.20	0.10	0.35

Unpaved roads in several parts of North Dakota are experiencing heavy traffic related to oil-field activities, and dust has the opportunity to collect on standing and cut forages from ditches adjacent to these heavily used roads. Dust contamination was noted in several of the samples taken for the core oil-field counties, with ash content (essentially inert, indigestible material) reaching a maximal value of 37 percent, compared with our average value of 10.8 percent.

The cutting date of samples ranged from June 10 to Sept. 10. The concentration of crude protein in samples was impacted by the cutting date, with forage harvested early in the year having greater concentrations of crude protein, compared with those harvested later in the year (Figure 2). This trend was expected because the protein content of standing forages decreases with plant maturity during the course of the growing season.

Across North Dakota, road ditches consist of cool-season introduced grass species, the most

common being smooth bromegrass. These species initiate growth early in the spring and reach peak production in early July. To achieve the best combination of quality and quantity, this would be the optimal time to harvest; however, specific regulations regarding the timing of ditch hay harvest for roads under certain jurisdictions may prohibit harvesting forage of optimum quality.

Approximately 25 percent of the samples submitted were rained on during the interval from cutting to baling. The number of days the forages were wet in the swath ranges from one-half a day to more than 14 days, with four days being the average. Rain was associated with an increased ash content, and the TDN content of samples that had been rained on was 2 points less than those that had not had rain fall on them.

To understand the variation in forage quality across the state, samples were divided to represent eastern and western regions. The region did not impact the protein content of the forages, but acid detergent fiber and TDN were impacted.

Samples from the eastern region had greater TDN (via reduced ADF), compared with samples from the western region. Variations in soil type, temperature, moisture and species composition between regions all likely contributed to the differences observed.

Individual reports of the nutrient content of sampled hay allowed producers to incorporate the hay into a ration while ensuring the nutritional requirement of their livestock were being met. In addition, these producers have an increased awareness of factors influencing hay quality and management practices that can be implemented to improve hay quality.

The results of this project allowed us to understand the variation in quality of ditch hay within a single year's harvest and factors contributing to that variation. The largest factor influencing hay quality is cutting date. To achieve the best combination of quality and quantity, early July is the optimal time to harvest. The variation in the results reinforces the importance of testing nutrient contents of individual feeds to ensure appropriate delivery of nutrients to different classes of livestock.

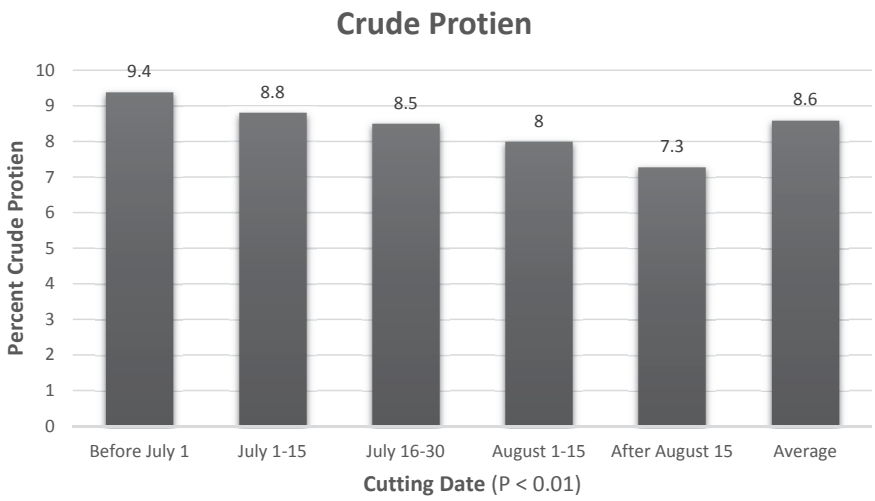

Figure 2. Concentrations of crude protein in ditch hay samples by cutting date

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Effects of grazing intensity and advancing season on chemical composition and in vitro organic matter disappearance in steers supplemented with dried distillers grains grazing mixed-grass prairie

Kayla E. Chilcoat[1], Matthew S. Crouse[1], Bryan W. Neville[2] and Joel S. Caton[1]

The objectives of this study were to evaluate the effects of advancing season and grazing intensity on diet chemical composition and in vitro organic matter disappearance (IVOMD). The results indicate that advancing season does and grazing intensity does not influence chemical composition of the diet. The influence of grazing intensity may have been mitigated by the supplemental feeding of dried distillers grains with solubles.

Summary

A study was conducted to evaluate the influence of advancing season and grazing intensity on dietary chemical composition and in vitro organic matter disappearance (IVOMD) in beef steers grazing mixed-grass prairie in the Missouri Coteau of south-central North Dakota. Five sampling periods were conducted from mid-May to early September 2015. Twelve ruminally cannulated crossbred steers were used to collect diets, while 188 crossbred steers were used to maintain specific grazing intensities on 12 pastures. Treatments were light (LT), moderate (MOD), heavy (HVY) and extreme (EXT) grazing intensities. Each treatment was assigned to three pastures. Grazing treatment × sampling period interactions were not present ($P \geq 0.29$) for all variables measured except IVOMD ($P < 0.01$). We found no main effects of grazing treatment for neutral detergent fiber (NDF), acid detergent fiber (ADF), total nitrogen (N), soluble N (SN), insoluble N (IN), and acid detergent insoluble nitrogen (ADIN). Responses to grazing season were evaluated with linear, quadratic and cubic contrasts. Neutral detergent fiber increased linearly ($P < 0.01$) and cubically ($P = 0.01$), while ADF tended (P = 0.17) to increase linearly with advancing season. Dietary N decreased linearly ($P < 0.01$), quadratically ($P = 0.01$) and cubically ($P = 0.01$). Soluble N and IN expressed a linear ($P < 0.001$) and quadratic ($P = 0.03$) decrease across advancing season, while IN also showed a cubic response ($P < 0.001$). Acid detergent insoluble N did not change as the season advanced ($P > 0.14$). In vitro OM digestibility decreased from May to September ($P < 0.01$) in all sampling periods, but did not show any trends across treatments ($P = 0.82$). However, IVOMD did show a treatment × period interaction ($P < 0.01$). In summary, these data indicate increases ($P < 0.001$) in dietary NDF and decreases ($P < 0.001$) in N, SN, IN and IVOMD with advancing season. These data suggest seasonal factors are a more important driver of grazed masticate forage nutrient composition than the grazing intensities evaluated in this study.

Introduction

The dietary chemical composition of grazed forage, when coupled with forage intake and digestion, are important factors in rangeland-based cattle production systems. We know that as forage maturity increases, dietary crude protein (CP), digestibility and intake often decline, while dietary fiber usually increases (McCollum et al., 1985; Olson et al., 1994; Johnson et al., 1998; Cline et al., 2009).

Bryant et al. (1970) found that if grazing pressure is intense enough to cause a low availability of herbage, the quality of herbage ingested decreases due to the reduced opportunity for selective grazing. Furthermore, as grazing intensity increases, diet quality decreases (Pieper et al., 1959).

Maintaining herds on native grass to reduce input costs of harvested and purchased feeds is common for beef cattle operations. Therefore, modulating cattle stocking rates on pasture is a common management tool used to achieve long-term goals of optimizing forage use, livestock production and agroecosystem sustainability (Biondini et al., 1998).

However, information regarding the impact of grazing intensity on forage intake and digestion by cattle grazing mixed-grass prairie is lacking. Hence, our objectives were to evaluate the effects of advancing season and grazing intensity on diet

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chemical composition and in vitro OM digestibility (IVOMD) by steers grazing mixed-grass prairie in the Missouri Coteau of south central North Dakota.

Experimental Procedures

Protocols described herein were approved by the North Dakota State University Institutional Animal Care and Use Committee. Angus-cross beef steers (n = 188; 706 ± 77.6 pounds initial body weight [BW] were used to establish grazing pressure, and 12 ruminally cannulated steers (600 ± 74.1 pounds) co-grazed with the noncannulated animals.

All steers had free access to water and trace mineral salt blocks (salt 95.5 to 98.5 percent, zinc 3,500 parts per million [ppm], iron 2,000 ppm, manganese 1,800 ppm, copper 280 to 420 ppm, iodine 100 ppm and cobalt 60 ppm; American Stockman Hi-Salt with EDDI; North American Salt Co., Overland Park, Kan.).

Steers were fed dried distillers grains with solubles (DDGS) daily at sunrise at 0.3 percent of their BW. All animals were weighed every 28 days to determine gains as the grazing season progressed, as well as to adjust the DDGS fed. All steers were implanted with Revalor-G (40 milligrams [mg] of trenbolone acetate and 8 mg estradiol; Intervet Inc., Millsboro, Del.) one day before being turned out on pasture.

The grazing trial was conducted at the Central Grasslands Research Extension Center (CGREC) on the Missouri Coteau in south-central North Dakota. The study site had been divided into 12 pastures of approximately 31.9 acres each in 1989. Cattle grazed from May 15 to Sept. 11, 2015. Patton and Nyren (2014) reported the botanical composition of the plant communities at the study site the year before this study.

The most common grasses in 2014 were Kentucky bluegrass *(Poa pratensis L.)*, western wheatgrass *(Pascopyrum smithii A.)*, sun sedge *(Carex inops)*, green needlegrass *(Nassella viridula)*, obtuse sedge *(Carex obtusata Lilj.)* and blue grama *(Bouteloua gracilis)*. Common forbs were heath aster *(Symphyotrichum ericoides)*, common dandelion *(Taraxacum officinale)* and western yarrow *(Achillea millefolium L.)*. Buckbrush *(Symphoricarpos occidentalis)* was the only common shrub.

Steers were stocked at densities so that at the end of the grazing season, 65 (LT), 50 (MOD), 35 (HVY) and 20 percent (EXT) of an average annual above-ground biomass remained at the end of the grazing season. Each of the cannulated steers was assigned to a pasture at random, with each treatment having three pastures. Animals were removed at the end of the grazing season when forage utilization on half of the pastures had reached desired grazing intensity.

Five 10-day collection periods were conducted for May, June, July, August and September. Sampling periods began with collection of diet samples.

At sunrise, cannulated steers were restrained and subjected to total ruminal evacuation. Ruminal digesta was removed physically from each cannulated steer and the rumen then was double-rinsed with water to assure complete removal of contents.

Steers then were allowed to graze on their assigned pastures for 30 to 45 minutes. Then ruminal masticate samples were removed, labeled and immediately placed on ice. Previously collected ruminal contents were placed back in the animal. All samples then were frozen at minus 20 C for later analysis.

Masticate samples were lyophilized (Genesis 25LL, Virtis, Gardiner, N.Y.). Dry matter, ash and CP were determined using AOAC (1990). Neutral detergent fiber and ADF of diet samples were determined using ANKOM procedures (ANKOM, Macedon, N.Y.). Acid detergent insoluble N was calculated as N remaining in the ADF residue.

Soluble N was extracted with 0.15 M NaCl according to the procedure of Waldo and Goering (1979). In vitro OM digestibilities (Tilley and Terry, 1963) were conducted to determine IVOMD. Masticate forage and ruminal fluid collected from each animal was used for in vitro determinations.

Chemical composition and IVOMD were analyzed as a repeated measures design using a mixed model approach in SAS (SAS Inst. Inc., Cary, N.Y.). Effects for sampling period, grazing treatment and period × treatment interactions were included in the model. In the absence of interactions, orthogonal contrasts were used to determine linear, quadratic and cubic, responses across the grazing season (sampling period).

Sampling period × grazing treatment interactions ($P \leq 0.05$) were detected for IVOMD; therefore, the simple effect means were separated using the LSMEANS statement in SAS. The procedures of SAS were used for all statistical analysis and P-values ≤ 0.05 were considered different.

Results and Discussion

No treatment × period interactions ($P > 0.05$) were observed for diet analyses, with the exception of interactions of IVOMD, which will be discussed later in this section. Therefore, main effect means are reported for grazing intensity treatment and grazing period (Table 1).

Organic matter, NDF and ADF of cattle diets were not affected ($P > 0.05$) by grazing intensity. Crude protein, total N, soluble N (SN), insoluble N (IN) and ADIN also did not differ among grazing intensity treatments ($P > 0.05$).

Table 1 shows the effects of

grazing intensity and advancing season on the chemical composition of the diet as well as IVOMD. Neutral detergent fiber and ADF changed with advancing season ($P < 0.01$). These results coincided with Olson et al. (1994) for south-central North Dakota, Johnson et al. (1998) for western North Dakota and McCollum et al. (1985) for south-central New Mexico.

Neutral detergent fiber increased with advancing season ($P < 0.01$ and $P = 0.01$, respectively for a linear and cubic response) and ADF tended ($P = 0.17$; linear) to increase as the season advanced. These responses are supported by previous data from south-central North Dakota (Olson et al., 1994) and western North Dakota (Johnson et al., 1998), as well as south-central New Mexico (McCollum et al., 1985); these researchers observed similar responses.

Nitrogen (percent of OM) decreased linearly ($P < 0.01$), quadratically ($P < 0.01$) and cubically ($P < 0.01$) as the season advanced. Typically, forage masticate N concentration declines with increasing forage maturity associated with advancing season. Such was the case in our study and the work of others within the region (Olson, et al., 1994; Johnson, et al., 1998; Cline et al., 2009). Soluble N decreased ($P < 0.01$) in a linear fashion, whereas IN data were represented by declining linear, quadratic and cubic responses ($P < 0.01$).

McCollum et al. (1985) also found that N, SN and IN decreased with advancing grazing season. In the present study, ADIN was not impacted by advancing season. However, Cline et al. (2009) observed an increase in ADIN from late June to mid-November.

We found a sampling period × by grazing intensity interaction ($P = 0.01$; Table 1) for in vitro organic matter disappearance (IVOMD); therefore, interactive means are discussed (data not shown). In vitro OM digestibility decreased from May to September ($P < 0.05$) in all grazing intensities. In May, IVOMD was similar across all grazing intensities ($P > 0.05$). In June, LT and MOD had greater ($P < 0.05$) IVOMD, compared with HVY, while EXT was similar to all grazing intensities (75.7, 73.4, 62.9 and 69.1 ± 2.8 percent, respectively).

In July, LT had the lowest and HVY the greatest IVOMD ($P < 0.05$). In August, LT had similar ($P > 0.05$) IVOMD, compared with all other grazing intensities, while MOD was lower ($P < 0.05$) than HVY. In September, IVOMD was 52.5, 44.9, 50.3, and 42.8 ± 5.1 percent; $P > 0.05$) for LT, MOD, HVY and EXT grazing intensities.

Table 1. Effects of grazing intensity and advancing season on dietary chemical composition and in vitro OM digestibility (IVOMD) in steers grazing mixed-grass prairie.

	Grazing Intensity (TRT)[1]					Grazing Period (PD)[2]						*P*-value[3]					
Item	LT	MOD	HVY	EXT	SEM[4]	May	Jun	Jul	Aug	Sep	SEM[5]	TRT	PD	TRT × PD	L	Q	C
No. of Observations	15	15	15	15	-	12	12	12	12	12	–	–	–	–	–	–	-
OM, %	81.3	82.2	80.6	82.3	1.49	74.6	82.4	83.9	83.7	83.2	3.08	0.83	0.05	0.44	0.02	0.02	0.16
	Percentage of OM																
NDF	67.5	69.6	70.7	65.6	2.05	58.4	69.9	67.5	70.7	75.2	3.81	0.34	<0.01	0.89	<0.01	0.32	0.01
ADF	38.5	40.2	41.5	36.1	1.85	37.2	38.5	37.1	39.5	43.1	4.05	0.25	<0.01	0.87	0.17	0.33	0.44
CP	18.7	17.7	17.8	19.6	0.63	29.9	18.3	16.9	14.9	12.3	0.86	0.18	<0.01	0.63	<0.01	<0.01	<0.01
N	2.99	2.84	2.85	3.14	0.10	4.78	2.92	2.70	2.38	1.97	0.14	0.18	<0.01	0.63	<0.01	<0.01	<0.01
Soluble N	0.70	0.73	0.69	0.82	0.06	1.08	0.81	0.66	0.57	0.55	0.09	0.36	<0.01	0.29	<0.01	0.03	0.73
Insoluble N	2.28	2.11	2.16	2.32	0.08	3.70	2.11	2.05	1.81	1.42	0.12	0.22	<0.01	0.59	<0.01	<0.01	<0.01
ADIN	0.48	0.42	0.44	0.47	0.04	0.52	0.37	0.47	0.44	0.45	0.06	0.77	0.26	0.93	0.70	0.31	0.15
IVOMD	60.4	62.6	63.4	60.6	2.62	75.9	70.3	62.1	52.8	47.6	3.35	0.82	<0.01	0.01	0.97	0.97	0.14

[1]LT = light, MOD = moderate, HVY = heavy and EXT = extreme grazing intensities.

[2]Grazing period collections were May (May 11 to 22), Jun (June 10 to 19), Jul (July 8 to 17), Aug (Aug. 5 to 14), and Sep (Sept. 2 to 11).

[3]Significance level of the F-test for treatment (TRT), period (PD), treatment by period (TRT × PD), linear (L), quadratic (Q) and cubic (C) effects for items.

[4]Standard error of mean for grazing intensity, n = 15. Most conservative standard error mean values were used.

[5]Standard error of mean for grazing period, n = 12. Most conservative standard error mean values were used.

The results of this study demonstrate that grazed forage by beef cattle in the Missouri Coteau increase in fiber and decrease in N as season advances. Grazing intensity had little impact on grazed forage nutrient composition. Consequently, previously observed differences in livestock production due to grazing intensity in the Missouri Coteau must be driven by changes in dietary intake or in vivo digestion. Additional research accessing changes in intake and rates of digestion are needed.

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The use of testicular fine-needle aspiration, histology and immunohistochemistry for determining bull fertility at an early age

Nicolas Negrin Pereira[1], Pawel Borowicz[1], Bryan Neville[2], Jordan Flaten[1] and Carl R. Dahlen[1]

The objective of the study was to assess the use of different techniques to allow for early, low-cost, reliable and low-invasive methodologies for the determination of Sertoli cell populations and germ cells in the bull. The techniques are: fine-needle aspiration with a fine needle (FNA-F), fine-needle aspiration with a gross needle (FNA-G), classic histology cuts and immunohistochemistry (androgen receptor expression by fluorescence). A significant correlation exists between histology and immunohistochemistry measurements, which positions the immunohistochemistry technique as a novel, very specific and reliable methodology for precocious determination of future fertility in young bulls.

Summary

Testicular parenchyma samples from 14 young peri-pubertal bulls were taken for the assessment of four different techniques: fine-needle aspiration using two different needle calibers or by open cut for histology (hematoxylin/eosin) or immunofluorescence (androgen receptor expression). For fine-needle aspiration, we used two different needle calibers attached to a syringe: 22G (FNA F) or 16G (FNA G). Once the needle was inserted in the testicular parenchyma, a vacuum was produced inside the syringe by pulling back the plunger. A smear was obtained by expelling the sample onto a glass slide. Then it was air-dried, fixed with 70 percent alcohol and stained with hematoxylin/eosin. Tissue samples were cut into 4- by 4-millimeter (mm) pieces using a microtome blade, fixed in a 10 percent formaldehyde solution, embedded in paraffin and cut into sections 5 micrometers (µm) thick using a microtome. Samples were stained with hematoxylin-eosin for histology or incubated sequentially with mouse monoclonal antibody to androgen receptor and goat-antirabbit (IgG CF633) fluorescent stain. To evaluate slides, images were taken at 200 times (FNA and histology) or 100 times magnification (immunohistochemistry) using an epifluorescence microscope equipped with a camera. Within each image, four to six seminiferous tubules within the five randomly chosen fields were selected for determination of Sertoli cell number and germ cell number. The ratio of germ to Sertoli cells was calculated and the CORR procedure of SAS was used to determine correlation of this ratio among each respective evaluation technique. Differences were considered significant at $P < 0.05$. A correlation coefficient of 0.58 ($P < 0.001$) was observed among the technique of histology (5.27 ± 0.41) and AR expression through fluorescence (4.44 ± 0.60) for germ cells/Sertoli cell ratio. No significant correlations were found among FNA techniques and histology or immunohistochemistry cell ratios. Expression of AR by fluorescence in Sertoli cells represents a new, highly specific technique for precocious detection of more potential fertile bulls as young peri-pubertal calves.

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Introduction

Fertility in the bull can be defined as the ability to produce viable calves. This characteristic of the bull is key in beef farm profitability. In the U.S., more than 95 percent of the herds rely on natural service. An early and accurate fertility prediction technique in the bull could have a great impact on profitability of beef operations (Wiltbank et al., 1986).

A bull breeding examination has proven to be a reliable and cost-effective technique to detect those animals that are satisfactory potential breeders and those not apt for their use (Barth et al., 2002). The inclusion of semen analysis has improved the effectiveness of this examination, but a significant range of different fertility levels still occurs within those bulls classified as apt for breeding (Chenoweth and McPherson, 2016).

Researchers have demonstrated for several years the importance that the final establishment of the Sertoli cell population has in determining future daily sperm production in most mammals (Berndston et al., 1987; P.J. O'Shaughnessy et al., 2011). The relationship between

the size of the Sertoli cell population and number of germ cells has been used as a tool for determining fertility in different mammal species (Berndston et al., 1987). Determining the size of the Sertoli cell population in the bull at an early age can be a powerful tool in detecting those individuals with a potential higher sperm capacity.

The fine-needle aspiration technique has been used for several years in human and stallion testicles, providing a reliable, low-cost, diagnostic, low-invasive tool with minimal complications for cytology studies in the testis (Aridogan et al., 2003; Leme et al., 2012).

Expression of AR has been described in specific cells within the mammalian testis, such as in Leydig and peritubular myoid cells being expressed exclusively in Sertoli cells within the seminiferous tubules but not being expressed by germ cells (O'Hara et al., 2015).

Hardly any information is available about the application of different techniques for the determination of Sertoli and germ cell populations in the male calf and their potential use for detecting higher daily sperm producers later in adult life as bulls. The aim of this study was the comparison of four different techniques for determining Sertoli and germ cell population sizes in the peripubertal bulls: FNA F (22G needle), FNA G (16 G needle), classic histology cuts (hematoxylin/eosin stain) and immunofluorescence (AR expression).

Experimental Procedures

Fourteen Aberdeen Angus and Shorthorn bull calves (287 ± 3.3 days of age, 683 ± 29 pounds) from the North Dakota State University Beef Unit were used in the study. Previous to castration, bulls were restrained and given epidural anesthesia.

The scrotum skin was opened using a scalpel and the testicles exposed. Plexus pampiniform, testicular artery and vas deferens were crushed and severed using an emasculator to prevent bleeding.

Testicular tissue samples were obtained for evaluation via: 1) fine-needle aspiration with a fine needle (FNA F) using a sterile 22-gauge, 1¼-inch needle, 2) fine-needle aspiration with a gross needle (FNA G) using a sterile 16-gauge, 1¼-inch needle, 3) histology cut (stained with hematoxylin and eosin) and 3) immunofluorescence (androgen receptor expression).

For the FNA techniques, needles were connected to a 5- or 10-milliliter (ml) syringe and gently inserted perpendicularly into the testicular parenchyma. Once fully inserted in the parenchyma, the plunger was pulled back to produce a vacuum inside the syringe.

The needle was moved backward and forward within the testis two or three times for approximately four seconds. Once the needle was outside the testicle, a syringe filled with air was reattached to the needle and the plunger pressed to expel the sample onto a glass slide.

A smear was produced by sliding a second glass slide at an angle, extending the sample on the glass surface. The slide then was air-dried, fixed in 70 percent alcohol and stained with hematoxylin-eosin.

For histological examination, 4- by 4-mm testis parenchyma samples from the same region of each testis were taken and placed in a 10 percent formaldehyde fixative solution, embedded in paraffin and cut in 5-µm-thick sections using a microtome (Leica Biosystems Inc., Buffalo Grove, Ill.). Slides for histology were stained with hematoxylin-eosin.

Immunohistochemistry sections were submerged in sodium citrate buffer and placed in an antigen retriever (2100 Retriever, Aptum Biologics, UK) and incubated sequentially using mouse monoclonal antibody to androgen receptor (ab9474, abcam, Cambridge, Mass.) at 4 C overnight with agitation, and then stained with goat-antirabbit IgG CF633 fluorescent stain.

For each slide or tissue section, images were taken at 200 times magnification (FNA smears and histology slides) or 100 times magnification (immunohistochemistry slides) using a Zeiss Imager M2 epifluorescence microscope equipped with Zeiss piezo automated stage and AxioCam HRm camera (Carl Zeiss International, Jena, Germany). Image analysis (Image-Pro Plus, Media Cybernetics Inc., Bethesda, Md.) was performed for images of five randomly chosen fields. Within each image, four to six seminiferous tubules were selected randomly for Sertoli and germ cells individual cell counts using the Image-Pro Plus image analysis software (Media Cybernetics Inc., Rockville, Md.).

The germ cell to Sertoli cell ratio was calculated by dividing the total number of germ cells by the total number of Sertoli cells within each tubule. The mean of all ratios were determined for each testicle and analyzed using the correlation procedure of SAS (SAS Inst. Inc., Cary, N.C.). Significant differences were considered when $P < 0.05$.

Results and Discussion

The different ratios between total germ cells and Sertoli cells were determined for each technique and presented in Table 1.

A correlation of 0.58 was observed ($P = 0.001$) between germ-to-Sertoli cell ratios obtained via histology and ratios obtained via immunohistochemistry (Table 2). In addition, a correlation of 0.69 was observed in germ-to-Sertoli ratio obtained via FNA F and FNA G techniques ($P = 0.001$). No cor-

relations were found, however, in germ-to-Sertoli cell ratios between samples obtained via FNA F and FNA G techniques (3.60 ± 0.47 and 3.59 ± 0.39, respectively) and histology (5.27 ± 0.41) or AR expression by fluorescence (4.44 ± 0.59).

The difference found between the ratios obtained by FNA and histology contrasts with the findings of other authors (Aridogan et al., 2003), who obtained a 0.9 correlation in human patients between fine-needle aspiration and histology techniques. To our knowledge, this is the first time that a specific immunohistochemistry fluorescent method against AR has been used in peri-pubertal bulls as a specific predictive tool of potential fertility in the adult individual. AR expression through immunofluorescence has shown to be a specific and novel useful tool for determining Sertoli cell populations in the young bull.

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Table 1. Testicular cytology determination in young peri-pubertal bulls using four different techniques: fine-needle aspiration with a fine needle (FNA-F), fine-needle aspiration with a gross needle (FNA-G), histology and immunohistochemistry.

	Technique			
Trait	FNA F	FNA G	Histology	Immuno-histochemistry
Ratio (germ cells/ Sertoli cell)	(Mean ± SEM)	(Mean ± SEM)	(Mean ± SEM)	(Mean ± SEM)
	3.605^{a} ± 0.468 n = 12	3.598^{a} ± 0.393 n = 13	5.271^{b} ± 0.409 n = 14	4.440^{b} ± 0.599 n = 14

FNA F = fine-needle aspiration with a fine needle; FNA G = fine-needle aspiration with a gross needle; SEM = standard error of the mean.

Table 2. Correlation among four different techniques for testicular cytology determination in young peri-pubertal bulls.

Technique		FNA-F	FNA-G	Histology	Immunohistochemistry
FNA-F	Pearson Correlation	1.000	0.686	-0.008	-0.217
(N = 22)	*P* value	–	0.001	0.971	0.331
FNA-G	Pearson Correlation	0.686	1.000	0.175	-0.202
(N = 22)	*P* value	0.001	–	0.434	0.366
Histology	Pearson Correlation	-0.008	0.175	1.000	0.581
(N = 27)	*P* value	0.971	0.434	–	0.001
Immunohistochemistry	Pearson Correlation	-0.217	-0.202	0.581	1.000
(N = 28)	*P* value	0.331	0.366	0.001	–

FNA-F = fine-needle aspiration with a fine needle; FNA-G = fine-needle aspiration with a gross needle.

The effect of Vitamin A treatment on testicular development in young peri-pubertal bulls

Nicolas Negrin Pereira[1], Pawel Borowicz[1], Jordan Flaten[1], Bryan Neville[2] and Carl R. Dahlen[1]

The establishment of the final number of Sertoli cells in the bull calf testicle around puberty is one of the key determining factors of the animal's adult fertility. Vitamin A administration did not have any significant effect in testicular development in peri-pubertal bull calves.

Summary

Fourteen Angus and Shorthorn bull calves between 11 and 12 months of age were assigned randomly to one of two treatments: 1) Intramuscular injection of 1 million International Units (IU) of vitamin A (Vit A) or 2) no treatment (Control). Scrotal circumference (SC) was measured in all bull calves at the time of the treatment application and 11 days later at castration. Testes and epididymis were dissected and weighed, and samples of parenchyma were collected from each testicle. Samples were fixed in formaldehyde, embedded in paraffin and cut. Slides were deparaffinized with successive washes of xylene and alcohol. After antigen retrieval and blocking with 10 percent normal goat serum, sections were incubated sequentially with mouse monoclonal antibody to androgen receptor and goat-antirabbit (IgG CF633) fluorescent stain. Samples were examined under a fluorescent microscope and the images captured with a digital camera and processed using Image-Pro Plus software. Effects of treatment on SC, testicular weight, testicular parenchyma weight and epididymis weight, number of Sertoli cells, germ cell, and ratio of germ cells to Sertoli cells within the seminiferous tubule (ST) were analyzed using the ANOVA procedure of SAS. No differences were observed among treatments for SC (1.63 ± 0.26 vs. 2.17 ± 0.17), testicular weight (228.169 ± 17.002 vs. 221.792 ± 24.983), testicular parenchyma weight (grams [g]) (141.02 ± 11.82 vs. 131.46 ± 14.49), epididymis weight (g) (12.01 ± 1.10 vs. 9.43 ± 1.01), number of Sertoli cells/ST (45.56 ± 3.14 vs. 48.04 ± 2.18), number of germ cells/ST (217.29 ± 26.83 vs. 156.04 ± 16.75) and the ratio of germ cells/Sertoli cell (5.03 ± 0.93 vs. 3.30 ± 0.43) for vitamin A and control, respectively. These results suggest that vitamin A has no positive effect on fertility when administered in peri-pubertal bulls.

Introduction

More than 95 percent of our beef herds rely on natural service as the main breeding system. Very little information is available about interventions administered during the peri-pubertal period in the bull and their ramifications on adult fertility.

Sperm production in the bull is influenced early in life through the establishment of the definite number of Sertoli cells in the testicle, which nourish developing sperm before puberty, when they stop replicating (Sharpe et al., 2003). Bulls with a larger Sertoli cell population have greater daily sperm production (DSP), testicular weight and SC, compared with bulls having fewer Sertoli cells (Berndston et al., 1987).

Recent findings showed that the proportion of Sertoli cell numbers was higher in bulls that produced good-quality semen with higher numbers of viable spermatozoa after thawing in comparison with bulls that had lower proportions of Sertoli cells (Rajak et al., 2016). Sertoli cell proliferation has a specific window of time that extends from the fetal stage at midgestation up to six to 10 weeks in the newborn calf (Moura et al, 1997).

Recent findings suggest that influencing the final number of Sertoli cells in the bull testis is possible once differentiated (Zakhidov et al., 2015). Several factors have been described as having an effect on Sertoli cell replication, such as thyroid hormone (T3), testosterone (T), follicle-stimulating hormone (FSH), insulin growth factor (IGF-I) and vitamin A through its active compounds retinoic acid (RA) and retinol (RE) (Lucas et al., 2014).

Retinoic acid also has been reported to interact with transforming growth factor beta (TGF-β) in various other tissues, not limited to the testis, affecting cell proliferation and differentiation (Cupp et al., 1999).

Retinoic acid receptors RARα and RARαhave been discovered in rat Sertoli cell nucleus (Livera et al., 2002), and the fundamental role of RA in spermatogenesis has been known for several years, where animals deficient in vitamin A are sterile with a complete halt in spermatogenesis. This was demon-

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strated in genetically engineered mice lacking RA receptors, showing a delay in Sertoli cell differentiation, progressive spermatogenic degeneration and infertility (Nicholls et al., 2013). Retinoic acid in the rat had a detrimental effect in the fetal testis and a beneficial effect on the neonatal rat testis (Livera et al., 2000).

Most of the studies performed on Sertoli cell proliferation and differentiation have been done on species such as rats, sheep, humans and pigs but very little information is available on the effects exerted by vitamin A on Sertoli cell populations in the bull.

Experimental Procedures

Fourteen Aberdeen Angus and Shorthorn bull calves (28 7± 3.3 days, 683 ± 29 pounds) from the North Dakota State University Beef Unit were used in the study. Ten days prior to castration, bulls were assigned randomly to one of two treatments; 1) intramuscular injection of 1 million IU of vitamin A (Vitamin AD Injectable, Durvet Laboratories, Blue Springs, Mo.; Vit A); or 2) no treatment (Control).

Testicle scrotal circumference (SC) was measured in each bull at the time of treatment administration and also at the time of castration 11 days later. All bulls were castrated using the open method with a scalpel following application of epidural and local anesthesia. Once the testicles were removed, the epididymis was dissected and detached from the testicles. Testicles and epididymis were weighed separately.

The tunica albuginea was dissected from each testicle and the testicular parenchyma was weighed. Samples for histological examination (4 by 4 millimeters [mm]) from one region of each testis parenchyma were taken, fixed in a 10 percent formaldehyde solution, embedded in paraffin and cut into sections 5 micrometers (µm) thick using a microtome (Leica Biosystems Inc., Buffalo Grove, Ill.).

Samples were submerged in sodium citrate buffer and placed in an antigen retriever (2100 Retriever, Aptum Biologics, UK) and incubated sequentially using mouse monoclonal antibody to androgen receptor (ab9474, abcam, Cambridge, Mass.) at 4 C overnight with agitation, and then stained with goat-antirabbit IgG CF633 fluorescent stain.

For each tissue section, images were taken at 100 times magnification using a Zeiss Imager M2 epifluorescence microscope equipped with Zeiss piezo automated stage and AxioCam HRm camera (Carl Zeiss International, Jena, Germany). Image analysis (Image-Pro Plus, Media Cybernetics Inc., Bethesda, Md.) was performed for images of five randomly chosen fields. Within each image, four to six seminiferous tubules were selected randomly for Sertoli and germ cell individual cell counts using the Image-Pro Plus image analysis software (Media Cybernetics Inc., Rockville, Md.).

The ANOVA procedure of SAS (SAS Inst. Inc., Cary, N.C.) was used to analyze differences in scrotal circumference, testicular weight, testicular parenchyma weight and epididymis weight between treatments. The number of Sertoli cells and germ cells per seminiferous tubule (ST) were counted and means calculated for each testicle.

The ratio of germ cells to Sertoli cells was calculated by dividing the total number of germ cells by the total number of Sertoli cells within each tubule. Total means were obtained for each testicle and analyzed using the same statistical procedure. Significant differences were considered when $P < 0.05$.

Results and Discussion

No differences were observed between treatments (Table 1) for measures of scrotal circumference ($P = 0.13$), and weights of the testicles ($P = 0.83$), parenchyma ($P = 0.61$) or epididymis ($P = 0.11$; Table 1). In addition, no differences were observed between treatments in the number of Sertoli cells per ST ($P = 0.44$), number of germ cells per ST ($P = 0.20$) or the ratio of germ cells/Sertoli cell ($P = 0.16$).

This preliminary experiment indicated that the administration of vitamin A in young peri-pubertal bulls did not have a beneficial effect in testicular development. The lack of effects of vitamin A on the different testicular cell types could be the

Table 1. Effect of vitamin A on testicular development in young beef bulls.

	Vitamin A		Control		
Item	Mean	SEM	Mean	SEM	*P* Value
No. bulls	8		6		
Difference in SC (cm)	1.63	0.26	2.17	0.17	0.13
Testicular weight (g)	228.17	17.00	221.79	24.98	0.83
Testicular parenchyma weight (g)	141.02	11.82	131.46	14.49	0.61
Epididymis weight (g)	12.01	1.10	9.43	1.01	0.11
Sertoli cells/ST	45.56	3.14	48.04	2.18	0.56
Germ cells/ST	217.29	26.83	156.04	16.75	0.10
Ratio (germ cells/Sertoli cell)	5.03	0.93	3.30	0.43	0.1

SEM = standard error of the mean; SC = scrotal circumference; ST = seminiferous tubules.

reflection of an already differentiated and stable Sertoli cell population because previous studies indicate that the end of Sertoli cell division occurs before 30 to 40 weeks of age in the bull (Rawlings et al., 2008).

The lack of information about precise time frames for obtaining beneficial effects on testicular development in the bull by the application of different treatment and management strategies highlights the need for further research.

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The influence of beef quadriceps hot-processing on carcass chilling and beef round quality

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This project evaluated the impact of hot-carcass boning on beef round meat quality attributes in a small processor setting. Temperature and pH declines were monitored on chilling beef carcasses that had one carcass side where the beef knuckle was separated from the femur within 1.5 hours of stunning. Beef quality tenderness and shelf-life attributes were evaluated after aging. Our research indicates that hot-boning techniques applied in a small processing setting may not create added value to the beef round.

Summary

The objective of the present study was to determine the effects of partial hot-boning on meat quality attributes in deep and superficial portions of the beef *semimembranosus* (SM). At the entrance of the carcass-chilling cooler during slaughter (60 to 90 minutes postmortem), the beef knuckle (quadriceps) was partially hot-boned on one side of each beef carcass (n = 15), whereas the opposite side remained intact throughout the 48-hour chilling period. Randomized treatments were deep SM hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC). Postmortem temperature decline was monitored every 10 minutes for 24 hours and post-mortem pH decline was recorded at 45 minutes, three hours, and 24 hours. Samples were collected after 24 hours (protein degradation and protease activity measurements) and 10 days (tenderness and display life evaluation) of aging in an air-chilled cooler. The deep portion of the SM had a slower chill rate and a sharper pH decline when compared with the superficial SM, regardless of hot-boning treatment. No treatment differences were observed for beef color L* and b* values ($P > 0.05$). By day 4 of display life, both deep muscle treatments were less red ($P < 0.001$) when compared with superficial SM locations. Modified hot-boning did not ($P > 0.49$) influence tenderness in deep or superficial portions of the SM.

Introduction

Compared with traditional boning of refrigerated carcasses, partial hot-boning (limited separation of meat from the skeleton pre-rigor) is a well-established technique used to optimize meat processing parameters, including processing time, chilling costs and contamination reduction (Kastner, 1977; Røtterud et al., 2006). Inconsistent meat quality attributes of the SM are possibly due to variations in pH and temperature decline between the deep and superficial muscle locations (Tarrant and Mothersil, 1977; Seyfert et al., 2005; Sawyer et al., 2007).

Generally, the deep portion of the SM is a larger, thicker muscle, exhibiting a slower chill rate and more rapid pH decline than its superficial counterpart. As a result, meat from the inner SM tends to have inconsistent color stability and protein functionality.

Tenderness differences within the beef round muscle are well-documented (Johnson et al., 1988; Kim et al., 2010). Limited studies have investigated how partial hot-boning of the SM might affect post-mortem determinants of meat quality in view of differences in chilling and pH conditions of the superficial and deep SM.

Therefore, the objective of this study was to examine the effects of partial hot-boning on pre-rigor temperature and pH decline and subsequent proteolysis of the superficial and deep portions of the SM in relation to beef palatability traits.

Experimental Procedures

Fifteen market-weight beef heifers were purchased from area commercial feedlots and harvested at the U.S. Department of Agriculture-inspected meat laboratory at North Dakota State University during a period of six months. The carcasses were split and one half of each carcass was assigned randomly to a hot-boning technique conducted 60 to 90 minutes after stunning, where the quadriceps complex, along with the patella, was separated from the insertion at the distal end of the femur, whereas the other half of each carcass remained as a control.

Following the hot-boning procedure, temperature and pH were monitored in the deep and superficial portions of the SM for 24 hours. At 24 hours post-mortem, muscle biopsies were taken within the SM. Samples collected at 24 hours post-mortem were frozen immediately for measurement of troponin-T

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degradation by Western blot, as well as for calpain 1 and calpain 2 activity by casein zymograms (Melody et al., 2004).

Hanging carcasses were air-chilled in a dark cooler for 10 days at 36 F, upon which steaks were cut from deep and superficial portions of the SM for immediate display life assessment and Warner-Bratzler shear force measurement for tenderness.

Results and Discussion

The pH declined from an average value of 6.66 at one hour post-mortem to 5.68 at 24 hours post-mortem in the four muscle locations and their corresponding treatments (n = 15 per treatment; Figure 1). Treatments DH and DC had similar ($P > 0.05$) pH decline, indicating that hot-boning was not enough to slow pH decline in the deep portion of the SM.

SC and SH pH decline values were similar ($P > 0.05$). Differences between superficial and deep for either boning treatment were significant ($P < 0.05$) at 45 minutes and three hours post-mortem; however, all treatments had similar pH values 24 hours post-mortem.

Temperature decline was similar (Figure 2) among all muscle locations monitored. As expected, the superficial muscles investigated (SC and SH) had a faster rate of decline than those locations from the deep SM. Treatments DH and DC had similar temperature decline rates, indicating that partial hot-boning was not enough to hasten temperature decline in the deep portion of the SM.

The temperature of the cooling chamber during the SM treatment oscillated around 41 F during the first 12 hours and reached 36 F at the end of chilling. While 36 F is consistent with similar studies investigating beef hot-boning treatments (Seyfert et al., 2005; Pivotto et al., 2014), the warmer temperature observed during the first 12 hours may have adversely influenced the speed at which the SM muscle temperature dropped.

No treatment differences ($P > 0.05$) were observed for beef color L* and b* values. By day 4 of display life, both deep muscle treatments were less red ($P < 0.001$) when compared with superficial SM locations. However, by day 10 of display life, only the SC-treated SM had a greater a* value ($P < 0.01$), compared with all other treatments.

Shear force values did not differ ($P > 0.49$) between hot- and cold-boned SM muscle locations (Table 1). However, at 24 hours post-mor-

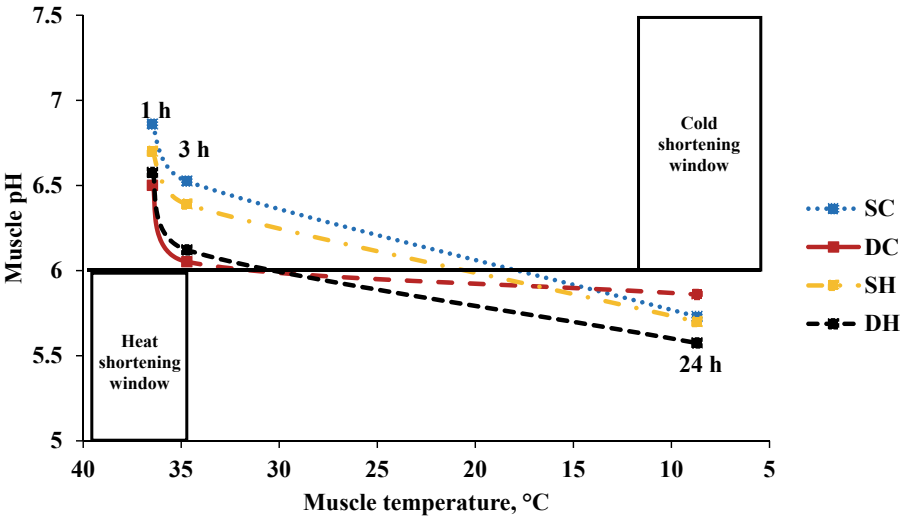

Figure 1. Means of decline in pH at one, three and 24 hours post-mortem relative to the temperature of the SM muscle location. Heat and cold shortening windows adapted from Thompson, J. 2002. Meat Sci. 62:295-308. Treatments on beef semimembranosus muscle were deep hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC).

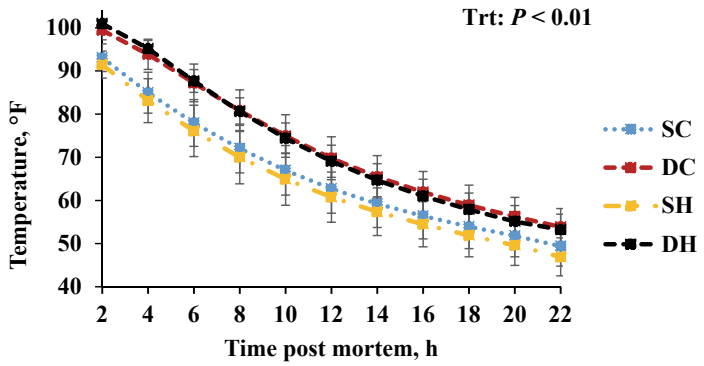

Figure. 2. Mean temperature fall [± standard deviation] of bovine semimembranosus muscle with modified processing conditions up to 22 hours post-mortem (n = 15 per treatment). Treatments were deep SM hot-boned (DH) or cold-boned (DC), and superficial SM hot-boned (SH) or cold-boned (SC).

tem, SC- and SH-treated sides had greater ($P < 0.01$) calpain 1 activity when compared with both deep SM treatments, whereas the activity of calpain 2 was similar for all treatments.

However, the troponin-T degradation products were less in the DC ($P < 0.01$), compared with SH-treated sides, with DH and SC treatments being intermediate. The degradation of troponin-T has been linked to early post-mortem impacts on meat tenderness. In the present study, while we did see differences in troponin-T degradation, we did not observe differences in tenderness.

Results indicate that differences in meat quality across deep and superficial locations of the SM were not altered by partial hot-boning in the conditions of the NDSU Meat Science Laboratory chilling cooler. Because the treatment did not alter temperature decline or pH in the DH-treated carcasses, meat tenderness or color attributes also were not impacted.

Results from this study did reveal location differences within the muscle regarding meat quality and protein degradation, demonstrating the need for future investigations to consider variation between the inner and outer SM when developing strategies to improve overall quality of the beef round muscle.

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Table 1. Least squares means and standard errors for tenderness measurements from semimembranosus muscle of beef heifers with modified processing conditions.

Variable[A]	SH	DH	SC	DC	SEM	*P*-value
WBSF[B], lb.	9.1	9.1	8.5	4.0	0.58	> 0.49
calpain 1 activity[C]	0.33[a]	0.10[b]	0.29[a]	0.15[b]	0.04	< 0.01
Autolyzed calpain 1 activity[C]	0.01[a]	0.07[b]	0.02[a]	0.06[b]	0.01	< 0.01
calpain 2 activity[C]	0.40	0.40	0.42	0.43	0.03	> 0.80
Troponin-T, 30-kDa band[D]	1.16[a]	0.82[ac]	0.83[ac]	0.50[bc]	0.15	< 0.01

[A]Treatment abbreviations: SH = superficial hot-boned, DH = deep hot-boned, SC = superficial cold-boned, DC = deep cold-boned.

[B]Warner-Bratzler shear force.

[C]Calpain activity was assessed in SM collected at 24 hours post-mortem by casein zymography. Values are relative to the activity of a control of partially purified calpain 2, which was set to 1.

[D]Troponin-T degradation in SM collected at 24 hours post-mortem was assessed by Western immunoblotting and values are relative to the 30-kDa band of a pooled-control loin sample.

[abc]Within rows, mean values without a common superscript differ ($P < 0.05$).

Does beef inclusion in a modern diet influence risk factors for obesity-related metabolic disorders using a swine biomedical model

Alexis M. Siomka[1], Korry Hintze[2] and Eric P. Berg[1]

Using swine as a model for humans, the objectives of this project were to determine if replacing sugar (total Western diet [TWD]) with beef (total Western diet-cooked ground beef [TWD-GB]) in a total Western diet would alter body composition, the onset of puberty and risk factors for obesity-related disorders. The results showed that gilts on the TWD-GB diet had greater growth during the test period due to an increase in fat-free lean growth as evidenced by greater longissimus muscle area. TWD-GB had significantly less total cholesterol due to a decrease in low-density lipoprotein cholesterol (LDLch) and high-density lipoprotein cholesterol (HDLch). The reproductive tracts were prepubertal across both treatments; however, follicular development was observed in the TWD-GB gilts. No differences were observed with blood chemistry at the end of the test period.

Summary

Using swine as a model for humans, this study was conducted to determine if replacing sugar in a total Western diet (TWD) with nutrient-dense beef (TWD-GB) would alter body composition, onset of puberty and risk factors for obesity-related disorders. Twenty-four Berkshire gilts were obtained at weaning, assigned to one of two dietary treatments (TWD vs. TWD-GB) and pair-fed at 3.7 percent body weight (BW) for 91 days. Through time, TWD-GB gilts had superior BW gain ($P < 0.01$). At the end of the test, TWD-GB gilts had larger cross-sectional longissimus muscle area ($P < 0.0001$), less subcutaneous fat depth ($P = 0.0005$) and greater percentage of lean BW ($P < 0.0001$) than swine on the TWD. Reproductive tracts were prepubertal across treatments; however, follicular development was observed in TWD-GB gilts. Sodium, hematocrit, hemoglobin and insulinlike growth factor 1 were higher and ionic calcium lower for TWD-GB gilts, compared with TWD gilts.

Introduction

Red meat and dietary fat have been targeted as the cause of increased obesity and obesity-related metabolic disorders in children and adults in the U.S. and abroad. Many shifts have occurred in dietary recommendations from the U.S. Department of Agriculture through the years.

Recent dietary advice suggesting limiting the intake of red meat is unnecessarily restrictive and may have led to many unintended health consequences (Binnie et al., 2014). Obesity and Type 2 diabetes mellitus are common and growing, and are related problems (Centers for Disease Control and Prevention, 2011).

Obesity has become so prevalent that it is considered to be a worldwide epidemic and a public health concern; however, the cause of these obesity-related diseases is unclear. The major determinants driving obesity are complex but clearly involve interactions with our environment, particularly related to food supply, eating behaviors and genetics, as well as public policies (Dixon, 2010).

To maintain a healthy lifestyle, an understanding of the importance of a proper diet and nutrition is essential. The nutritional state of an individual might change in accordance with the type (or types) of dietary patterns he/she follows at any given time in his/her life. Ultimately, poor diet can result in decreased metabolic efficiency and may lead to nutrient disorders or an unbalance of nutritional conditions in the body.

Using swine as a model for humans, the objectives of this project were to determine if replacing sugar with nutrient-dense beef in a total Western diet (TWD) will alter body composition, the onset of puberty and risk factors for obesity-related metabolic disorders. The TWD for this project was developed for swine using information obtained from the 2007-2008 National Health and Nutrition Examination Survey, "What We Eat in America."

Nutrient requirements for swine are known definitively down to the specific requirements for individual amino acids. Human diets are much less formulated because of the diffi-

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culty in evaluating scientifically the many food combinations available to the average American and feeding habits that typical humans have.

Compared with conventional swine diets, the total Western diet of an average American is more energy dense because of its much higher fat content. It is lower in total carbohydrates yet higher in high glycemic carbohydrate (sucrose) and about equal in crude protein. A TWD is higher in sodium and many of the B vitamins, likely because these vitamins are commonly fortified in human foods.

Compared with conventional swine diets, a TWD is much lower in several minerals, including calcium, phosphorus, magnesium, copper, iron and zinc. The nutritional shortfalls of the diets are obvious to swine nutritionists because of extensive production research, which is absent in human nutrition. However, this study holds relevance to the American dietary pattern because the diets were formulated so that micronutrients in the TWD corresponded to American intakes at the 50th percentile when adjusted for nutrient density (mass of nutrients/calories).

The hypothesis of this study is that the consumption of red meat as a replacement for sugar in a TWD would decrease the risk factors for obesity and obesity-related metabolic disorders.

Experimental Procedures

Twenty-four Berkshire gilts were obtained at weaning from Newman Farm Heritage Berkshire Pork (Myrtle, Mo.) and transported 918 miles to the NDSU Animal Nutrition and Physiology Center (ANPC; Fargo, N.D.). All gilts represented a common sire and were born within a seven-day window.

Upon reaching approximately 40 pounds, gilts were sorted, blocked by litter and weight, and penned individually. Gilts were assigned to one of two dietary treatments (TWD vs. TWD-GB) and pair-fed at 3.7 percent of body weight (BW) (12 gilts per treatment) for 91 days. Table 2 displays the dietary components expressed as a percentage of total diets for both treatments.

A TWD was developed for swine using the results of the 2007-2008 National Health and Nutrition Examination Survey, "What We Eat in America." In the TWD-GB diet, cooked ground beef (70:30 lean-to-fat blend) replaced sugar in the TWD on a kilocalorie (kcal) for kcal basis. Diets were formulated to be isocaloric.

Blood samples were collected on day 0 prior to treatment administration and then every 28 days. Weekly BW were taken. Subcutaneous fat depth (FD) and longissimus muscle area (LMA) were measured at the 10th thoracic vertebra on day 42, then every 14 days thereafter.

The percentage of lean BW was estimated from an equation using FD, LMA and live BW. A dietary feed analysis was performed on both treatment diets. Data were analyzed using the mixed procedure of SAS (SAS Institute Inc., Cary, N.C.) as repeated measures with fixed effects of treatment, day and treatment × day, with pig serving as the repeated variable. *P*-values for least square means were adjusted using the Tukey-Kramer method.

Diet Formulation and Feeding Protocol

Our TWD was designed for swine by Korry Hintze (Utah State University) by selecting the average (50th percentile) daily intake levels for all reported nutrients for individuals greater than 2 years old reported to the National Health and Nutrition Examination Survey (NHANES), "What We Eat in America," for 2007-2008. Hintze translated the human NHANES diet into a dietary ration suitable for swine. The swine diet provided by Hintze served as the base diet for the TWD treatment (Table 1).

Table 2 displays the dietary components expressed as a percentage of total diets for both treatments. Fifty percent of the total carbohydrates in the TWD were comprised of sugar (sucrose; fine ground table sugar) and the remaining 50 percent was represented by starch. In the TWD-GB diet, cooked ground beef (70:30 lean-to-fat blend) replaced sugar in the TWD on a kcal for kcal basis. Diets were formulated to be isocaloric and administered as described above. The nutrient information necessary to formulate the TWD-GB treatment was obtained from the USDA National Nutrient Database ground beef calculator (http://ndb.nal.usda.gov/ndb/beef/show). Due to the fact that the USDA's ground beef calculator allowed a maximum of 30 percent fat to be entered, 70:30 lean-to-fat percentages were chosen for this project.

Results and Discussion

A feed analysis was performed on both treatment diets. The TWD-GB diet was overall higher in crude protein, crude fat and lower in total carbohydrates when compared with the TWD (Table 3).

The TWD-GB gilts had greater BW gain through time ($P < 0.01$; Figure 1). A linear increase in LMA and calculated lean BW were observed in TWD-GB vs. TWD (Figures 1 and 3). At the end of the test, TWD-GB had a larger cross-sectional LMA (33.1 centimeters $[cm]^2$ vs. 14.3 cm2; $P < 0.0001$; Figures 2 and 3), less FD depth (2.0 cm vs. 3.1 cm; $P = 0.0005$), and greater percentage lean BW (51.6 percent vs. 34 percent; $P < 0.0001$) than TWD. Stunting of growth, attenuation of muscle depo-

Table 1. Swine TWD[1]. All nutrients supplied at the 50 percent NHANES[2]. Adjusted to calories for swine 50 to 80 kg (1998 NRC).

Ingredients	Total Amount	Carbohydrates (g/kg)	Protein (g/kg)	Fat (g/kg)	Fiber (g/kg)
Corn (ground, yellow, dent)	420.00	281.23	39.56	19.91	30.66
Sugar	229.33	229.33	0	0	0
Whey protein concentrate 80	165.00	9.08	128.70	13.2	0
Soybean oil	31.40	0	0	31.40	0
Butter	28.47	0	0.24	23.10	0
Olive oil	28.00	0	0	28.00	0
Lard	28.00	0	0	28.00	0
Beef tallow	24.80	0	0	24.80	0
Vitamin mix[3]	35.00	4.01			
Mineral mix[4]	10.00	8.49			
Total g/kg	1,000	532.14	168.50	168.41	
Total kcal/kg	4,318	2,129	674	152	
Total kcal (%)	100	49.3	15.6	35.1	

[1]Total western diet

[2]National Health and Nutrition Examination Survey

[3]Vitamin premix content: niacin (3.6 grams per kilogram [g/kg]); calcium pantothenate (1.7 g/kg); pyridoxine HCL (0.2 g/kg); thiamin HCL (0.38 g/kg); riboflavin (0.35 g/kg); folic acid (0.2 g/kg); biotin (0.03 g/kg); vitamin B12, 0.1 percent in mannitol (1.3 g/kg); vitamin E, DL-alpha tocopheryl acetate (2.0 g/kg); vitamin A palmitate (0.7 g/kg); vitamin D3, cholecalciferol (0.046 g/kg); vitamin K1, phylloquinone (0.013 g/kg); choline bitartrate (140 g/kg); sucrose, fine ground (849.481 g/kg)

[4]Mineral premix content: calcium carbonate (60.57 g/kg); potassium phosphate, monobasic (257.14 g/kg); potassium citrate, monohydrate (71.43 g/kg); sodium chloride (491.43 g/kg); ferric citrate (2.4 g/kg); zinc carbonate (0.686 g/kg); manganous carbonate (1.57 g/kg); cupric carbonate (0.06 g/kg); potassium iodate, (0.0086 g/kg); sodium selenite (0.011 g/kg); sucrose, fine ground (102.4044 g/kg); cholesterol (12.29 g/kg)

sition and increased adiposity were partially alleviated by TWD-GB.

Blood chemistry treatment differences were observed ($P < 0.01$) with blood serum sodium, hematocrit and hemoglobin reading higher for TWD-GB vs. TWD. On day 17 and day 45, gilts on the TWD-GB treatment had less total cholesterol (111.8 vs. 151 and 111.5 vs. 153.1, respectively) than TWD gilts ($P < 0.001$). This was due to a decrease in low-density lipoprotein and high-density lipoprotein cholesterol on those two days ($P < 0.01$). However, at the end of the test period, we found no difference in cholesterol levels or triglycerides ($P > 0.65$) between treatments.

We observed that the animals on the TWD developed porcine acne and thinning of hair, com-

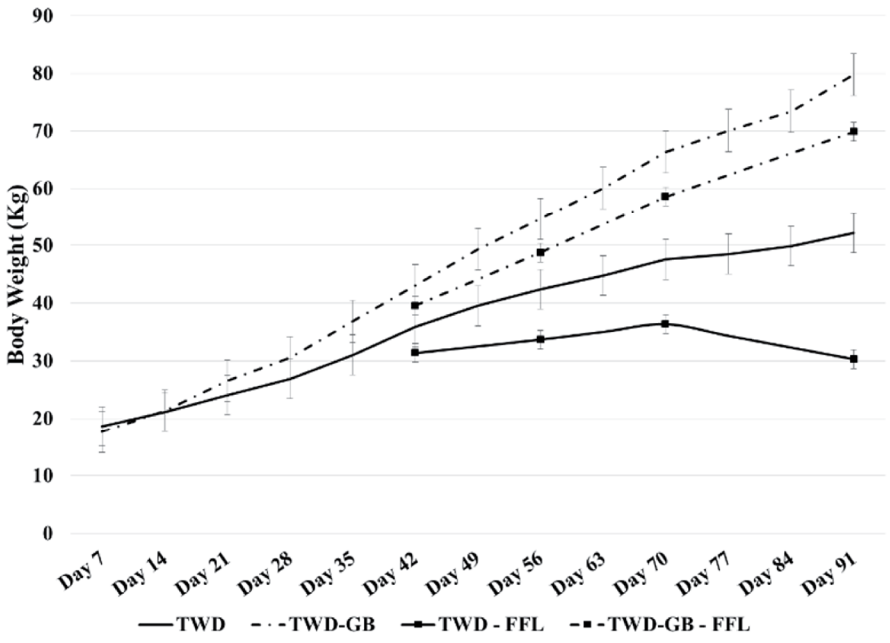

Figure 1. Weekly body weights (TWD and TWD-GB) and lean body weight estimates (TWD – FFL and TWD-GB – FFL) determined by ultrasound measurements.

Table2. Dietary components expressed as a percentage of total diet for TWD[1] and TWD-GB[2].

Ingredients	TWD%	TWD-GB%
Corn, ground	42.0	37.0
Whey, dried	16.5	14.5
Cooked Ground Beef	0.0	32.0
Sugar (sucrose)	22.9	0.0
Soy Oil (blend)	3.9	3.4
Butter	2.8	2.5
100% Olive Oil	2.1	1.9
Lard	2.8	2.5
Beef Tallow	2.5	2.2
Vitamin Mix	3.5	3.1
Mineral Mix	1.0	0.9
Total	100	100

[1]total Western diet.
[2]total Western diet with sugar replaced by cooked ground beef.

Table 3. Diet analysis on an as-fed percentage.

Analysis	TWD[1]	TWD-GB[2]
Crude Protein	5.51	11.54
Crude Fat	13.17	20.13
Crude Fiber	0.55	0.62
Moisture	8.10	24.87
Ash	4.22	3.93
Total Carbohydrates[3]	69.55	40.15

[1]TWD refers to total western diet
[2]TWD-GB refers to total western diet with sugar replaced by cooked ground beef
[3]Total Carbohydrates is calculated by Crude Fiber + NFE[4]
[4]Nitrogen free extract is calculated by 100 - (moisture + ash + crude protein + crude fat)

pared with the TWD-GB gilts. A gilt on the TWD-GB diet became nonambulatory and was removed from the test. A modified necropsy revealed a preliminary diagnosis of rickets, resulting in termination of the research project at 91 day. During final processing, we discovered that the animals on both treatments possessed uncharacteristically brittle bones.

Replacing sugar with ground beef in the present study appears to have influenced the release of the anabolic hormone, insulin-like growth factor 1 (IGF-1). Gilts consuming the TWD-GB had higher ($P < 0.0001$) concentrations of IGF-1 by day 17 of the test. These higher IGF-1 concentrations continued throughout the trial. IGF-1 likely is a key player in the superior anabolic accumulation of muscle tissue seen in gilts consuming TWD-GB.

Central adiposity is yet another risk factor associated with metabolic syndrome. Central adiposity in humans is the result of accumulation of adipose tissue between the internal and external abdominal muscles, as well as internally, where adipose accumulates around the kidneys (referred to as perirenal fat). In the present study, TWD-fed gilts had nearly two times more perirenal fat accumulation than TWD-GB (Table 4).

Beef consumption has been targeted by some researchers as the cause of early (precocious) puberty in young American girls. We previously addressed the role of beef consumption and reproductive (puberty) development (see: Magolski et al., 2014) and found no link. In the present study, the reproductive tracts were pre-pubertal across both treatments; however, follicular development was observed in the

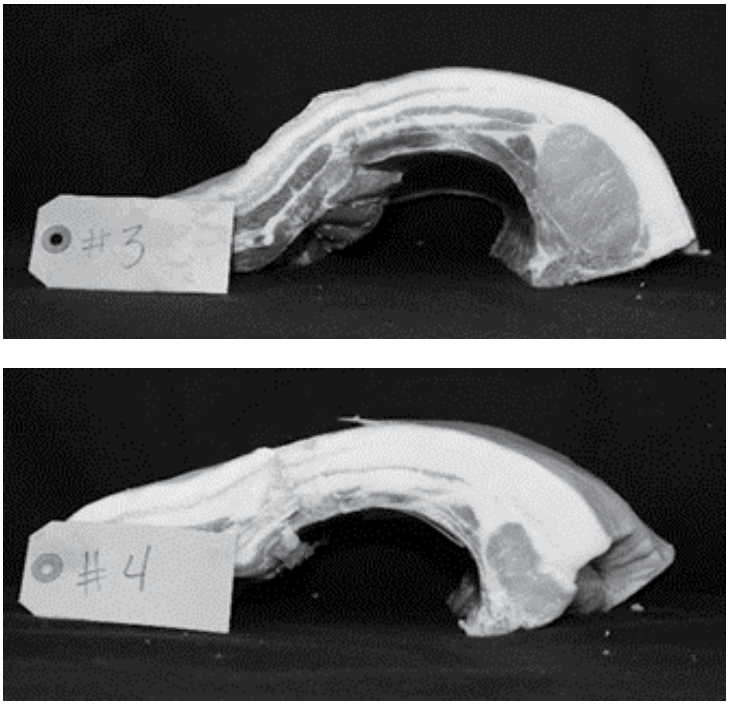

Figure 2. Cross-sectional LMA comparison between littermate gilt pair 3 (TWD-GB) and 4 (TWD) collected at slaughter.

TWD-GB gilts. Furthermore, uterine weights expressed as a percentage of eviscerated body weight from gilts receiving the TWD tended (P = 0.0695) to be larger relative to eviscerated body weight than those from TWD-GB (Table 4).

Gilts fed ground beef had more muscle mass and less body fat. Furthermore, subjective evaluation showed that swine on the TWD-GB treatment had fewer skin acne lesions and less hair thinning.

The nutritional shortfalls of the diets are obvious to swine nutritionists because of extensive production research, which can be absent in human nutrition. However, this study still holds relevance to the American dietary pattern because the diets were formulated so that micronutrients in the TWD corresponded to American intakes at the 50th percentile when adjusted for nutrient density (mass of nutrient/calorie).

Both treatment groups exhibited brittle bones, and TWD-GB gilts were less ambulatory by day 91. Further analysis is necessary to determine the physiological reason and relationship to human nutrition.

Acknowledgments

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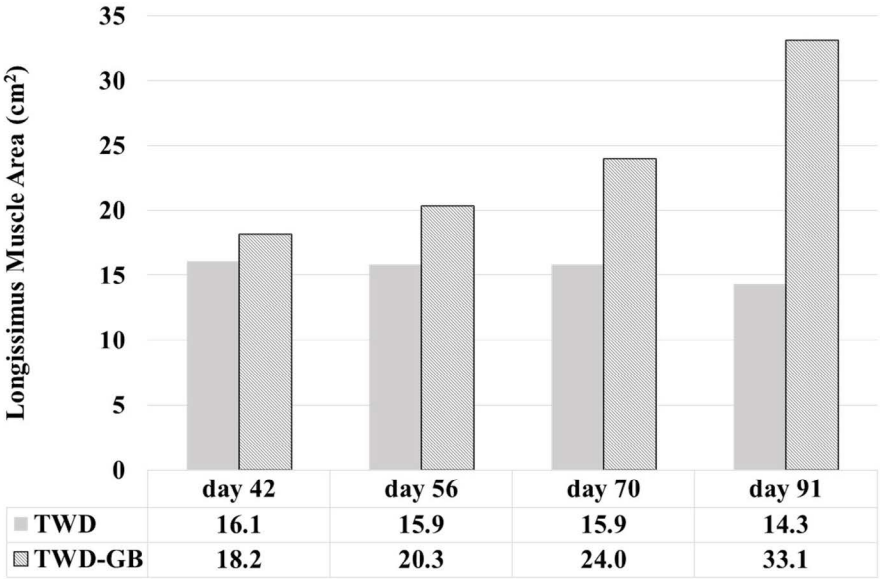
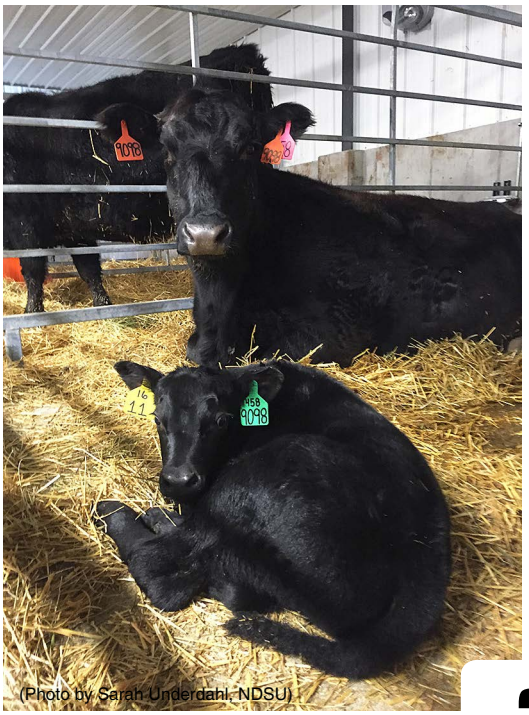


Figure 3. Longissimus muscle area (cm2) at the 10th thoracic vertebra through time for gilts consuming a total Western diet (TWD) versus a TWD-GB where cooked ground beef replaced dietary sugar on a kcal for kcal basis.

Table 2. Least squares means (standard error) for organ weights expressed as a percentage of eviscerated body weight obtained from gilts consuming a total western diet (TWD) versus a TWD where cooked ground beef (GB) replaced dietary sugar on a kcal for kcal basis.

	Perirenal fat	Kidneys	Pancreas	Uterus
TWD	2.55 (0.1836)	0.33 (0.012)	0.101 (0.0059)	0.45 (0.0124)
TWD-GB	1.32 (0.2053)	0.41 (0.014)	0.098 (0.0066)	0.17 (0.0139)
P-value	0.0004	0.0011	0.7643	0.0695



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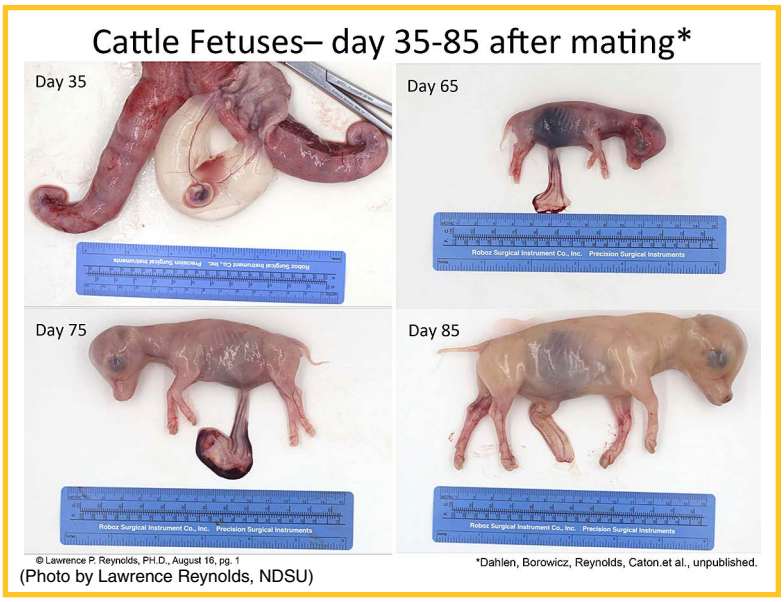

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