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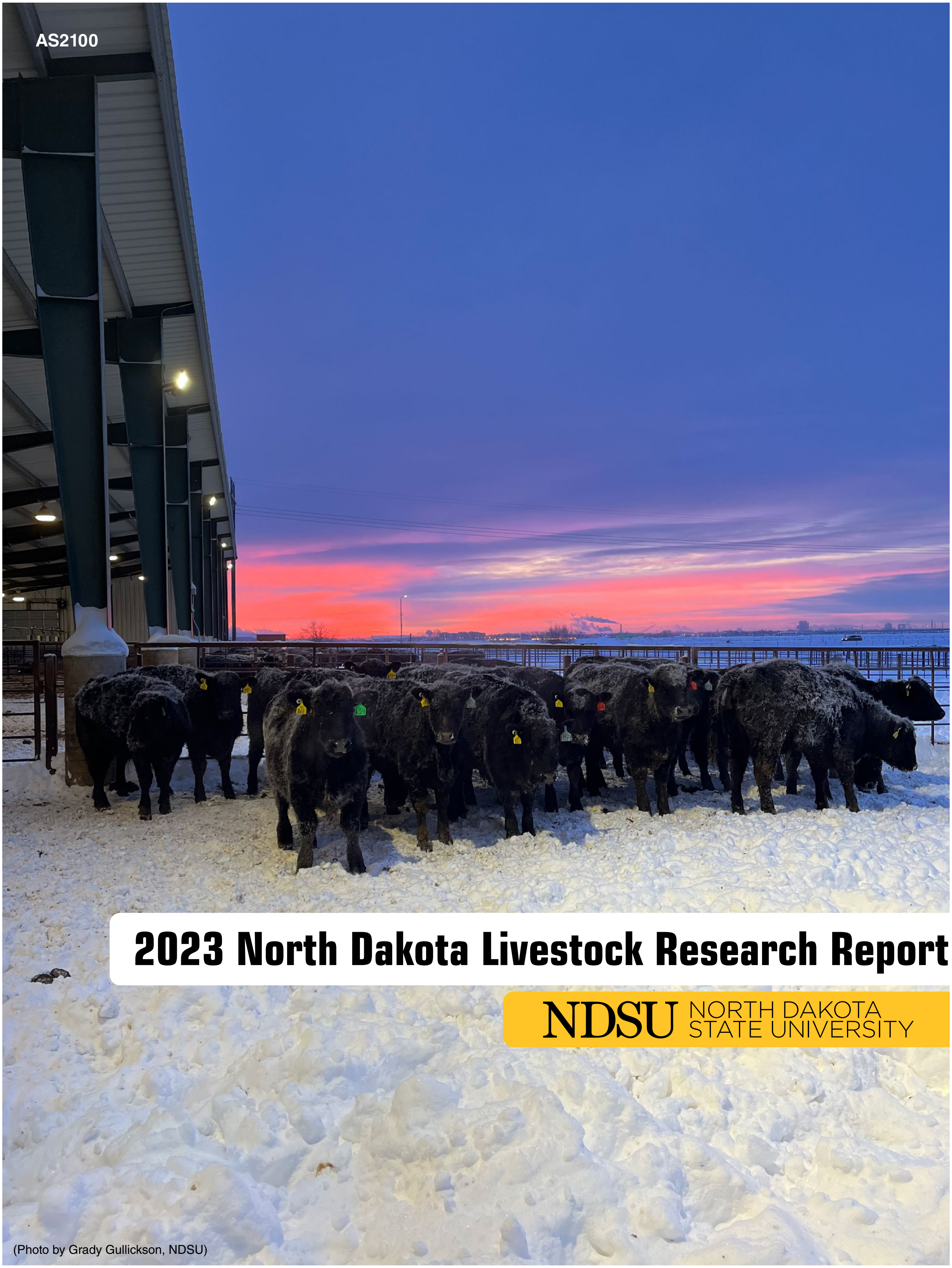

2023 North Dakota Livestock Research Report

NDSU NORTH DAKOTA STATE UNIVERSITY

(Photo by Grady Gullickson, NDSU)

2023 North Dakota Livestock Research Report

This is the 12th year that I have been the coordinator and editor of this report. I continue to do this because I know it is an important means to report our research findings to producers and industry personnel across North Dakota and beyond, and because I enjoy helping others with writing and editing scientific reports and manuscripts. An added bonus is that I get to interact with researchers and learn more about the great livestock research occurring throughout the state.

The report has expanded its scope through the years evolving from the North Dakota Beef Report to the North Dakota Beef and Sheep Report and now to the North Dakota Livestock Research Report. However, the objectives of providing current research results to those who are interested across the state and elsewhere are still the same. I hope this report will continue to remind all of us of the quality and breadth of our livestock research and Extension programs in North Dakota.

When perusing this year's report, I hope you find something of interest and learn something new. Our research ranges from discovery type research, which could develop into new innovations or technologies to improve production in the future, to more translational research, which provides information that can be used immediately by producers and industry personnel. Both are equally important and often are strongly linked within our research projects and programs.

One of our major goals is to get the most out of each and every research project that we conduct, especially considering the challenges in procuring grant funding to support our research programs. Additionally, we aim to have strong linkages between our research and Extension programs and to get the information to those across the state who can use it. Please consider participating in Extension events or accessing Extension publications and materials in the coming year.

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

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

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

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Winter feeding systems and supplementation of beef cows in mid-gestation: Effects on cow/calf performance and subsequent steer feedlot performance

Michael Undi[1], Colin Tobin[2], Tim Long[1] and Kevin Sedivec[1]

This study examined the impact of winter feeding systems (bale grazing versus dry lot pen feeding) and DDGS supplementation on beef cow performance and pre- and post-weaning calf performance. Winter feeding systems or DDGS supplementation did not influence cow performance. In the feedlot, winter feeding systems or DDGS supplementation did not influence steer performance during the backgrounding phase. There was a tendency during the finishing phase toward greater final BW and ADG and lower feed-to-gain ratio in steers from supplemented cows. Winter feeding system or DDGS supplementation did not influence carcass characteristics. Results show that winter feeding systems such as bale grazing do not negatively impact cow performance and subsequent steer feedlot performance.

Summary

The impact of winter feeding systems (bale grazing versus dry lot pen feeding) and DDGS supplementation on cow/calf performance and steer feedlot performance was evaluated. The study was divided into a bale grazing/dry lot phase and a feedlot phase. During the bale grazing/dry lot phase, 100 cows in mid-gestation were allocated to four replicated treatments as follows: a) bale-grazing grass hay, b) bale-grazing grass hay plus corn DDGS, c) dry lot pen feeding grass hay, and d) dry lot pen feeding grass hay plus DDGS. After weaning, 40 steers (five from each replicate) were shipped to the Carrington Research Extension Center for finishing. Cow performance was not influenced ($P \geq 0.05$) by winter feeding system or supplementation. As well, winter feeding system or supplementation did not influence ($P \geq 0.05$) calf birth weights, weaning weights, weaning age, and ADG. In the feedlot, final weights, ADG, and feed-to-gain ratios were not influenced ($P \geq 0.05$) by winter feeding system or supplementation during the backgrounding phase. There was, however, a tendency during the finishing phase toward greater final BW ($P = 0.12$) and ADG ($P = 0.11$) and lower ($P = 0.14$) feed-to-gain ratio in steers from supplemented cows. Carcass characteristics, namely hot carcass weight, marbling, backfat thickness, ribeye area, and yield grade, were not influenced ($P \geq 0.05$) by feeding system and supplementation. Results show that winter feeding systems such as bale grazing do not negatively impact cow performance and subsequent steer feedlot performance. Supplementation with DDGS may not be necessary when good-quality grass hay is offered to cows in mid-gestation.

Introduction

Spring calving season in North Dakota traditionally extends January to May. In this system, cows are in mid- to late gestation in fall to early winter. Maternal nutrition during gestation plays an essential role in proper fetal development as well as long-term growth, health, and reproductive performance of offspring (Funston et al., 2010). Therefore, nutritional management during mid- and late gestation is critical, and diets should contain adequate energy, protein, and minerals to meet nutrient requirements of the pregnant cow. This is easily accomplished in wintering pens where animals can be fed balanced diets as total mixed rations. Meeting nutrient requirements of animals kept in extended grazing systems can be a challenge since diets are forage-based. In such situations, nutrient requirements can be met through provision of good-quality forages and appropriate feed supplements. Corn DDGS is commonly fed as a supplement in extended grazing systems. As a supplement, corn DDGS compares favorably with supplements such as soybean meal

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and canola meal since corn DDGS is a good source of protein, fat, phosphorus, and readily digestible fiber.

Studies examining the effect of supplementing cows in mid- to late gestation on steer performance have reported variable results, probably due to differences in stage of pregnancy, type of supplement offered, level of supplementation, and environmental conditions. Pre-partum supplementation of cows during late gestation with cottonseed meal did not impact calf performance and subsequent carcass characteristics (Mulliniks et al., 2012). In other studies (Larson et al., 2009), however, late gestation cow supplementation improved calf weaning weights and steer carcass characteristics. A long-term study (Larson et al., 2009) reported trends toward greater final weights and ADG in steers and changes in carcass characteristics following cow supplementation during late gestation. This study was conducted with cows in mid-gestation to examine the impact of winter feeding systems and supplementation on beef cow performance, calf performance, and steer feedlot performance and carcass characteristics.

Experimental Procedures

Animal handling and care procedures were approved by the North Dakota State University Animal Care and Use Committee. This study was conducted with non-lactating pregnant Angus cows that had been bred by artificial insemination with semen from five bulls. The study had two phases: a bale grazing/dry lot phase and a feedlot phase. During the bale grazing/dry lot phase, 100 non-lactating pregnant Angus-cross beef cows were divided into 8 groups of similar average body weight to evaluate four systems: a) bale grazing grass hay only, b) bale grazing grass hay with corn DDGS supplementation, c) pen feeding grass hay only and, d) pen feeding grass hay with corn DDGS supplementation. Bale grazing was conducted in 1.3 ha paddocks that were separated by three-strand, high-tensile wire electric fencing. Pen-fed cows were kept in dry lot pens that were surrounded by wooden windbreaks on 3 sides of the pen. All cows were fed grass hay round bales (8.6% CP, 57.2%; TDN; Table 1). For supplemented cows, corn DDGS (31.2% CP, 75.3% TDN; Table 1) was delivered twice weekly and fed in bunks.

Table 1. Chemical composition (mean ± SD; % DM) of grass hay and corn DDGS fed to cows.

Item	Grass hay	Corn DDGS[1]
CP	8.6 ± 0.62	31.2 ± 1.21
TDN	57.2 ± 0.84	75.3 ± 1.46
NDF	62.0 ± 0.70	31.0 ± 2.02
ADF	40.8 ± 1.08	14.5 ± 2.60
Ca	0.63 ± 0.08	0.06 ± 0.01
P	0.20 ± 0.04	1.04 ± 0.04
Mg	0.21 ± 0.01	0.41 ± 0.01
K	1.94 ± 0.08	1.30 ± 0.09
S	0.19 ± 0.03	0.71 ± 0.06

After weaning in late October, 40 steers (five from each replicate) were shipped to a feedlot for finishing. To eliminate pen effects and maintain in-utero treatment effects, steers were managed as one group. Upon arrival at the feedlot, steers were implanted with Synovex Choice (100 mg trenbolone acetate; 14 mg estradiol benzoate; Zoetis, NJ). Steers were fed a backgrounding diet (14.4% CP and 69.7% TDN; Table 2) for approximately 60 days before receiving a finishing diet (13.3% CP and 81.3% TDN; Table 2), which was fed for 126 days.

Feeding steers was accomplished using "clean bunk" feeding management. The goal of clean bunk management is for all feed delivered to a pen to be consumed daily, with bunks being empty for a certain period of time prior to next feeding, without restricting feed intake. The steers were fed once daily at approximately 09:00 each day, and feed bunks were targeted to be empty of feed by the

Table 2. Ingredient and chemical composition of diets fed to steers.

Ingredient, %	Backgrounding ration	Finishing ration
Corn grain	20.5	68.3
Modified Distillers	19.8	13.4
Corn silage	32.3	9.4
Straw	23.5	6.8
Supplement[1]	3.0	1.3
Limestone	0.9	0.8
DM, %	56.4	69.8
Chemical composition		
Crude Protein	14.4	13.3
NEg, Mcal/kg	0.91	1.19
TDN	69.7	81.3
NDF	32.7	17.7
ADF	22.2	8.9
EE	3.9	4.3
Ash	8.2	3.5
Ca	0.6	0.4
P	0.5	0.4
Mg	0.3	0.2
K	1.0	0.8
S	0.3	0.3

[1]Trace mineral premix, vitamin ADE premix, and monensin.

following morning. Amount of feed delivered to bunks each week was based on bunk clearance from the previous week. Feed intake was estimated as the daily feed consumed by steers divided by number of steers in the pen. Steers had *ad libitum* access to fresh water, mineral supplement, and salt blocks. Steer weights were taken at 28-day intervals. Steers remained in the feedlot for 186 days (60-day backgrounding and 126-day finishing phase) before shipping to a commercial abattoir for harvest and carcass quality data collection.

Results and Discussion

Initial cow BW were similar ($P = 0.92$) among treatments (Table 3). Winter feeding system and supplementation did not influence ($P \geq 0.05$) final cow BW and ADG. Initial cow BCS were similar ($P = 0.97$) among treatments. Final BCS and change in BCS were not influenced ($P \geq 0.05$) by winter feeding system or supplementation (Table 3). These findings are consistent with studies (Mulliniks et al., 2012) in which pre-partum cow supplementation did not influence cow performance. However, other studies have reported beneficial effects of pre-partum cow supplementation (Larson et al., 2009; Marshall et al., 2013; Wilson et al., 2015). Differences among studies could be due to differences in forage fed since cows fed higher quality forage may be in a more positive nutrient balance, and their progeny may be less susceptible to nutrient restriction during prenatal development (Wilson et al., 2015). In this study, the grass hay (8.6% CP and 57.2% TDN) likely met the energy and CP requirements of dry cows in the middle one-third of pregnancy.

Calf performance is shown in Table 4. There was no difference ($P \geq 0.05$) in calf birth weights, weaning weights, weaning age, and ADG among treatments. Studies that have reported greater calf weaning weights following pre-partum cow supplementation attribute this effect to alterations in fetal growth (Marshall et al., 2013). Supplemented cows consume more nutrients and readily surpass nutrient requirements necessary for fetal growth and gain during later stages of pregnancy (Marshall et al., 2013). In the feedlot, final weights, ADG, and feed-to-gain ratios were not influenced ($P \geq 0.05$) by treatment during the backgrounding phase. There was a tendency during the finishing phase toward greater final weight ($P = 0.12$) and ADG ($P = 0.11$) and lower ($P = 0.14$) feed-to-gain ratio in steers from supplemented cows. This finding is similar to Larson et al. (2009) who reported a trend for greater final weight and ADG in steers from supplemented cows. There was no difference ($P \geq 0.05$) in hot carcass weight, marbling, backfat thickness, ribeye area, and yield grade among treatments (Table 4). These findings are consistent with studies (Marshall et al., 2013; Wilson et al., 2015) that have reported that cow supplementation in late gestation does not influence carcass characteristics. The greater ($P \leq 0.05$) ribeye area in steers from cows overwintered in the dry lot relative to bale-grazed pasture is difficult to explain as all other carcass characteristics between the winter feeding systems were similar. Changes in carcass characteristics are more likely to occur as a result of differences in nutrient supply rather than feeding systems.

Results show that winter feeding systems such as bale grazing do not negatively impact cow performance and subsequent steer feedlot performance. Supplementation with DDGS may not be necessary when good-quality grass hay is offered to cows in mid-gestation.

Acknowledgements

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Table 3. Performance of cows kept in two winter feeding systems and fed grass hay or grass hay supplemented with corn DDGS.

	Diet[1] (D)			Feeding System[2] (S)			*P*-value		
	Hay	H-DDG	SE	BG	DL	SE	D	S	D x S
Initial weight, lb	1404	1402	29.0	1404	1402	29.0	0.92	0.93	0.92
Final weight, lb	1558	1569	29.3	1565	1561	29.3	0.70	0.89	0.57
ADG, lb/d	1.89	2.02	0.09	1.92	1.98	0.09	0.18	0.53	0.20
Initial BCS	5.8	5.8	0.07	5.8	5.8	0.07	0.71	0.83	0.61
Final BCS	6.2	6.1	0.08	6.2	6.1	0.08	0.77	0.41	0.46
BCS change	0.40	0.35	0.05	0.41	0.35	0.05	0.34	0.12	0.07

[1]Hay = grass hay; H-DDG = Hay plus corn DDGS
[2]BG = bale grazing; DL = dry lot pen feeding

Table 4. Performance of steers from cows kept in two winter feeding systems and fed grass hay or grass hay supplemented with corn DDGS.

	Diet[1] (D)			Feeding System[2] (S)			*P*-value		
	Hay	H-DDG	SE	BG	DL	SE	D	S	D x S
Birth to weaning									
Birth weight, lb	89	90	3.7	88	91	3.7	0.96	0.37	0.58
Weaning weight, lb	607	623	18.6	616	614	18.6	0.40	0.92	0.15
Weaning age, d	189	190	1.4	189	190	1.4	0.21	0.49	0.61
ADG, lb/d	2.75	2.80	0.10	2.80	2.75	0.10	0.56	0.67	0.17
Backgrounding phase									
Initial weight, lb	670	690	18.0	675	685	18.0	0.24	0.59	0.09
Final weight, lb	866	882	21.8	867	881	21.8	0.49	0.55	0.21
ADG, lb/d	3.28	3.18	0.13	3.20	3.26	0.13	0.46	0.67	0.66
Feed:gain	7.12	7.45	0.32	7.35	7.22	0.32	0.31	0.69	0.69
Finishing phase									
Initial weight, lb	866	882	21.8	867	881	21.8	0.49	0.55	0.21
Final weight, lb	1354	1399	29.9	1360	1393	29.9	0.14	0.27	0.17
ADG, lb/d	3.87	4.10	0.15	3.91	4.06	0.15	0.11	0.28	0.43
Feed:gain	7.30	6.89	0.27	7.26	6.94	0.27	0.14	0.24	0.42
Overall									
Initial weight, lb	670	690	18.0	675	685	18.0	0.24	0.59	0.09
Final weight, lb	1354	1399	29.9	1360	1393	29.9	0.14	0.27	0.17
ADG, lb/d	3.68	3.81	0.15	3.69	3.81	0.15	0.27	0.28	0.61
Feed:gain	7.22	6.98	0.22	7.23	6.97	0.22	0.31	0.25	0.60
Carcass characteristics									
HCW, lb	819	819	23.1	819	819	23.1	0.97	0.99	0.54
Marbling	536	540	28.7	530	546	28.7	0.88	0.57	0.98
Yield grade	3.4	3.4	0.2	3.5	3.3	0.2	0.76	0.12	0.63
Backfat, in	0.64	0.68	0.04	0.67	0.64	0.04	0.29	0.59	0.85
Ribeye area, in^2	13.3	13.4	0.38	13.0	13.8	0.38	0.88	0.05	0.13

[1]Hay = grass hay; H-DDG = Hay plus corn DDGS
[2]BG = bale grazing; DL = dry lot pen feeding

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Vitamin/mineral supplementation to beef heifers during pregnancy on immunoglobulin concentrations in colostrum and immune responses in the offspring

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Beef heifers were provided with a vitamin/mineral supplement or no vitamin/mineral supplement during pregnancy to determine the effects on colostrum immunoglobulins (Ig) and passive transfer of immunity to their naturally or artificially reared offspring. Vitamin/mineral supplementation in the dam did not affect concentrations of Ig in colostrum or calf serum, but calves receiving maternal colostrum sources had greater passive transfer of immunity compared with calves receiving a colostrum replacement product. In the postnatal evaluation of antibody titer responses to vaccination, calves born to vitamin/mineral supplemented dams and nonsupplemented dams had similar immune responses to vaccination. These data suggest that in utero vitamin/mineral supplement exposure did not alter immune responses in suckling calves through weaning.

Summary

Two experiments were conducted to evaluate the impacts of feeding a vitamin/mineral supplement to beef heifers throughout gestation on concentrations of immunoglobulin (Ig) in colostrum and in calf serum 24 hours (h) after consumption of maternal colostrum (Exp. 1) or a colostrum replacement product (Exp. 2). Angus-based heifers were provided with a basal diet during gestation (CON) or were provided with the basal diet plus the addition of a vitamin/mineral supplement during gestation (VTM). Colostrum was collected from heifers in both experiments at calving, and blood was collected from calves at birth (pre-suckling) and 24 h after suckling to evaluate passive transfer of Ig through colostrum. Calves in Experiment (Exp.) 1 were evaluated postnatally to determine immune responses to vaccination at birth, pasture turn out, and at weaning. Blood was collected from calves on the day of vaccination and 14 days (d) after to examine antibody responses to Bovine Viral Diarrhea Virus (BVDV) Type 1 and Type 2, Bovine Respiratory Syncytial Virus (BRSV), Infectious Bovine Rhinotracheitis (IBR), and Parainfluenza 3 (PI3). In both Exp. 1 and 2, maternal dietary treatment (CON or VTM) did not affect ($P \geq 0.21$) concentrations of IgG, IgM, or IgA in colostrum at calving or in calf serum at 24 h. However, concentrations of IgG, IgM, IgA, and total Ig in calf serum at 24 h were greater ($P \leq 0.01$) in calves receiving maternal colostrum (Exp. 1) compared with those receiving a colostrum replacement product (Exp. 2). No effect of treatment (CON vs VTM) or the interaction of treatment and day were observed ($P \geq 0.93$) for antibody responses at birth, pasture turn out, or weaning for CON or VTM calves in Exp. 1. Taken together, maternal dietary treatment during pregnancy did not impact colostrum Ig, passive transfer of Ig, or postnatal titer response to vaccination for CON or VTM calves, but consumption of maternal colostrum appeared to be a more effective method of delivery of Ig compared with the colostrum replacement product.

Introduction

The immune system of neonatal beef calves established early in life is integral for the long-term health, productivity, and economics of cow-calf enterprises. In the immediate postnatal period for a newborn calf, it is imperative that calves receive successful passive transfer of immunity via colostrum ingestion and intestinal absorption of immunoglobulins in colostrum either from the dam or a colostrum replacement product (Chase et al., 2008). During fetal development, maternal nutrition may have the potential to affect the physiological, metabolic and immune functions in the gestating calf (Wu et al., 2004; Price et al., 2017), a concept known as fetal/developmental programming

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(Barker, 2004). Research on vitamin/mineral nutrition, specifically during pregnancy and colostrogenesis, on concentrations of immunoglobulins in colostrum, passive transfer of immunity to the neonatal calf, and postnatal health and immune function of the offspring require further investigation. Therefore, our objectives were to determine the impacts of maternal vitamin/mineral supplementation during gestation in beef heifers on concentrations of immunoglobulins (Ig) in colostrum, passive transfer of immunity in naturally and artificially reared offspring, and postnatal antibody responses to vaccination.

Procedures

Two experiments were conducted to evaluate the impacts of feeding a vitamin/mineral supplement to beef heifers throughout gestation on concentrations of immunoglobulin (Ig) in colostrum and in calf serum 24 h after consumption of maternal colostrum (Exp. 1) or a colostrum replacement product (Exp. 2). Angus-based heifers (*n* = 72, 14 to 15 months of age, initial body weight [BW] = 838.6 ± 111.47 pounds [lbs]) were managed in an individual feeding system (American Calan; Northwood, NH) at the NDSU Animal Nutrition and Physiology Center (ANPC; Fargo, ND). Heifers were randomly assigned to receive either the basal diet targeting gain of 1 lb/heifer/day (CON; *n* = 36) or the basal diet plus a loose product vitamin/mineral supplement (Table 1; Purina Wind and Rain Storm All-Season 7.5 Complete, Land O'Lakes, Inc., Arden Hills, MN) top-dressed on the total mixed ration (TMR) at a rate of 4 oz/heifer/day (VTM; *n* = 36). All heifers were subjected to a 7-day Select-Synch + CIDR estrus synchronization protocol and bred via artificial insemination (AI) to female-sexed semen from a single sire. Transrectal ultrasonography was conducted to determine pregnancies at day 35 post-insemination, and fetal sex was determined at day 65 after AI to confirm pregnancies with female fetuses.

For Exp. 1, diet treatments began at the time of AI. Heifers becoming pregnant with female fetuses after first service AI (CON, *n* = 14; VTM, *n* = 17) were transported to the NDSU Beef Cattle Research Complex (BCRC; Fargo, ND), adapted to the Insentec Roughage Intake Control Feeding System (Hokofarm B.V., Marknesse, The Netherlands), and diet treatments were continued throughout pregnancy. The basal diet for heifers on Exp. 1 consisted of corn silage; alfalfa, millet, or prairie hay; and dried corn distillers grains plus solubles. During late-gestation, feed deliveries were adapted to provide *ad libitum* feed intakes through calving. At calving, heifer calves were allowed to nurse their dams and remained alongside their dams until weaning.

For Exp. 2, heifers that did not become pregnant to first-service AI (CON, *n* = 19; VTM, *n* = 18) were synchronized for estrus and rebred via AI 60 days after initial dietary treatments began and continued treatments throughout pregnancy at the ANPC. The basal diet consisted of grass hay, corn silage, and dried corn distillers grains plus solubles. During late-gestation, pregnant heifers were transported to the BCRC, and feed deliveries of the basal diet were adapted to provide ad libitum intakes through calving. The basal diet consisted of corn silage, alfalfa hay, dried corn distillers grains plus solubles, and a corn-based premix. Heifer calves born (CON, *n* = 7; VTM, *n* = 7) were removed from their dams at birth, relocated to individual pens, and fed 1.5 liters of colostrum replacer containing 150 g globulin protein

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

	Assurance levels	
Item	Min	Max
Minerals		
Ca, g/kg of DM	135.0	162.0
P, g/kg of DM	75.0	-
NaCl, g/kg of DM	180.0	216.0
Mg, g/kg of DM	10.0	-
K, g/kg of DM	10.0	-
Mn, mg/kg of DM	3,600.0	-
Co, mg/kg of DM	12.0	-
Cu, mg/kg of DM	1200.0	-
I, mg/kg of DM	60.0	-
Se, mg/kg of DM	27.0	-
Zn, mg/kg of DM	3,600.0	-
Vitamins, IU/kg of DM		
A	661,500.0	
D	66,150.0	
E	661.5	

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

(Lifeline Rescue High-Level Colostrum Replacer; APC, Inc; Ankeny, IA) via an esophageal feeder within 2 h of birth. Every 12 h, calves were fed 2 liters of milk replacer (Duralife Optimal Non-Medicated Calf Milk Replacer; Duralife; Fort Worth, TX) via an esophageal feeder.

In both experiments, samples of colostrum from the dam at calving were obtained by completely milking the rear-right quarter of the udder using a portable milk machine (InterPuls, Albinea, IT). Blood samples were collected from calves pre-suckling (within 2 h of birth) and 24 h after colostrum consumption via jugular venipuncture. Concentrations of immunoglobulin G (IgG), M (IgM), and A (IgA) were quantified in colostrum and serum (pre-suckling and 24 h post-suckling) using bovine radial immunodiffusion plate kits (Triple J Farms; Bellingham, WA).

For Exp. 1, blood was collected at numerous time points relative to vaccination at 24 h of age, pasture turn out, and at weaning to assess antibody titer response to vaccination. Blood samples were collected on the day of vaccination (24 h of age, pasture turnout, and 7 d pre-weaning) and 14 days following vaccination, totaling six blood collection time points. At 24 h of age, vaccinations administered included protection against respiratory viruses (IBR, PI3, and BRSV) and clostridial diseases. At the time of pasture turn out on native range pasture, calves were administered vaccinations to protect against respiratory viruses (IBR, PI3, BRSV, BVDV-1, BCDV-2, and Mannheimia haemolytica), clostridial diseases, pinkeye, and an anthelmintic was administered. At 7 d prior to weaning, calves received vaccinations to protect against respiratory viruses (IBR, PI3, BRSV, BVDV-1, BVDV-2, and Mannheimia haemolytica), clostridial diseases, and pinkeye.

Blood samples were allowed to clot after collection and placed on ice until centrifugation. Samples were centrifuged at 1,500 × g at 4º for 20 minutes, aliquoted into 2-mL plastic microtubes, and stored at -20º until analysis. Serum was analyzed at Oklahoma State University Animal Disease Diagnostic Laboratory (Stillwater, OK) via serum neutralization (SN) for detection of antibodies for BVDV Type 1 and Type 2, BRSV, IBR, and PI3. Data for both experiments were analyzed for the effect of treatment using the MIXED procedure in SAS. Significance was considered at $P \leq 0.05$.

Results and Discussion

Immunoglobulin Concentrations in Colostrum and Serum

Maternal dietary treatment (CON or VTM) did not affect ($P \geq 0.21$) concentrations of IgG, IgM, or IgA in colostrum at calving or in calf serum at 24 h in either experiment (Figures 1 and 2; Table 2). All calves from

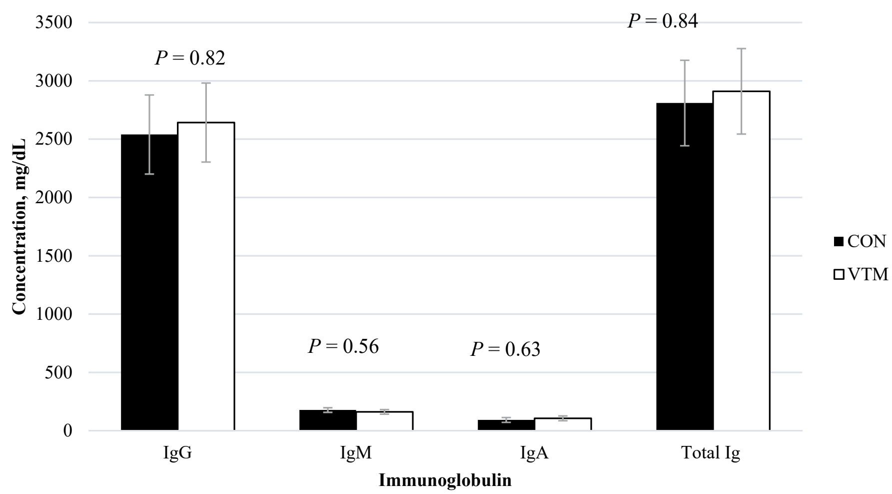

Figure 1. Concentrations of immunoglobulin (Ig) G, M and A in neonatal calf serum 24 h after consumption of dam's colostrum (Experiment 1) and total serum Ig concentrations in female calves born to beef heifers assigned to receive a basal diet (CON) or a basal diet with the addition of a vitamin/mineral supplement (VTM) during gestation. Significance considered at $P \leq 0.05$.

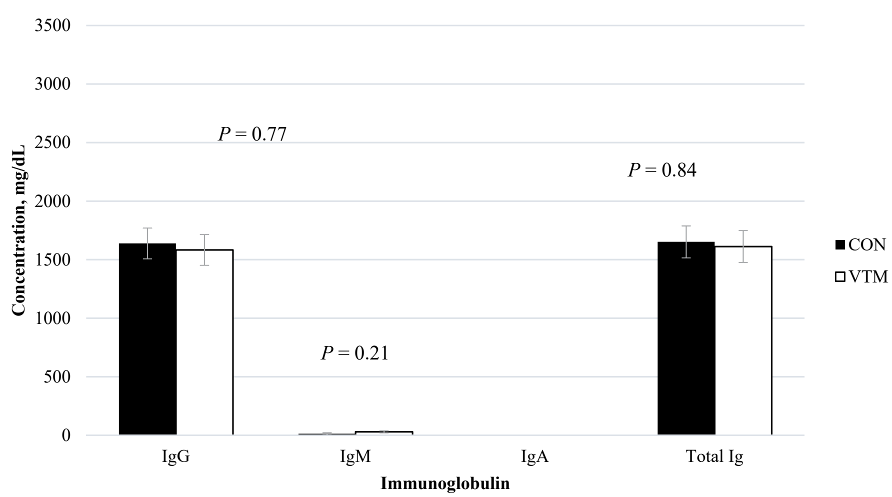

Figure 2. Concentrations of immunoglobulin (Ig) G, M and A in neonatal calf serum 24 h after consumption of colostrum replacement product (Experiment 2) and total serum Ig concentrations in female calves born to beef heifers assigned to receive a basal diet (CON) or a basal diet with the addition of a vitamin/mineral supplement (VTM) during gestation. Significance considered at $P \leq 0.05$.

both experiments had undetectable concentrations of these respective immunoglobulins at birth, which was expected as calves are born with a naïve immune system. In calves that received maternal colostrum, serum concentrations of IgG were greater ($P = 0.01$; average concentration: 2596 ± 535 mg/dL) than that of calves receiving colostrum replacer (average concentration: 1611 ± 335 mg/dL) at 24 h after suckling. Concentrations of IgA, IgM, and total Ig in serum at 24 h were also greater ($P \leq 0.002$) in calves fed maternal colostrum in Exp. 1 compared with artificially reared calves in Exp. 2. Interestingly, we were able to determine Ig concentrations in the colostrum replacement source and found that the product only contained 9494 ± 77.8 mg/dL of IgG, 609 ± 16.6 mg/dL of IgM, and IgA was undetectable. Given the differences in Ig content in the colostrum replacement product, this likely explains the lower serum Ig values reported for calves in Exp. 2.

Our results suggest that maternal vitamin/mineral supplementation throughout gestation did not impact Ig concentrations in colostrum or the resultant serum Ig concentrations in calves either 24 h after suckling or after delivery of a commercial colostrum replacer. Investigating the intestinal morphological characteristics, blood metabolite and endocrine profiles, and other postnatal physiological responses of calves born to CON and VTM dams may support the lack of treatment differences in terms of passive transfer of immunity observed here. However, our results suggest that maternal colostrum is a more effective delivery of immunoglobulins compared with a commercial colostrum replacement product.

Table 2. Concentrations of immunoglobulin (Ig) G, M and A in colostrum and total colostrum Ig concentrations in beef heifers assigned to receive a basal diet (CON) or a basal diet with the addition of a vitamin/mineral supplement[1] (VTM) during gestation

	Treatment			
Concentration, mg/dL	CON	VTM	SE	*P*-value
Experiment 1[2]				
IgG	12769	13003	1150.8	0.88
IgM	376.03	359.72	25.201	0.64
IgA	293.81	300.95	29.367	0.86
Total Ig	13439	13664	1173.6	0.89
Experiment 2[3]				
IgG	10109	7482	1704.34	0.30
IgM	296	302	48.9	0.93
IgA	198	227	35.7	0.58
Total Ig	10603	8011	1764.5	0.32

[1]Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN). VTM supplement provided at a rate of 4 oz/heifer/day to gestating heifers on respective VTM treatment.
[2]Heifers in Experiment 1 were assigned to dietary treatments of CON or VTM at breeding and remained on respective treatments throughout gestation. Calves born to dams in Exp. 1 were naturally reared and allowed to suckle from their dam.
[3]Heifers in Experiment 2 were assigned to dietary treatments of CON or VTM 60 days prior to AI breeding and remained on respective treatments throughout gestation. Calves born to dams in Exp. 2 were artificially reared; thus, calves were separated from their dams at birth and provided with a colostrum replacement product and milk replacer.

Antibody Titer Response to Vaccination

No treatment or treatment by day interactions were observed ($P \geq 0.93$) for antibody responses to vaccinations administered at birth, pasture turnout, or weaning (Table 3). At weaning, calves elicited an immune response as suggested by a day effect ($P \leq 0.02$) between 184.4 ± 3.73 days of age (pre-weaning/day of vaccination) and 198.4 ± 3.73 days of age (post-weaning) to BVD-2, IBR, and PI3. Interestingly, no effects of day ($P \geq 0.87$) were observed at pasture turn out, suggesting that antibody titer levels were similar on the day of vaccination and 14 d following vaccination at pasture turn out. Our results suggest that maternal vitamin/mineral supplementation during pregnancy was not critical in altering postnatal immune responses in naturally reared calves.

Taken together, supplementing vitamins and minerals during pregnancy in beef heifers did not influence passive transfer of immunity or titer response to vaccination in calves from birth to weaning. Investigating additional characteristics of calves exposed to *in utero* vitamin/mineral supplementation may shed light on other potential programming outcomes of the offspring, such as influences on growth performance, efficiency, and future reproductive success.

Acknowledgements

We would like to express our appreciation to the funding support by the North Dakota State Board of Agricultural Research and Education (SBARE) and to the Central Grasslands Research Extension Center (CGREC) for supplying the cattle used in these experiments.

Table 3. Antibody titer responses to vaccination in postnatal beef calves with evaluation at 24 h of age, pasture turn out, and weaning. Dams of the calves born were exposed to the basal diet from breeding to calving (CON) or received the basal diet plus the addition of a vitamin/mineral supplement from breeding to calving (VTM)[1]

Calf Age	24 h		15 d			P-values[4]		
Birth[2]	CON	VTM	CON	VTM	SE	TRT	Day	TRTxDay
BVD-1[3]	1082.7	1040.5	249.0	618.4	420.36	0.70	0.14	0.63
BVD-2	2560.0	2021.7	1750.7	766.1	802.23	0.35	0.20	0.78
IBR	25.00	35.53	12.33	14.59	7.01	0.37	0.02	0.56
BRSV	142.00	178.12	82.00	79.29	46.40	0.72	0.09	0.68
PI3	341.3	401.9	101.3	198.1	116.66	0.50	0.06	0.88
Calf Age	**40.4 ± 3.73**		**54.4 ± 3.73**			***P*-values**		
Pasture turn out	**CON**	**VTM**	**CON**	**VTM**	**SE**	**TRT**	**Day**	**TRTxDay**
BVD-1	90.0	304.2	82.0	149.7	89.06	0.12	0.37	0.41
BVD-2	151.67	364.24	106.33	255.53	96.65	0.07	0.43	0.74
IBR	5.00	5.88	4.67	6.59	1.124	0.22	0.87	0.65
BRSV	25.33	32.24	41.33	46.12	12.52	0.64	0.24	0.93
PI3	62.33	77.88	22.33	43.53	23.64	0.44	0.12	0.91
Calf Age	**184.4 ± 3.73**		**198.4 ± 3.73**			***P*-values**		
Weaning	**CON**	**VTM**	**CON**	**VTM**	**SE**	**TRT**	**Day**	**TRTxDay**
BVD-1	6.33	8.47	20.36	21.65	5.73	0.77	0.02	0.94
BVD-2	21.0	63.5	312.0	1130.82	402.1	0.29	0.10	0.34
IBR	4.0	4.0	200.0	113.2	43.13	0.32	0.0008	0.32
BRSV	4.00	20.25	6.91	61.18	22.10	0.12	0.33	0.39
PI3	5.33	4.00	431.64	316.00	123.39	0.64	0.004	0.65

[1]Treatments of the dams were: VTM (n = 17): heifers received the basal diet plus the addition of a vitamin and mineral supplement (Purina Wind and Rain Storm All Season 7.5 Complete Mineral (Land O' Lakes, Inc., Arden Hills, MN) from breeding through parturition; or CON (n = 14): heifers received the basal diet from breeding through parturition.
[2]Collection periods for blood samples occurred at 3 different time points with 2 blood samples per time point – the first sample on the day of vaccination and the subsequent sample on d 14 following vaccination. Calf ages at for birth collections were: 24 h of age and 15 d of age; pasture turn out: 40.4 ± 3.73 d of age and 54.4 ± 3.73 d of age; and weaning: 184.4 ± 3.73 d of age and 198.4 ± 3.73 d of age.
[3]Serum neutralization (SN) analyses were conducted to determine antibody titer response to vaccination at Oklahoma State University Animal Disease Diagnostic Laboratory (Stillwater, OK) for detection of antibodies for Bovine Viral Diarrhea Virus (BVDV) Type 1 and Type 2, Bovine Respiratory Syncytial Virus (BRSV), Infectious Bovine Rhinotracheitis (IBR), and Parainfluenza 3 (PI3).
[4]Significance considered at $P \leq 0.05$.

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Relative value of field peas as an alternative to corn distillers dried grain with solubles (DDGS) in beef heifer growing diets

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Field peas can effectively replace corn DDGS in growing heifer diets; however, the high price of field peas often limits utilization of field peas. This study was conducted to determine a price point at which field peas would competitively replace corn DDGS in growing heifer diets formulated to produce similar heifer performance. Field peas can economically replace corn DDGS in growing heifer diets when the price of field peas is less than or equal to 84% of the price of corn DDGS. Within a speculative price range of field peas of $267 to $367/t ($8 to $11/bushel) and corn DDGS at $250/t, field peas are not an attractive alternative to corn DDGS in beef heifer growing diets.

Summary

Corn distillers' dry grains with solubles (DDGS) is one of the most common supplements for cattle in North Dakota. Utilization of corn DDGS is affected by availability and pricing, thus, there is a need to evaluate alternative feed ingredients. This study was conducted to determine a price point at which field peas can competitively replace corn DDGS in diets of growing heifers. The study was conducted with growing heifers that were fed corn DDGS-based and field pea-based diets formulated to produce similar heifer performance. The response allowed a comparative ration cost analysis to be conducted without the need to account for differences in animal performance. Compared to corn DDGS, approximately 43% more field peas by weight were required in a field pea-based diet to meet nutrient requirements of growing heifers. At this level of incorporation, field peas would economically replace corn DDGS when the price of field peas is less than or equal to 84% of the price of corn DDGS. At the current speculative price of field peas of $267 to $367/t ($8 to $11/bushel) and corn DDGS at $250/t, field peas are not an attractive alternative to corn DDGS in beef heifer growing diets.

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Introduction

Corn distillers' dry grains with solubles (DDGS) is one of the most common supplements used across the Great Plains region of the United States (Troyer et al., 2020). Corn DDGS compares favorably with supplements such as soybean meal and canola meal as a good source of protein, fat, phosphorus, and readily digestible fiber. Continued utilization of corn DDGS in cattle rations will likely be affected by availability and pricing. Being a coproduct of ethanol production, corn DDGS availability and pricing will be influenced by fuel prices since ethanol is used as a gasoline additive and alternative fuel in vehicles. Thus, fluctuation in gasoline prices will increase demand for alternative feed ingredients that can replace corn DDGS in livestock diets.

Field peas are a palatable source of protein and energy, which makes them a valuable livestock feed (Anderson et al., 2007). In field pea growing areas, such as North Dakota and Montana, utilization of field peas in livestock diets presents a realistic, on-farm value-adding opportunity for field pea growers (Lardy et al., 2009). Compared to other feedstuffs, the price of field peas is likely to be a major factor in determining utilization of field peas in cattle rations (Anderson et al., 2007). However, identifying a price for field peas as livestock feed presents quite a challenge since field peas are normally priced for human food and pet food markets (Troyer et al. 2020). Situations that result in excess production of field peas, resulting in lower prices of field peas, might offer opportunities for utilizing field peas in cattle diets. This study was conducted to determine a competitive price point for field peas relative to corn DDGS for inclusion into diets of growing heifers.

Experimental Procedures

Animal handling and care procedures were approved by the North Dakota State University Animal Care and Use Committee.

The study extended over two years. Starting in the fall of each year, 162 growing Angus heifers (2020/2021, body weight = 688 ± 88 lb; 2021/2022, 525 ± 71 lb) were divided into two groups of similar average body weight (BW), and the groups were randomly assigned to six dry lot pens. Three groups of heifers (27 heifers/pen) were then assigned randomly to a total mixed ration (TMR) containing supplemental field peas or corn DDGS (Table 1). The diets were formulated to be isocaloric and isonitrogenous and to meet nutrient requirements of growing heifers. The diets were fed as a TMR using cane molasses to minimize ingredient separation from forages. Field peas were coarse-rolled through a roller mill before incorporation into the TMR.

Heifers were fed once daily at approximately 09:00 each day, and feed bunks were targeted to be empty of feed by 16:00. Amount of feed delivered to bunks each week was based on bunk clearance from the previous week. Heifers had *ad libitum* access to fresh water, mineral supplement, and salt blocks. Heifer performance was assessed from the average of two-day body weights taken at the start and end of the study.

Comparative Economic Analysis

Comparative economic analysis was conducted under two scenarios: a) comparing ration costs resulting from inclusion of corn DDGS or field peas into corn DDGS-based and field peas-based diets at similar corn DDGS and field peas price points, and b) identifying a price point at which field peas would competitively replace corn DDGS in growing heifer diets. To compare ration costs resulting from inclusion of corn DDGS or field peas at similar price points, ration costs were generated in Microsoft Excel (Microsoft, Redmond, WA) over a common price range of $200 to $363/t for both corn DDGS and field peas. Identifying a price point at which field peas would competitively replace corn DDGS in growing heifer diets was accomplished by calculating corresponding price points of corn DDGS and field peas that would produce rations with similar ration costs.

Comparative economic analysis of rations was conducted with two assumptions. First, the price of corn DDGS and field peas would fluctuate from $200 to $363/t depending on market supply and demand for these commodities. This range was selected to encompass price fluctuations of both corn DDGS and field peas. Second, the decision to utilize these ingredients in diets would depend on the total commodity price including the cost of transportation. At the time of analysis, corn grain, hay, and silage were priced at $250, $80, and $31/t, respectively. Corn DDGS was priced to fluctuate from $220 to $400/t since USDA Agricultural Marketing Service suggests a range of 80% to 100% or more the price of corn (Buckner et al., 2008). The price of silage was based on local production and was estimated from corn production. Identifying a price for field peas as livestock feed presents quite a challenge since field peas are normally priced for human food and pet food markets (Troyer et al. 2020). At the time of this study, we speculated, through conversations with field pea producers, that the

Table 1. Ingredients and chemical composition of total mixed rations fed to growing heifers.

	Year			
	2020/2021		2021/2022	
	Corn DDGS	Field peas	Corn DDGS	Field peas
Ingredients, % as fed				
Hay	37.9	36.7	42.3	43.1
Corn silage	40.7	40.6	41.3	39.6
Corn grain	14.4	13.8	9.1	8.3
Peas	-	5.8	-	6.2
DDGS	3.9	-	4.5	-
Cm30[1]	3.1	3.1	2.8	2.8
Chemical composition, % DM				
CP	12.2	12.3	13.4	13.6
Net energy for gain, Mcal/lb	0.32	0.30	0.29	0.28
Neutral detergent fiber	42.9	42.1	47.7	44.7
Acid detergent	29.4	29.0	32.1	31.3
Ether extract	2.9	2.0	3.2	2.7
Calcium	0.82	0.86	1.2	1.1
Phosphorus	0.27	0.27	0.35	0.29
Magnesium	0.35	0.21	0.30	0.28
Potassium	1.57	1.43	1.88	1.86
Sulfur	0.24	0.19	0.23	0.20

[1]Core Max 30 liquid protein supplement (30% CP, 0.1% CF, 11.3 to 13.5% Ca, 0.08% P, 4.4 to 5.4% salt, 2% K, 5.5 ppm Se, 50,000 IU/LB Vit A., 8% total sugars, 33.0% moisture).

price of field peas was in the range of $267 and $367/t ($8 to $11/bushel).

All ingredient prices were expressed in US tons (t). Ration costs ($/head/day), which were utilized as the basis for comparative economic analysis, were calculated from daily ingredient intake and ingredient prices. Ingredient intake was calculated from feed delivered (lb/head/d) and diet composition. During the two-year study, an average of 4.2% DDGS and 6% field peas were required in the corn DDGS-based and field peas-based diets, respectively (Table 1). At a feed intake of approximately 29 lb/day for corn DDGS-based and field peas-based diets, 1.23 and 1.76 lb/day of corn DDGS and field peas were included in the respective diets.

Results and Discussion

Diets offered to heifers in this study were formulated to be isonitrogenous and isocaloric (Table 1). In 2020, approximately 3.9% and 5.8% of DDGS and field peas, respectively, were required to produce diets containing 12% CP and net energy for gain (NEg) of 0.32 Mcal/lb. In 2021, approximately 4.5% and 6.2% of DDGS and field peas, respectively, was required to produce diets containing 13.5% CP and NEg of 0.27 Mcal/lb.

Dry matter intake (DMI) was not influenced by treatment ($P = 0.72$) and averaged 17.6 lb/d (Table 2). When expressed as a percentage of body weight (BW), DMI was not influenced ($P = 0.38$) by treatment, with intakes of 2.6% for both treatments. Heifers were well balanced between treatments for initial BW, which were similar ($P = 0.255$) between treatments. Final BW and average daily gain were not influenced ($P \geq 0.05$) by treatment, which was expected since diets were formulated to be isocaloric and isonitrogenous. Heifer performance was similar when 1.23 lb/d and 1.76 lb/d of corn DDGS and field peas, respectively, were incorporated into corn DDGS-based and field peas-based diets. Similar animal response between treatments allowed comparative ration cost analysis without the need to account for animal performance.

When both corn DDGS and field peas were priced $200/t, ration costs were greater for the field peas-based diet relative to the DDGS-based diet (Table 3). When the price of corn DDGS and field peas increased to

Table 2. Performance of growing heifers consuming field peas-based or corn DDGS-based total mixed rations.

	Diet (D)1			Year (Y)			P-value		
	DDGS	FP	SE	2020/21	2021/22	SE	D	Y	D x Y
DMI, lb/d	17.6	17.6	0.12	17.6	17.2	0.12	0.72	0.003	0.97
DMI, % BW	2.6	2.6	0.03	2.5	2.7	0.03	0.38	<0.001	0.25
Initial BW, lb	657	649	7.9	689	615	7.9	0.26	<0.001	0.13
Final BW, lb	732	728	8.1	764	696	8.1	0.57	<0.001	0.34
ADG, lb/d	1.72	1.69	0.04	1.86	1.56	0.04	0.41	<0.001	0.79

[1]Corn DDGS and field peas.

Table 3. Relative ration costs ($/head/day) when corn DDGS and field peas are priced at similar and different price points.

Common ingredient price[1] ($/t)	Ration cost ($/head/day)		Cost difference (DDGS – FP)	Ingredient price[2] ($/t)		Ration cost ($/head/day)	Relative FP price (% DDGS price)
	DDGS-based diet	FP-based diet		Corn DDGS	Field peas		
200	1.34	1.36	-0.02	200	176	1.34	88
218	1.35	1.38	-0.03	218	189	1.35	87
236	1.36	1.40	-0.04	236	200	1.36	85
254	1.37	1.41	-0.04	254	211	1.37	83
272	1.39	1.43	-0.04	272	229	1.39	84
290	1.40	1.44	-0.04	290	241	1.40	83
308	1.41	1.46	-0.05	308	254	1.41	82
327	1.42	1.48	-0.06	327	268	1.42	82
345	1.43	1.49	-0.06	345	280	1.43	81
363	1.44	1.51	-0.07	363	291	1.44	80

[1]Corn DDGS and field peas at the same price.
[2]Prices used: hay, $80/t; silage, $31/t; corn grain, $250/t; and Cm30, $319/t.

$363/t, ration costs increased to $1.44 and $1.51/head/day for corn DDGS-based and field peas-based diets, respectively. As the price of corn DDGS and field peas increased, contribution of hay, silage, and corn grain to total ration costs decreased, reflecting the greater contribution of field peas to the field peas-based ration. Inclusion of field peas into livestock diets will likely increase total feed costs due to the relatively high price of field peas. The relative value of field peas in diets for growing heifers was mainly driven by the level of incorporation of field peas into the diet and the price of field peas. When compared to a corn DDGS-based diet, a field peas-based diet that met nutrient requirements of growing heifers required approximately 43% more field peas. Moreover, the price of field peas would have to be consistently lower than the price of corn DDGS for the corn DDGS-based and field peas-based diets to produce similar ration costs. The relative price of field peas decreased from 88% to 80% as the price of corn DDGS increased from $200 to $363/t. On average, corn DDGS-based and field peas-based diets produced diets with similar ration costs when field peas were priced at approximately 84% of the price of corn DDGS (Table 3). At the current price of $250/t for corn DDGS, field peas, priced at $267 to $367/t, would not be a competitive supplement for use in heifer rations.

Results from this study support studies that have shown a competitive economic advantage of corn DDGS relative to feeds such as dry-rolled corn (Buckner et al., 2008) or field peas (Troyer et al. 2020). Inclusion of corn DDGS in the diet resulted in higher profits relative to a dry-rolled corn-based diet (Buckner et al., 2008). A recent economic evaluation of field peas and corn DDGS as a supplement for heifers grazing crested wheatgrass (Troyer et al. 2020) showed that field peas can be utilized as a supplement when the peas are competitively priced at 90% of the price of corn DDGS. Due to lower costs relative to feeds such as wheat, barley, corn, canola meal, and soybean meal, feed co-products such as DDGS will likely continue to be common and cost-effective ingredients in beef and dairy diets. Situations that result in excess production of field peas, resulting in drastically lower prices of field peas, might offer opportunities for competitively priced field peas for use in cattle diets.

Field peas can competitively replace corn DDGS in cattle diets when the price of field peas is less than or equal to 84% of the price of corn DDGS. At the current price of field peas of $267 to $367/t ($8 to $11/bushel) and corn DDGS at $250/t, field peas are not an attractive alternative to corn DDGS in beef heifer growing diets.

Acknowledgements

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Maternal amino acid supplementation from pre-breeding through early gestation alters fetal muscle development

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The objectives of this study were to evaluate effects of specific amino acid supplementation during pre-breeding through early gestation on subsequent blood amino acid concentrations in the heifer and their effects on early fetal development. Methionine and guanidinoacetic acid are amino acids that can impact key metabolic processes called one-carbon metabolism. Proper one-carbon metabolism is essential for fetal development and postnatal outcomes, including muscle growth. In this study, supplementing methionine during breeding and early gestation resulted in increased fetal muscle size; however, supplementation of guanidinoacetic acid did not impact fetal growth.

Summary

Increased efficiency is sought after across all sectors of the beef industry. Epigenetic modifiers, which are metabolites that change one-carbon metabolism and alter how DNA is read, may serve to enhance the efficiency of offspring development through maximizing genetic potential. Methionine (**MET**) is an essential amino acid that plays a key role in creating alterations on the genome as an epigenetic modifier. Guanidinoacetic acid (**GAA**) consumes products of MET utilization (creating an inverse effect of methionine) and produces creatine, which can be stored in tissues or excreted as waste. We hypothesized that maternal supplementation of MET or GAA during pre-breeding to early gestation will create changes in fetal organ and muscle development. The objectives of this study were to evaluate effects of specific amino acid supplementation from pre-breeding through early gestation on subsequent blood serum amino acid concentrations in the heifer and their effects on fetal muscle development. Eighty MARC II (¼ Angus, ¼ Hereford, ¼ Gelbvieh, ¼ Simmental) heifers (n = 20 per treatment, initial BW = 763 ± 18 pounds) were stratified by age and weight to one of four treatment groups to receive 0.22 pounds per day of supplement: ground corn carrier as control (**CON**), MET (0.02 lb./d) in ground corn, GAA (0.09 lb./d) in ground corn, and MET + GAA (0.02 lb./d MET + 0.09 lb./d GAA) in ground corn. Supplementation began 63 days before breeding (d –63) and continued until day 63 of gestation (d +63). Serum samples were collected before feeding on d -63, at breeding (d 0), and d +63. Heifers were bred using male sexed semen from the same sire, and 35 heifers were confirmed pregnant and harvested at d +63 of gestation to collect maternal and fetal samples. Data were analyzed as a 2 × 2 factorial design with 2 levels of MET and 2 levels of GAA. Methionine concentrations in maternal blood were greater ($P = 0.05$) in MET and MET + GAA supplemented heifers at d 0 and d +63 compared with CON and GAA at d -63, d 0, and d +63. There were no differences ($P \geq 0.15$) in the concentration of GAA or creatine due to supplementation. Fetuses from MET supplemented heifers had greater ($P = 0.01$) brain and *Longissimus dorsi* weight than dams not receiving MET, but no differences in fetal body weight ($P = 0.37$). We conclude that MET supplementation during pre-breeding through early gestation resulted in increased fetal muscle and brain development.

Introduction

Beef production in the U.S. has a multi-billion-dollar global impact. By identifying how maternal supplementation during pre-breeding and early gestion alters fetal development via changes to DNA function, also known as epigenetic changes, there is potential to establish a more resilient foundation for offspring to have improved immunity, growth performance, and feed efficiency

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(Caton et al., 2020). Two amino acids that can influence epigenetic changes are methionine (MET) and guanidinoacetic acid (GAA). Methionine serves a critical role as an essential amino acid and a precursor for epigenetic changes by creating S-adenosyl methionine (SAM), which can either enhance or inhibit genome activity (Walker, 1979). Guanidinoacetic acid irreversibly consumes SAM by producing creatine, a metabolism by-product that can either be utilized for muscle tissue growth or excreted (Li et al., 2020). Methionine supplementation through early gestation has been shown to improve fetal muscle growth (Amorin et al., 2023). Reducing supplies of SAM could limit genomic activity in muscle cells, resulting in decreased fetal viability and subsequent offspring performance (Palacios and Puri, 2006). There is limited research on the impact of such supplementation strategies on fetal development and calf performance. Therefore, we hypothesized that maternal supplementation of MET or GAA during pre-breeding through early gestation will result in changes of circulating amino acid concentrations and create changes in fetal organ and muscle development. The objectives of this study were to evaluate effects of MET and GAA supplementation during pre-breeding through early gestation on subsequent amino acid concentrations in the heifer and its effects on early fetal development.

Procedures

This experiment was approved by the United States Meat Animal Research Center (USMARC) Institutional Animal Care and Use Committee (EO # 165.0).

Eighty MARC II (¼ Angus, ¼ Hereford, ¼ Gelbvieh, ¼ Simmental) heifers (age = 384 ± 10 d, initial BW = 764 ± 9 pounds) were trained for at least one month prior to the start of the study to consume feed from individual feeders (American Calan, Northwood, NH). Heifers were sorted into four pens by age with twenty in each pen. After acclimation to individual feeders, heifers were stratified by age and starting weight and assigned to one of four treatments: CON: 0.22 lb./d ground corn carrier; MET: 0.02 lb./d rumen protected MET (Smartamine M, Adisseo, Alpharetta, GA), + ground corn carrier; GAA: 0.09 lb./d GAA (Creamino, AlzChem Group, Trostberg, Germany), + ground corn carrier; and MET + GAA: 0.02 lb./d MET + 0.09 lb./d GAA, + ground corn carrier. All heifers received a total mixed ration (TMR) consisting of corn silage, alfalfa hay, cracked corn, alfalfa haylage, and mineral pellet which met or exceeded the recommended metabolizable energy and protein requirements to gain 1.5 ± 0.09 lb./d (NASEM, 2016). Heifers were fed treatment diets beginning 63 days prior to breeding (d -63), through breeding (d 0), until d 63 of gestation (d +63) at which time the feeding period was concluded. Heifers were weighed twice a month and feed allotments were adjusted to maintain weight gain trajectory. Blood samples were collected on d -63, 0, and +63 of gestation via jugular venipuncture. From these blood samples, maternal circulating concentrations of MET, GAA, and creatine were determined.

All heifers were bred via fixed time artificial insemination using the 7-day CO-Synch + CIDR protocol with male sexed semen from a single bull. Heifers pregnant with bull calves (35 total) were identified via transrectal ultrasonography on d +61 and harvested at the USMARC abattoir on d +63 of gestation. The fetus was extracted from the gravid uterus, allowing for total fetal body measurements to be recorded. Through dissection, individual fetal organ weights were recorded.

Results and Discussion

Methionine concentrations in maternal blood were greater ($P = 0.05$) in MET and MET + GAA supplemented heifers at d 0 and d +63 compared with CON and GAA at d -63, d 0, and d +63 (Figure 1). There were no differences ($P \geq 0.15$) in the concen-

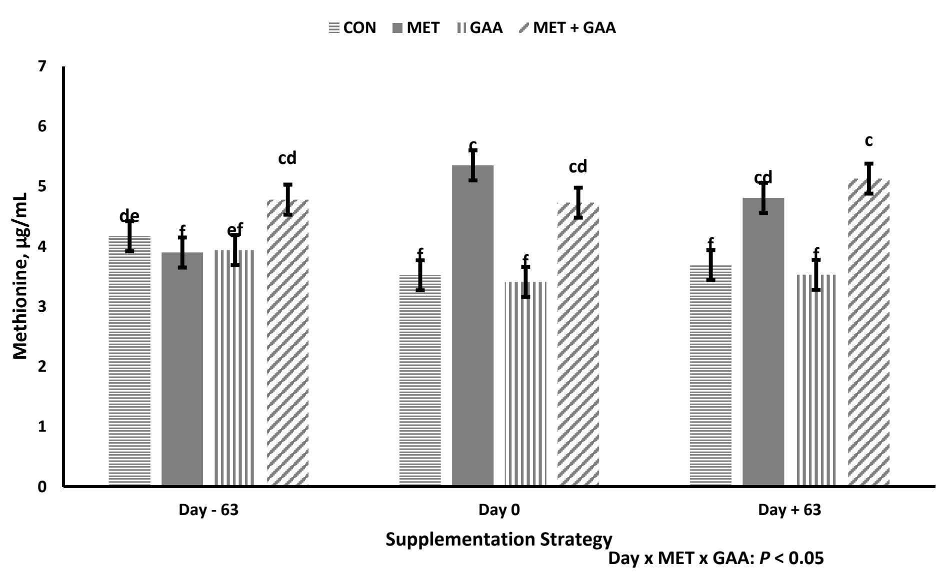

Figure 1. Changes in circulating methionine concentrations in maternal blood at d -63, d 0, and d +63 in heifers treated with CON (horizontal stripes), MET (solid), GAA (vertical stripes) or MET + GAA (diagonal stripes). Means without a common superscript differ by interaction of Day × MET × GAA ($P = 0.05$). CON, $n = 10$; MET, $n = 8$; GAA, $n = 7$; MET + GAA, $n = 10$.

tration of GAA or creatine due to supplementation. Fetuses from MET supplemented heifers had greater (P = 0.01) muscle (*longissimus dorsi*) and brain weight than heifers not receiving MET (Figure 2), but there were no differences in fetal body weight (P = 0.37; Figure 3).

Our supplementation strategies of MET and MET + GAA yielded an increase of MET in heifer circulation; however, feeding GAA did not result in an increase in circulating GAA or an increase of creatine concentrations. Therefore, we accept our hypothesis that supplementation of MET during pre-breeding through early gestation would result in increased maternal blood MET concentrations and thus altered fetal organ weight at d +63 of gestation without increasing total fetal body weight; however, we reject our hypothesis that supplementation of GAA would result in differences in maternal concentration of MET or GAA, or differences in fetal development.

Supplementation treatments concluded at the time of peak fetal primary muscle fiber development, and the increase in fetal muscle size and maternal MET concentration could be indicative of epigenetic changes. The increases in fetal muscle weight could indicate that nutrient partitioning during gestation exceeded the requirements of other fetal organ development, thus diverting excess nutrient availability to muscle tissues, which is of lower priority than other organogenesis. Recent reports have shown that calves from dams supplemented with MET during this timeframe had increased muscle growth, gained faster, and had greater gain:feed than control calves (Amorín et al., 2023). Taken together, these data suggest that MET supplementation between pre-breeding and early gestion in heifers positively influences muscle development of the fetus during gestation.

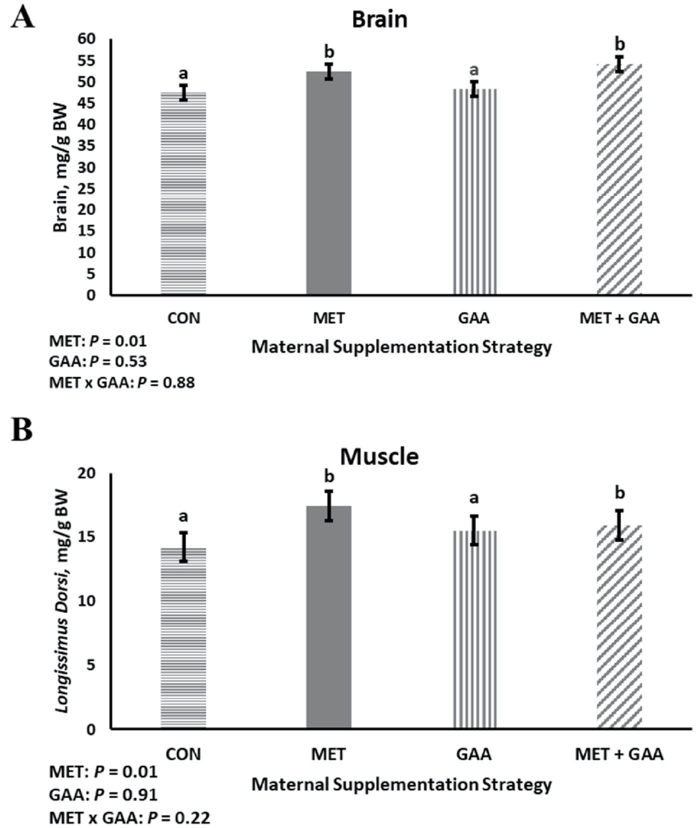

Figure 2. A. Fetal brain weight measurements in each treatment as milligram of fetal brain weight normalized per gram of fetal body weight. Means without a common superscript differ by main effect of MET (*P* = 0.01). B. Fetal muscle weight measurements in each treatment as milligram of fetal muscle weight normalized per gram of fetal body weight. Means without a common superscript differ by main effect of MET (*P* = 0.01).

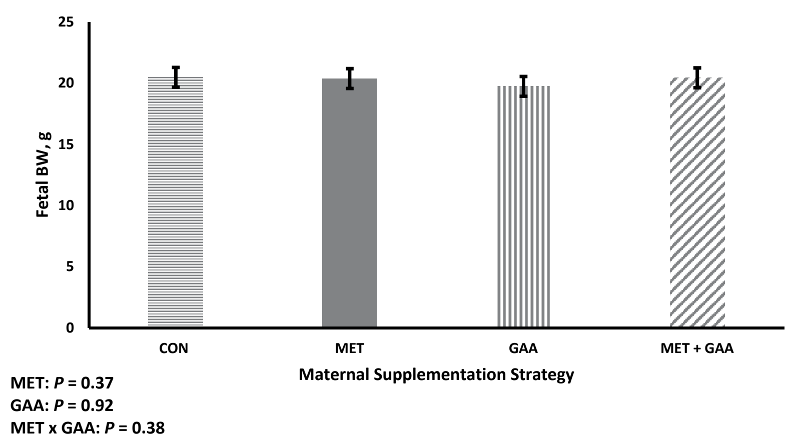

Figure 3. Fetal body weight measurements in each treatment as grams of fetal body weight.

Supplementation with methionine between pre-breeding and early gestation increases methionine blood concentration in heifers. Increasing maternal availability of methionine could increase the amount available for offspring during gestation, thus potentially increasing fetal muscle size without increasing total fetal body weight. There is still a need to develop maternal amino acid supplementation strategies that improve fetal development and subsequent offspring performance. Studies are underway within our research group investigating the influence of similar treatments on offspring throughout subsequent production cycle(s).

Acknowledgements

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Effects of providing vitamin and mineral supplementation throughout gestation on subsequent F1 replacement heifer liver and muscle oxygen consumption and mitochondrial function throughout pregnancy

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Results show increased muscle mitochondria inefficiency in offspring with dams lacking vitamin and mineral supplementation during pregnancy. Vitamin and mineral supplementation throughout pregnancy impacts fetal development with potential lasting metabolic effects in live offspring.

Summary

Fetal programming research largely involves maternal overall caloric or macronutrient restriction. Evaluation of vitamin and mineral supplementation throughout gestation is needed to better understand how this easily adoptable production practice influences offspring energetic and metabolic traits. The objective of this study was to evaluate the effects of maternal vitamin and mineral supplementation during pregnancy on F1 heifer offspring liver and muscle energy utilization throughout pregnancy. We hypothesized that gestational vitamin and mineral supplementation would alter and improve mitochondrial function within the liver and muscle tissue of F1 heifer offspring. Sixteen pregnant heifers whose dams were supplemented (VTM; n = 8) or not (CON; n = 8) with a vitamin and mineral supplement throughout gestation were used in this study. During the second and third trimesters of gestation, liver and muscle biopsies were collected to evaluate any possible effects of maternal dietary treatment on energy metabolism. Liver mitochondrial function and oxygen consumption in F1 heifers was not influenced by gestational VTM ($P \geq 0.70$) or stage of gestation. Muscle mitochondrial LEAK respiration (L) – basal respiration - was greater in CON heifers compared with VTM heifers ($P = 0.05$). This may indicate decreased efficiency of energy utilization, as dietary energy is not utilized for functional purposes but is rather dissipated as heat. Additionally, L was greater during the third trimester compared to the second trimester ($P = 0.02$), suggesting that maternal energy is being directed to the growing fetus to support its development. These data provide insight regarding fetal programming effects on heifer cellular energy consumption in key metabolic organs, which may be beneficial for better characterizing energy requirements and tissue function during growth, development, and pregnancy.

Introduction

Imbalances in nutrition during the periconceptual period, such as nutrient restriction or over-abundance, have the potential to alter outcomes of offspring. It was previously reported that weaning weights of F1 VTM heifers (from this experiment) were on average 36 lb heavier than CON heifers. This trend in body weights between heifers of differing gestational backgrounds (CON and VTM) persisted throughout the development period with VTM heifers weighing 37.5 lb more at approximately 14 - 15 months post-weaning and a 42 lb difference recorded at one year of age (Hurlbert et al., 2023).

A variety of organs and tissues play key roles in energy metabolism and maintenance. Organs develop, grow, and differentiate during the period of fetal development called organogenesis occurring within the first 50 days of pregnancy in cattle. Examples of metabolically active and important organs contributing to whole animal energy use include the liver, skeletal muscle, gastrointestinal tract, and, pancreas.

The liver comprises approximately 22% of basal energy requirements while accounting for less than

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2% of overall body weight in cattle (Caton et al., 2000). The liver is a vital organ and is a major site of metabolic mitochondrial processes and is highly adaptable and influenced by dietary changes. Muscle accounts for approximately 20% of energy use, whereas it comprises about 40% of the animal's overall body weight (Caton et al., 2000). Mitochondria are abundantly functioning organelles that regulate ATP production, protein synthesis, lipid metabolism, glucose metabolism, one-carbon metabolism, etc. Low feed efficient animals may have compromised mitochondrial activity in complex I and II of the electron transport chain (Casal et al., 2018).

The results of this study may potentially explain how function of complex I is linked to differences in weaning weight observed by Hurlbert et al. (2023), as CON heifers had greater LEAK respiration. The goal of this project was to evaluate the impacts of maternal gestational vitamin and mineral supplementation on F1 heifer liver and muscle oxygen consumption and mitochondrial function and to elucidate potential mechanisms of previously reported phenotypic observations.

Experimental Procedures

Experimental procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Thirty-one crossbred Angus heifers (F0 generation) were individually fed at the NDSU Animal Nutrition and Physiology Center and were randomly assigned to one of two treatment diets. Treatment diets for F0 heifers consisted of a basal diet, that either consisted of no additional supplementation (CON; n = 14) or a basal diet with addition of a vitamin and mineral supplement (VTM; n =17). The VTM supplement was a loose product (4oz, Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes, Inc., Arden Hills, MN) that was individually added to the daily diet allotment of F0 heifers beginning at breeding and throughout gestation. F0 heifers were estrus synchronized via a 7-day Co-Synch + CIDR protocol and then AI bred with female sexed semen of the same sire. F0 heifer pregnancies were confirmed using transrectal ultrasound at d 35 and fetal sex evaluated at d 65 to confirm female fetuses. Feeding management of F0 heifers and offspring performance was reported in Hurlbert et al. (2023).

Heifers were moved to the NDSU Beef Cattle Research Complex during the third trimester where they continued their respective treatment diets until calving. The F1 generation of heifer calves was utilized in the current study to evaluate fetal programming effects on energy metabolism during growth, development, and gestation.

Both cohorts of F0 dams were fed a common TMR post-calving diet, which included vitamin and mineral supplementation. The F1 heifer calves of differing gestational background (CON vs. VTM) were then reared by their dams. In mid-May 2021, F1 heifer calves were turned out to pasture with their F0 dams and were weaned in November 2021. At weaning, F1 heifers were fed a common TMR and transported at d 50 post-weaning to the Beef Cattle Research Complex (BCRC; Fargo, ND) for heifer development. At BCRC, F1 heifers were fed a TMR for *ad libitium* intake comprised of 70% winter wheat forage, 20% corn silage, and 10% DDGS premix with vitamin and mineral supplement.

In June 2022, thirty-one F1 heifers were estrus-synchronized with 7-d Select Synch + CIDR protocol and timed-AI bred at 72 h post-CIDR removal with female-sexed semen from a single sire. Pregnancies of F1 heifers were confirmed using transrectal ultrasound at d 35 of gestation and fetal sex evaluated at d 65 to confirm female fetuses. Sixteen pregnant F1 heifers (8 from VTM dams and 8 from CON dams) were selected for evaluation of cellular energy metabolism throughout pregnancy and were subsequently transported to ANPC. At ANPC, all F1 heifers were individually-fed a TMR consisting of 70% winter wheat forage, 20% corn silage, and 10% DDGS premix with vitamin and mineral supplement. Diet allotments were delivered at 1.5% of body weight on a dry matter basis.

Liver and muscle biopsies were collected on d 179 and d 247 +/- 3 to evaluate cellular energetics at the second and third trimester of pregnancy. Heifers entered a cattle squeeze chute and were restrained, hair was removed at each biopsy site with cattle clippers, and the sites were scrubbed three times with betadine and 70% ethanol. Flunixin meglumine (Banamine, Merck Animal Health; Madison, NJ) was dosed at 1.1 – 2.2 mg/kg body weight and administered intravenously. A local anesthetic (Lidocaine Injectable – 2%; MWI, Boise, ID; 3 mL at each biopsy site) was administered subcutaneously. For liver biopsies, a 1-cm incision was made at the biopsy site between the 10th and 11th ribs. Liver samples were collected using a 14-gauge Tru-Cut biopsy trochar (Merit Medical, South Jordan, UT; McCarthy et al., 2021). For muscle biopsies, a 2-cm incision was made on the back above the longissmus dorsi muscle. Muscle samples were collected using a Bergstrom muscle biopsy tool. The biopsy sites were closed with surgical staples, and wound spray (Aluspray, Neogen; Lexington, KY) was topically applied. Samples were placed in chilled preservation media and transported to the laboratory.

In the laboratory, liver and muscle samples were permeabilized in a saponin solution for 20 and 30 minutes, respectively. Permeabilized samples (4 – 6 mg) were then placed in chambers of the Oroboros O2k Fluorespirometer (Oroboros Instruments, Innsbruck, Austria) to assess tissue oxygen consumption and mitochondrial function utilizing a substrate-inhibitor-uncoupler protocol. The substrate-inhibitor-uncoupler protocol assesses oxygen consumption at different pathways within complex-1 of the electron transport chain, which is responsible for ATP production. The stages evaluated in this study include LEAK respiration (L), OXPHOS capacity (P), NADH-linked OXPHOS respiration (PI), and electron transfer capacity (E).

Data were analyzed to determine the effect of F0 dam VTM treatment on F1 offspring mitochondrial complex I respiration using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Data were considered significant at $P = 0.05$.

Results and Discussion

In liver there was no treatment × trimester interaction ($P \geq 0.13$). Liver mitochondrial function and oxygen consumption in F1 heifers were not influenced by gestational VTM supplementation ($P \geq 0.68$) or stage of gestation ($P \geq 0.27$; Table 1). In muscle, there was no treatment × trimester interaction ($P \geq 0.32$). LEAK respiration in muscle was greater ($P = 0.05$) in CON heifers compared with VTM heifers. Additionally, L respiration was greater ($P = 0.02$) in the third trimester compared to the second trimester (Table 2).

Knowing that the liver is a highly adaptable organ, it is important to consider that all F1 heifers were fed a common TMR that included vitamin and mineral supplement. The potential for the supplement to compensate for fetal programmed effects, as well as organ compensation, may exist (Prezotto et al., 2014). Based on the results of this experiment, it is likely that liver function was similar between the gestationally different cohorts as they received the same diet, which included vitamin and mineral supplement, post-weaning and throughout the experiment. Additionally, our lab previously reported similar results between supplemental treatments, with no differences in liver mitochondrial function and oxygen consumption at 30 hr post-birth in neonatal calves.

The observation that CON heifers tended to weigh less than VTM heifers may be related to muscle metabolism traits, as LEAK respiration was greater ($P = 0.05$) in CON heifers. Greater oxygen consumption during LEAK respiration indicates increased proton leak and potentially decreased efficiency of mitochondrial respiration (Gnaiger, 2019). Protons that leak or escape complex-1 are not utilized to produce ATP and as a result produce heat as a byproduct, resulting in a potentially less efficient animals.

Previously, we observed a greater capacity for ATP production, as indicated by greater oxygen consumption during several stages of mitochondrial respiration, in gestationally VTM-supplemented neonatal calves at 30 h post-birth; (Menezes et al., Not Published). These alterations

Table 1. Oxygen consumption (O2 Flux (pmol O_2 • s^{-1} • mg^{-1}) measured in liver and muscle tissue of F1 heifers with gestationally differing backgrounds (CON or VTM). The stages evaluated include LEAK respiration (L), OXPHOS capacity (P), NADH-linked OXPHOS respiration (PI), and electron transfer capacity (E).

	Treatment			
Oxygen Flux	**CON**	**VTM**	**SE**	***P*-Value**
Liver				
LEAK respiration (L)	2.47	2.47	0.29	0.99
OXPHOS capacity (P)	9.83	9.38	0.86	0.70
NADH-linked OXPHOS respiration (PI)	11.64	11.12	0.93	0.68
Electron transfer capacity (E)	14.65	14.23	1.51	0.79
Muscle				
LEAK respiration (L)	2.77	1.40	0.50	0.05
OXPHOS capacity (P)	23.57	20.12	2.40	0.30
NADH-linked OXPHOS respiration (PI)	25.96	23.06	2.68	0.43
Electron transfer capacity (E)	29.98	30.19	3.21	0.96

Table 2. Oxygen consumption (O2 Flux (pmol O_2 • s^{-1} • mg^{-1}) measured in liver and muscle tissue of F1 heifers during differing trimesters of pregnancy. The stages evaluated include LEAK respiration (L), OXPHOS capacity (P), NADH-linked OXPHOS respiration (PI), and electron transfer capacity (E).

	Trimester			
Oxygen Flux	**2**	**3**	**SE**	***P*-Value**
Liver				
LEAK respiration (L)	2.51	2.43	0.28	0.83
OXPHOS capacity (P)	9.31	9.90	0.81	0.61
NADH-linked OXPHOS respiration (PI)	10.69	12.08	0.88	0.28
Electron transfer capacity (E)	13.80	15.08	1.09	0.41
Muscle				
LEAK respiration (L)	1.22	2.95	0.47	0.0161
OXPHOS capacity (P)	21.04	22.64	2.26	0.63
NADH-linked OXPHOS respiration (PI)	23.22	25.8	2.52	0.48
Electron transfer capacity (E)	27.60	32.59	3.01	0.26

in mitochondrial function of metabolic organs are still present 18 to 22 months later in life indicating that "programming" had occurred.

Future laboratory analysis of mitochondrial quantity in muscle and liver tissue will provide additional knowledge regarding potential differences in programmed cellular energetics between the two treatments. Energy from feed ingested by cattle can be lost in manure, urine, methane, and heat. Continuing to study cellular and whole-animal energy metabolism is important for developing a deeper understanding of feeding strategies that will allow producers to select for more feed-efficient cattle through genetic selection or changes in feeding management.

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Exploring feeding performance of heavy yearling angus cattle – 2022 North Dakota Angus University Feedout

Colin Tobin[1] and Karl Hoppe[1]

The North Dakota Angus University feedout is a program through the North Dakota Angus Association (NDAA) where members can identify their genetic potential through growth and carcass characteristics. Average difference in profitability between consignments from the top five herds and the bottom five herds was $308.55 per head for the 2022 feeding period.

Summary

Cattle producers across North Dakota are using the North Dakota Angus University Feedout project to discover the actual value and provide benchmark feeding and carcass performance of their yearling spring-born beef steers. Cattle consigned to the feedout project were delivered to the NDSU Carrington Research Extension Center (CREC) Livestock Unit prior to June 13, 2022. After an average 118-day feeding period, cattle averaged 1482.8 pounds (shrunk harvest weight). Throughout the feeding period, animals required 6.7 lbs of feed (dry matter [DM] basis) for one pound of gain. Overall pen average daily gain ranged from 5 to 7.20 lbs. Feed cost per pound of gain was $0.85 and total cost per pound of gain was $1.14. Profit ranged from $218.88 per animal with superior growth and carcass traits to a loss of $89.67 per head with discounts and decreased performance. The variability among animals within herds continues to be substantial when discovering the feeding and carcass value of yearling, spring-born steers.

Introduction

The North Dakota Angus University Feedout program is a summer, retained-ownership project where cattle producers raising spring-born Angus cattle can learn more about the feeding performance, carcass characteristics, and profitability of their yearling steers.

Through involvement in this calf value discovery program, cow-calf producers can benchmark performance and identify superior genetics when fed with common feedlot management.

Procedures

Calves (68 head) were received in groups ranging from 5 to 23 head from five owners prior to June 13, 2022. Upon delivery to the CREC Livestock Unit, calves were weighed, tagged, and veterinary processed. Cattle were implanted with Synovex-Choice. Calves were penned by owner and provided a corn-based receiving diet. After a 10-day ration adaption, 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 harvested in two groups. The first group of cattle was harvested on October 5, 2022 (45 head) and the second group was harvested on October 21, 2022 (23 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Nebraska, on a grid basis, with premiums and discounts based on carcass quality. Carcass data were collected after harvest.

Results and Discussion

Cattle averaged 937.8 pounds upon delivery to the CREC Livestock Unit on June 13, 2022 (Table 1). After an average 118-day feeding period, cattle averaged 1482.8 pounds (at plant, shrunk weight). Death loss was 0% (0 head) during the feeding period. Average daily feed intake per head was 47.1 pounds on an as-fed basis and 31.1 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 $0.85. The overall yardage cost per pound of gain was $0.09. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $1.14. Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.13652* initial calf weight, pounds) + 285.1283) was determined by regression analysis on local livestock auction prices reported

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for the weeks before and after delivery. Overall, the carcasses contained U.S. Department of Agriculture Quality Grades at 10.3 percent Prime, 77.9 percent Choice (including 47.0 percent Certified Angus Beef), 11.8 percent Select, and 0 percent no roll. USDA Yield Grades for the carcasses were 7.4 percent YG2, 61.8 percent YG3, 29.4 percent YG4 and 1.4 percent YG5. Two carcasses weighed greater than 1050 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 per cwt received for Oct 6, 2022, was $235.19 Choice YG3 base with premiums: Prime $15, CAB $6, YG2 $3, and discounts: Select $24, YG4 $8, YG5 $20 and carcasses greater than 1050 pounds $20. The grid price per cwt received for Oct 22, 2022, was $242.94 Choice YG3 base with similar premiums and discounts except for Select $28/cwt. The top-profit pen of calves returned $218.88 per head, while the lowest profit (loss) calves returned ($89.67) per head. The spread between the top profit pen and the lowest profit pen was $308.55 per head. Yearling Angus steer performance varied between owners. Feed conversion ranged from 5.7 to 7.37 pounds dry matter fed per pound of gain. Average daily gain ranged from 5 to 7.20 pounds per day. Feedout projects continue to provide cattle producers an opportunity to learn about feedlot performance, individual carcass differences, and discover the value of their cattle.

Table 1. North Dakota Angus University Feedout 2022

Pen	No. head	No. died	Weight in, lb	Weight out, lb	Average daily gain, lb/day	Feed/gain, lb dry matter/ lb gain	Feed cost of gain/lb	Total cost of gain/ lb.	% prime	% CAB	Profit/head
1	9	0	941.3	1476.4	4.735	5.700	0.718	0.999	11.1	22.2	$84.94
2	5	0	977.0	1451.6	4.200	6.800	0.856	1.282	0.0	60.0	$80.65
3	10	0	1000.4	1534.5	4.727	6.673	0.839	1.132	20.0	80.0	$218.88
4	21	0	979.7	1544.6	5.000	6.604	0.831	1.115	19.0	47.6	$170.16
5	23	0	862.5	1413.3	4.269	7.375	0.928	1.238	0.0	8.7	$(89.67)
overall	68	0	937.8	1482.8	4.600	6.770	0.852	1.143	10.6	48.5	$78.19
std dev	7.9	0.0	54.4	55.5	0.3	0.6	0.1	0.1	9.78	28.66	117.7
number	5	5	5	5	5	5	5	5	5	5	5

Discovering performance and value in North Dakota calves: 2022-2023 Dakota Feeder Calf Show Feedout

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

The Dakota Feeder Calf Show is a feedout project where North Dakota cattle producers identify cattle with superior growth and carcass characteristics. Average difference in profitability between consignments from the top five herds and the bottom five herds was $312.11 per head for the 2022-2023 feeding period.

Summary

North Dakota cattle producers are using the Dakota Feeder Calf Show feedout project to discover the actual value of their spring-born beef steer calves, provide comparisons among herds, and benchmark feeding and carcass performance. Cattle consigned to the feedout project were delivered to the Carrington Research Extension Center livestock unit on Oct. 15, 2022. After a 228-day feeding period with 1.79% death loss, cattle averaged 1325.7 pounds (shrunk harvest weight). Feed required per pound of gain was 6.6 (dry-matter basis). Overall pen average daily gain was 3.18 pounds. Feed cost per pound of gain was $0.825, and total cost per pound of gain was $1.151. Profit ranged from $611.63 per head for pen-of-three cattle with superior growth and carcass traits to a loss of $299.53 per head (no death loss). The variability between producers' herds continues to be substantial when discovering the feeding and carcass value of spring-born calves.

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

Introduction

Cow-calf producers need to be competitive with increasing production costs and increasing returns. By determining calf value through a feedout program, cow-calf producers can identify profitable genetics under common feedlot management. Substantial marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass. Cost-effective feeding performance is needed to justify the expense of feeding cattle past weaning. Price premiums are provided for cattle producing highly marbled carcasses. Knowing production and carcass performance can lead to profitable decisions for ranchers raising North Dakota born and fed calves. This ongoing feedlot project provides cattle producers with an understanding of cattle feeding and cattle selection in North Dakota.

Procedures

The Dakota Feeder Calf Show was developed for cattle producers willing to consign steer calves to a show and feedout project. The calves were received in groups of three or four on Oct. 15, 2022, at the Turtle Lake weighing station, Turtle Lake, N.D., for weighing, tagging, veterinary processing, and display. The calves were evaluated for conformation and uniformity, with the judges providing a discussion with the owners at the beginning of the feedout. The number of cattle consigned was 168, of which 147 competed in the pen-of-three contest. The calves then were shipped to the Carrington Research Extension Center, Carrington, N.D., for feeding. Prior to shipment, calves were vaccinated, implanted with Synovex-S, dewormed and injected with a prophylactic long-acting antibiotic. Calves then were sorted and placed on corn and rye-based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.62 megacalorie of net energy for gain (Mcal NEg) per pound finishing diet. Cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were reimplanted with Synovex-Choice on Jan. 24, 2023.

At a Feb. 2, 2023, open house, cattle owners could review calves, ponder performance, and discuss marketing options. The cattle were harvested on June 1, 2023 (164 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Neb., on a grid basis, with premiums and discounts based on carcass quality. One calf was harvested locally due to lameness. Carcass data were collected after harvest. Ranking in the pen-of-three competition was based on the best overall score. The overall score was determined by adding the index values for feedlot average daily gain (25% of score), marbling score (25% of score) and profit (25% of score) and subtracting index value for calculated yield grade (25% of score). The Dakota Feeder Calf Show provided awards and recognition for the top-ranking pen of steers.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 577.5 pounds upon delivery to the Carrington Research Extension Center livestock unit on Oct. 15, 2022. After an average 228-day feeding period, cattle averaged 1,325.7 pounds (at plant, shrunk weight). Death loss was 1.79% (three head)

Table 1. Feeding performance - 2022-2023 Dakota Feeder Calf Show Feedout

Pen of three	Best Three Score Total	Average Birth Date	Average Weight per Day of Age, lbs	Average Harvest Weight, lbs.	Average Daily Gain, lbs.	Average Marbling Score[1]	Ave Calculated Yield Grade	Ave Feeding Profit or Loss/Head
1	2.614	8-Apr-22	3.31	1376.1	3.8	614	3.7	$667.99
2	2.610	11-Apr-22	3.04	1256.5	3.3	673	3.4	$606.62
3	2.475	16-Mar-22	3.40	1496.1	3.8	605	4.1	$669.92
4	2.355	24-Mar-22	3.39	1460.3	3.6	500	2.9	$559.09
5	2.346	14-Apr-22	3.15	1293.5	3.3	611	3.5	$554.55
Average Top 5 herds	**2.48**	**2-Apr-22**	**3.3**	**1376**	**3.6**	**601**	**3.49**	**$611.63**
6	2.327	30-Apr-22	3.10	1226.1	3.2	591	3.6	$629.54
7	2.294	5-Apr-22	3.26	1368.1	3.3	498	2.8	$577.81
8	2.283	8-Apr-22	3.26	1358.4	3.4	484	2.8	$571.70
9	2.184	2-Apr-22	3.37	1424.2	3.4	628	4.4	$578.03
10	2.146	27-Mar-22	3.19	1363.3	3.5	512	3.4	$543.83
11	2.129	22-Feb-22	3.01	1387.3	3.3	545	3.2	$476.47
12	2.087	23-Mar-22	3.24	1396.2	3.7	562	4.6	$616.77
13	2.057	16-Apr-22	3.28	1340.0	3.5	540	3.6	$479.80
14	2.050	30-Mar-22	3.29	1399.4	3.8	480	3.8	$536.99
15	2.015	27-Mar-22	3.23	1384.9	3.6	526	3.4	$421.10
16	2.006	11-Apr-22	3.20	1323.9	3.3	504	3.8	$560.97
17	2.000	30-Apr-22	3.26	1287.0	3.3	413	3.4	$620.24
18	1.976	5-Mar-22	3.14	1413.6	3.6	489	4.2	$601.06
19	1.945	5-Apr-22	3.02	1267.0	3.0	558	3.8	$491.67
20	1.909	21-Apr-22	3.30	1329.6	3.6	513	4.0	$482.97
21	1.863	8-Mar-22	3.31	1482.0	3.7	397	3.2	$446.02
22	1.817	23-Mar-22	3.12	1349.6	3.4	483	3.3	$373.81
23	1.801	19-Apr-22	3.20	1296.7	3.3	406	3.1	$458.69
24	1.749	4-Apr-22	3.10	1298.3	3.0	431	3.4	$489.38
25	1.704	3-May-22	3.22	1260.6	3.2	416	2.8	$329.88
26	1.634	24-Apr-22	3.39	1353.6	3.1	452	3.7	$439.40
27	1.631	16-Apr-22	3.15	1276.6	3.1	425	3.6	$445.08
28	1.628	25-Feb-22	2.78	1276.6	2.9	423	3.0	$371.40
29	1.613	21-Mar-22	3.16	1374.5	3.3	407	3.8	$465.43
30	1.559	26-Apr-22	1.85	1120.9	2.7	393	2.3	$286.19
31	1.553	19-Apr-22	3.49	1413.8	3.6	453	3.8	$319.76
32	1.507	27-Mar-22	3.0	1277.4	3.2	491	4.2	$371.70
33	1.365	29-Mar-22	2.9	1252.5	3.0	391	3.0	$266.67
34	1.358	15-Apr-22	3.1	1282.2	3.1	445	3.4	$206.97
35	1.338	20-Mar-22	2.7	1189.9	2.9	397	2.9	$235.67
36	1.318	6-Apr-22	1.6	1325.1	3.2	403	4.4	$416.63
Average bottom 5 herds	**1.38**	**1-Apr-22**	**2.7**	**1265**	**3.1**	**425**	**3.60**	**$299.53**
Overall average - pens of three	**1.92**	**3-Apr-22**	**3.10**	**1,332.83**	**3.34**	**490.48**	**3.51**	**$476.94**
Standard deviation		17.4	0.4	80.1	0.3	77.5	0.5	122.9
number		36	36	36	36	36	36	36

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

during the feeding period. Average daily feed intake per head was 31.2 pounds on an as-fed basis and 21.0 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 9.8 on an as-fed basis and 6.62 pounds on a dry-matter basis. The overall feed cost per pound of gain was $0.826. The overall yardage cost per pound of gain was $0.124. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $1.151. Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.057040968* initial calf weight, pounds) + 228.4227584) 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 2.4% Prime, 75.0% Choice (including 17.0 percent Certified Angus Beef), and 22.5% Select and 0% ungraded, and USDA Yield Grades at 3.7% YG1, 40.1% YG2, 49.4% YG3, and 6.8% YG4. Carcass value per 100 pounds (cwt) was calculated using the actual base carcass price plus premiums and discounts for each carcass. The grid price received for May 25, 2022, was $291.23 Choice YG3 base with premiums: Prime $25, CAB $6, YG1 $6.50 and YG2 $3, and discounts: Select minus $21, Standard (ungraded - no roll) minus $25.50, YG4 minus $8, YG5 minus $20, Mature minus $10 and carcasses heavier than 1075 pounds minus $20.

Results from the calves selected for the pen-of-three competition are listed in Table 1. Overall, the pen-of-three calves averaged 425.6 days of age and 1,332.8 pounds per head at slaughter. The overall pen-of-three feedlot average daily gain was 3.34 pounds, while weight gain per day of age was 3.10 pounds. The overall pen-of-three marbling score was 490.5 (average choice, modest marbling). Correlations between profit and average birth date, harvest weight, average daily gain, weight per day of age or marbling score are shown in Table 2. Average slaughter weight, average daily gain and marbling score had higher correlations to profitability than average birth date, average weight per day of age or yield grade. The top-profit pen-of-three calves with superior genetics returned $669.92 per head, while the bottom pen-of-three calves returned $206.97 per head. The average of the five top-scoring pens of steers averaged $611.63 per head, while the average of the bottom five scoring pens of steers averaged a loss of $299.53 per head. For the pen-of-three competition, average profit was $476.94 per head. The spread in profitability between the top and bottom five herds was $312.11 per head. North Dakota calf value is improved with superior carcass and feedlot performance. Favorable average daily gains, weight per day of age, harvest weight and marbling score can be found in North Dakota beef herds. Exceptional profit per head was a result of exceptional market price improvement in 2023. Feedout projects continue to provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

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

	Correlation coefficient
Profit and average birth date	-0.0372
Profit and average slaughter weight	0.4640
Profit and average daily gain	0.5750
Profit and weight per day of age	0.3908
Profit and marbling score	0.6635
Profit and yield grade	0.3694

Effects of replacing dried distillers grains with solubles with heat-treated soybean meal in forage-based growing cattle diets

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The objective of this experiment was to evaluate the effects of increased concentrations of metabolizable protein and lysine by feeding heat-treated soybean meal in forage-based growing cattle diets. The results from this experiment suggest that replacing dried distillers grains plus solubles with heat-treated soybean meal did not affect steer growth performance. Therefore, the inclusion of heat-treated soybean meal in growing cattle diets will likely be decided based on availability and cost.

Summary

Seventy Angus-based steers were utilized in an 85-day growing study evaluating the partial replacement of 16% dried distillers grains plus solubles (DDGS) with heat-treated soybean meal by substituting 0, 4, 8, and 12% of DDGS (dry matter basis) with AminoPlus® (Ag Processing Inc., Omaha, NE). Diets were formulated to increase metabolizable protein and lysine as the inclusion of treated soybean meal increased. Body weights and blood samples were collected every 28 days. Individual daily feed intake was measured using an automated feed system (Insentec Roughage Intake Control, Hokofarm B. V., Marknesse, The Netherlands). There were no differences ($P \geq 0.37$) in ending body weight, average daily gain, dry matter intake, and feed-to-gain ratio as heat-treated soybean meal replaced DDGS at increased levels. The increasing inclusion rate of heat-treated soybean meal resulting in theoretical increases in metabolizable protein and lysine concentrations did not affect steer growth performance.

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Introduction

As the biodiesel industry expands, soybean-crushing plants are being built in North Dakota and surrounding states. These processing facilities extract soybean oil and produce feed byproducts such as soybean meal and soy hulls. The North Dakota Soybean Council estimates yearly crushing capacity at 136 million bushels and the production of 940,000 tons of soybean meal by 2026. The increase in soybean meal production could allow producers to take advantage of a local feedstuff. Soybean meal (SBM) has a high protein content that offers a balanced amino acid profile, particularly lysine, for beef cattle diets. This could benefit producers in the Midwest as corn-based diets are typically limiting in the essential amino acid lysine. However, SBM is highly degradable in the rumen at 70% rumen degradable protein (RDP; NASEM, 2016) so most of the lysine from SBM does not flow to the small intestine (Borucki Castro et al., 2007).

Increasing the rumen undegradable protein content in SBM with non-enzymatic browning increases ruminal bypass that could improve cattle growth performance if protein and lysine requirements are not met (Coetzer et al., 1999). Heat-treated soybean meal (TSBM) supplies cattle with greater amounts of available amino acids, particularly lysine and metabolizable protein (MP) by increasing the rumen undegradable protein (RUP) content to approximately 70%.

The objectives of this study were to evaluate the effects of increasing concentrations of lysine and metabolizable protein by feeding heat-treated soybean meal in forage-based growing cattle diets. The hypothesis was that as TSBM replaces dried distillers grains plus solubles (DDGS), growth performance will improve due to increased metabolizable protein and intestinal supply of essential amino acids.

Materials and Methods

The North Dakota State University Institutional Animal Care and Use Committee approved all animal procedures. Seventy Angus-based steers (initial BW = 656 ± 36 lb) were utilized in an 85-day growing study at the NDSU Beef Cattle Research Complex in Fargo, North Dakota. Steers originated from the NDSU Central Grasslands Research Extension Center. Steers were provided ad libitum access to feed and water in a monoslope barn with drylot access. Based on 16% inclusion of DDGS, dietary treatments using TSBM were formulated to replace DDGS at increasing inclusion levels of 0 (CON), 4 (TSBM4), 8 (TSBM8), and 12% (TSBM12) on a dry matter (DM) basis (Table 1). Diets were formulated using the empirical solutions model of the Beef Cattle Nutrient Requirements Model 2016 (version 1.0.37.15; NASEM, 2016) to increase metabolizable protein and lysine as the inclusion of TSBM increased in the diet. Lysine requirements in the formulated diets were predicted to be deficient for TSBM0 and TSBM4 treatments and in excess for TSBM8 and TSBM12 treatments. In contrast, the metabolizable protein requirement was sufficient for all treatments (Table 2).

Prior to initiation of the study, steers were limit-fed a common diet containing 40% corn silage, 57% oat hay, and 3% dry meal supplement at 1.8% BW for five days followed by three days of weighing to minimize gut fill variation (Watson et al., 2013). The average of the 3-day weights served as the initial BW. Steers were blocked by weight into light (initial BW = 617 ± 14 lb), medium (initial BW = 653 ± 10 lb), and heavy (initial BW = 698 ± 18 lb) blocks and assigned randomly to treatments. The 3-day weight process was repeated at the end of the study to measure the ending BW. On day 0, steers were implanted with 80 mg of trenbolone acetate and 16 mg of estradiol (Revalor®-IS, Merck Animal Health, Summit, NJ). Body weights and blood were collected every 28 days. Blood was collected via jugular venipuncture, processed into plasma and serum samples, and stored at -4ºC until further analysis. Individual daily feed intake was measured using an automated feed system (Insentec Roughage Intake Control, Hokofarm B. V., Marknesse, The Netherlands).

Dietary DM was determined weekly by sampling ingredients and oven-drying at 60ºC for 48 hours. Weekly ingredient samples were collected and ground through a 1-mm screen using a Wiley Mill grinder (Thomas Scientific, Swedesboro, NJ). Ground samples were composited into 4-week intervals. Composited ingredient samples were analyzed for laboratory DM, crude protein (CP), organic matter (OM), acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, fat, calcium (C), and phosphorus (P).

Data were analyzed as a generalized randomized block design utilizing the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with treatment (n = 4), period (n = 3), and treatment × period interaction as fixed effects, initial BW as a fixed covariate, and period considered a repeated measure using the unstructured variance-covariance structure. Preplanned pairwise comparisons of treatment within period were evaluated and significant model effects ($P \leq 0.05$) were adjusted using the Tukey-Kramer methods. Model residual plots were evaluated to ensure mixed procedure assumptions were met and necessary outliers were removed.

Table 1. Experimental diets.

Ingredient, % DM	TSBM0	TSBM4	TSBM8	TSBM12
Corn Silage	44	44	44	44
Oat Hay	37	37	37	37
DDGS[1]	16	12	8	4
TSBM[2]	0	4	8	12
Supplement[3]	3	3	3	3

[1]Dried Distillers Grains with Solubles.
[2]Heat-treated Soybean Meal (AminoPlus®, Ag Processing Inc., Omaha, NE).
[3]Supplement formulated to provide 22.9 g/ton monensin (Rumensin 90, Elanco Animal Health). Supplement contained 1.62% fine ground corn, 1.00% limestone, 0.30% salt, 0.05% beef trace mineral, 0.0126% Vitamin A, 0.002% Vitamin D, 0.0003% Vitamin E on dry matter basis.

Table 2. Nutrient composition of the experiment diets.

Item	TSBM0	TSBM4	TSBM8	TSBM12
DM, % As-fed	46.90	46.90	46.90	46.90
CP, % DM	11.80	12.27	12.73	13.20
Fat, % DM	2.61	2.44	2.26	2.08
NDF, % DM	52.15	51.30	50.45	49.60
ADF, % DM	29.70	29.41	29.13	28.85
Starch, % DM	16.95	16.88	16.81	16.74
Metabolizable protein balance[1], g/d	60.7	89.2	110.2	137.9
Lysine balance[1], g/d	-4.94	-1.80	1.07	4.10

[1]Calculated utilizing the empirical solutions model of the Beef Cattle Nutrient Requirements Model 2016 (version 1.0.37.15; NASEM, 2016).

Results and Discussion

While exploring statistical models on growth performance traits collected, two steers were identified as having data on all traits that were outliers compared to the other steers (one from TSBM4 and one from TSBM8). Therefore, these two steers were removed from the analysis dataset, leaving 68 steers for data analyses. Furthermore, initial models evaluating all possible interactions, including BW block class effect with treatment and/or period, found that those interactions were sometimes significant. Environmental conditions were more likely to contribute to significance than treatment differences as steers performed inconsistently on the same treatment across blocks.

The interaction of treatment by period was significant ($P \leq 0.01$) for body weight (BW), average daily gain (ADG), and dry matter intake (DMI), with a tendency ($P = 0.10$) for feed:gain ratio (F:G). Pairwise comparisons of treatment within period did not differ ($P \geq 0.37$) for BW and DMI. However, from days 28 to 55, ADG was greater for TSBM4 than TSBM0 with TSBM8 and TSBM12 intermediates (Figure 1.). There were no differences ($P \geq 0.37$) in overall BW, ADG, DMI, and F:G ratio among treatments (Table 3).

As TSBM replaced DDGS, the energy of the diet was likely less due to less digestible fiber and oil in TSBM than in DDGS. However, F:G was not different among treatments, and while not statistically different, TSBM4 improved F:G by 7.5% compared to TSBM0 (6.16 and 6.66, respectively). The formulated metabolizable lysine supply for TSBM0 was deficient by 4.2 grams/day, but TSBM4 was only deficient by 1.8 grams/day. Thus, metabolizable lysine was possibly limiting in the DDGS-only diet but was met when TSBM replaced 4% of the DDGS. However, because MP was provided above the requirement in all diets, it is possible that as TSBM replaced DDGS, the additional MP provided by TSBM was utilized as an energy source.

These results agree with previous research when partially replacing wet corn distillers grains included at 20% of the diet with TSBM at 0, 6, and 12% dietary DM that did not affect the growth performance of steers fed smooth brome hay-based diets (Spore et al., 2021). The results of the current study suggest that increasing concentrations of metabolizable protein and lysine through heat-treated soybean meal supplementation does not affect growing cattle performance with the partial replacement of DDGS when included at 16% of the diet.

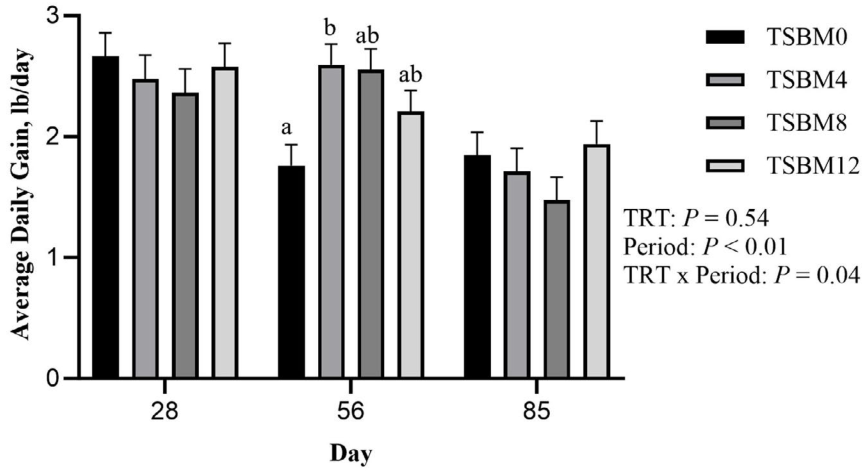

Figure 1. Effect of replacing 16% of diet dry matter distillers grains with solubles with heat-treated soybean meal (TSBM; 0, 4, 8, or 12% dry matter basis) in forage-based growing diets on average daily gain. [ab]Means with different superscripts within the same day range (1-28; 29-56; 57-85) differ ($P \leq 0.05$).

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Table 3. Overall performance of growing cattle on forage-based diets with heat-treated soybean meal.

	Treatments[1]					*P* - value		
Item	TSBM0	TSBM4	TSBM8	TSBM12	SEM	TRT	Period	TRT x Period
Steers, n	16	18	17	17	--	--	--	--
Initial BW, lb	656	656	656	656	3.8	0.99	--	0.99
Ending BW, lb	833	847	836	845	8.7	0.71	0.01	0.01
ADG, lb/day	2.09	2.26	2.13	2.24	0.101	0.54	0.01	0.04
DMI, lb/day	13.90	13.85	13.80	13.61	0.274	0.88	0.01	0.01
Feed:Gain	6.65	6.12	6.48	6.07	--	0.37	0.01	0.10

[1]Dietary percent of heat-treated soybean meal (TSBM) replacing a proportion of 16% dried distillers grains plus solubles in the diet; TSBM0: 0% heat-treated soybean meal, TSBM4: 4% heat-treated soybean meal, TSBM8: 8% heat-treated soybean meal, TSBM12: 12% heat-treated soybean meal.
[ab]Different superscripts in the same row differ $P \leq 0.05$.

NDSU Extension evaluates impacts of grazing use on grassland growth and production

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

Grazing management decisions can have long-term impacts on plant growth and forage production. The goal of this program is to demonstrate the impact of grazing use on grassland growth and development the following growing season to facilitate improved grazing management and enhanced climate resilience of forage resources. With the exception of Kentucky bluegrass in 2023, the highest growth occurred in pastures with slight to moderate use and the lowest growth in pastures with severe use. Severe use reduced forage production by as much as 57% (2022) and 54% (2023). The results of this program demonstrate the importance of having a grazing management plan and monitoring grazing use to reduce long-term impacts to grazing resources.

Summary

NDSU Extension evaluated the impact of grazing use intensity following the 2021 and 2022 grazing season on the growth and production of grasslands the following year. County and state Extension personal evaluated 51 pastures in 12 North Dakota counties over the two-year period. Samples were classified based on county and degree of use. Degree of use was classified using a visual assessment with four categories: 1) Slight to Moderate (<40% use), 2) Full (40%-60% use), Close (60%-80% use), and Severe (>80% use). Growth of key grass species was monitored weekly starting in late-April and ending June 2 in both 2022 and 2023. Forage production was determined prior to the initiation of grazing each year. Grazing management can have long-term impacts on forage growth and production. Severe use reduced forage production by as much as 57% (2022) and 54% (2023). Monitoring grazing use in the fall to reduce or eliminate overgrazing of fall tillers can enhance tiller development the subsequent spring and prevent long-term reductions in forage growth and production.

Introduction

Grazing management in the fall can have significant impacts on forage growth and production during the subsequent growing season (Goetz, H. 1963.; Heitschmidt et al. 1987; Dormaar et al. 1989). The Northern Plains grasslands are dominated by cool-season grasses, which can make up to 85% or more of the species composition. The most common native cool-season grass in the state is western wheatgrass. Research by Goetz (1963) reported that fall grazing reduced western wheatgrass growth by nearly 4 inches or 30%. This loss in growth translates to a loss in overall forage production.

Cool-season grasses develop tillers in the fall, and the development of these tillers has a direct impact on plant growth the next year. Most tiller development takes place from late August through early October, and again in April and May (Matthew et al. 2000). Plants initiate spring growth from the fall tillers. If these tillers are eaten or die due to drought stress, then spring growth must occur from new tillers developed in April and May.

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

In response to concerns expressed regarding the long-term impacts of grazing management during drought, NDSU Extension launched a program to evaluate the impacts of grazing use intensity on grassland growth and production following the 2021 drought. This program was continued for an additional growing season to further evaluate the influence of grazing use on forage growth and production under different fall moisture

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conditions. The goal of this program is to demonstrate the impact of grazing use on grassland growth and development the following growing season to facilitate improved grazing management and enhanced climate resilience of forage resources.

Experimental Procedures

NDSU Extension evaluated impacts of grazing use to grassland growth and production at 38 locations in ten counties in 2022 and 23 sites in seven counties in 2023. Samples were classified based on county and degree of use. In the fall of each year, degree of use was classified using a visual assessment approach adapted from Dyktserhuis (1951) that includes four categories: 1) Slight to Moderate (<40% use), 2) Full (40%-60% use), Close (60%-80% use) and Severe (>80% use). Monitoring occurred over a nine-week period from April 8, 2022, to June 2, 2022. Due to cold temperatures delaying plant growth in 2023, monitoring occurred over a six-week period from April 28, 2023, to June 2, 2023. Key grass species monitored included crested wheatgrass, smooth brome, Kentucky bluegrass, and western wheatgrass. Prior to initiation of grazing (May 26-June 15), clipping was completed to determine forage production. Clippings were completed at three plots per location using a 1.92 ft^2 frame, which was clipped to ground level. Samples were air dried and weighed to determine average forage production for each location.

Results and Discussion

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

The growth of key grass species was influenced by degree of use in both years (Figure 1). Growth of both smooth brome grass and western wheatgrass was highest at locations with slight to moderate use and lowest at locations with severe use. Kentucky bluegrass was strongly influenced by degree of use in 2022 (Figure 1c); however, this trend was not as strong in 2023 (Figure 1d). Due to the shallow rooting depth, Kentucky bluegrass growth and production is significantly impacted by drought (Toledo et al. 2023). We believe that the impacts of plant growth in 2022 were more influenced by drought conditions and for 2021 more impacted by management. The reduced growth of these cool-season grasses is likely caused by tiller mortality or a loss of plant vigor in the fall from a combination of drought stress and high grazing use that either removed the growing points or reduced plant vigor of the evaluated cool-season grasses. Plants that experience tiller mortality need to use carbohydrates that are stored in the roots to grow a new tiller in the spring, which results in delayed spring growth and the subsequent growth and production potential.

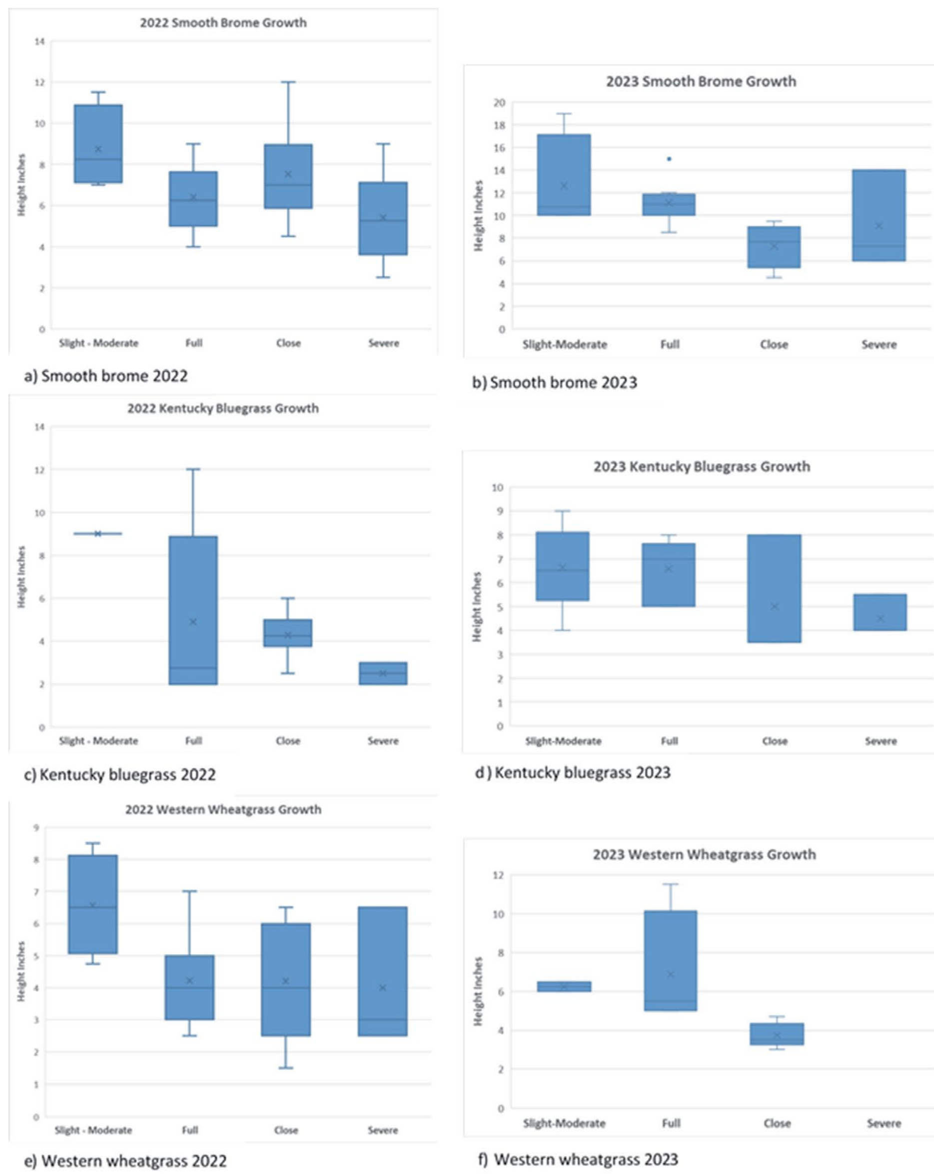

Figure 1. Growth of a) smooth brome in 2022, b) smooth brome in 2023, c) Kentucky bluegrass in 2022, d) Kentucky bluegrass in 2023, e) western wheatgrass in 2022 and f) western wheatgrass in 2023 in expressed as height in inches by degree of use slight-moderate (<40%), full (40%-60%), close (60%-80%) and severe (>80%).

The height of smooth brome was highest for slight to moderate use pastures with a median height of 8.25 inches in 2022 (Figure 1a). However, full use pastures had greater growth with a median height of 11 compared to 10.75 inches for the slight-moderate use in 2023 (Figure 1b). Severe use pastures had the lowest median height at 5.25 and 7.3 inches in 2022 and 2023, respectively. The height of Kentucky bluegrass was the highest for slight to moderate use pastures and lowest in the severe use pastures in 2022 with median heights of 9 and 2.5, respectively (Figure 1d). Whereas, in 2023 the full use pastures had the greatest growth at 6.5 inches and the close use pastures had the lowest growth at 3.5 inches. The height of western wheatgrass was the highest for slight to moderate use pastures across both years with a median height of 6.5 inches in 2022 and 6.25 inches in 2023 (Figures 1e and 1f). The full and close use pastures fell in the middle with median heights ranging between 3.5 and 6 inches. The severe use pastures had the lowest median height at 3 inches in 2023. Western wheatgrass was not found or documented in the severe use locations in 2023.

Forage production was impacted by grazing use in both 2022 and 2023 (Figure 2). The slight to moderate use sites had the greatest production with a median of 2,548 pounds per acre in 2022. However, the full use sites reported the highest production in 2023 with a median value of 2,925 pounds per acre. In 2022, the full and close use sites were similar with medians of 1,275.8 and 1,250 pounds per acre, respectively. This similarity is likely due to an outlier location with close use that reported much higher production than the other sites at 5,175 pounds per acre. Across both years the severe use sites had the lowest production, reporting median values of 1,091 and 1,335 pounds per acre in 2022 and 2023, respectively. When compared to the highest producing grazing uses the severe use locations had 57% (2022) and 54% (2023) reduction in forage production.

Grazing management decisions can have long-term impacts on forage growth and production. Severe use of grasslands, especially in the fall, can result in tiller mortality by either removal of the growing point or physiological stress to cool-season grasses. Tiller mortality can delay growth of cool-season grasses the following growing season, as well as reduce growth and overall forage production. These impacts are magnified following a drought as a result of increased tiller mortality caused by drought stress and the higher probability of pastures receiving heavier grazing use. The results of this program demonstrate the importance of having a grazing management plan and monitoring grazing use to reduce long-term impacts to grazing resources. Good grazing management paired with monitoring of pastures enhances the health and resilience of grazing systems. If you are interested in developing a grazing plan or learning more about tools to monitor grazing use, contact your local NDSU Extension agent.

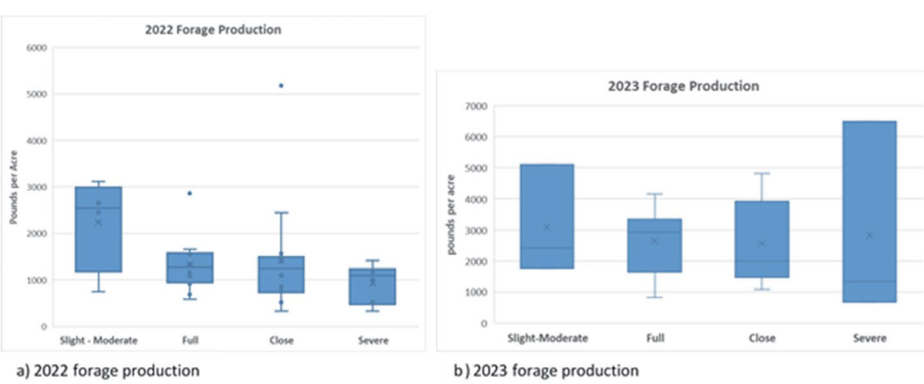

Figure 2. a) 2022 and b) 2023 forage production expressed as pounds per acre by degree of use slight-moderate (<40%), full (40%-60%), close (60%-80%) and severe (>80%).

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Enhancing profitability of soybean production through livestock integration

Joshua Wianecki[1], Miranda Meehan[1], Kevin Sedivec[2,3], Erin Gaugler[3], Zachary Carlson[1], Lindsay Malone[2], Colin Tobin[4], and Michael Ostlie[4]

The objective of this study is to identify the impacts of winter rye cover crop management through livestock integration on soil health, crop production, livestock performance, and economics. Livestock integration did not affect the function of winter rye as a cover crop, indicating potential for extended grazing periods in fall and spring on winter rye under favorable conditions.

Summary

A two-year study at the Central Grasslands Research Extension Center (CGREC) and Carrington Research Extension Center (CREC) investigated the effects of winter rye management with livestock integration on soil health, livestock performance, soybean production, and economics. The study evaluated four management scenarios: 1) dual grazing (fall and spring grazing), 2) spring grazing, 3) no grazing, and 4) no rye. The fall grazing period was short, ranging from 3 to 5 days, resulting in a loss of gain of 2.75 lb/day at CGREC and 6.28 lb/day at CREC. Livestock performance during spring grazing varied by location, with average gains of 0.54 lb/day at CGREC and an average loss of 1.48 lb/day at CREC. Spring forage yield of winter rye was not affected (P < 0.05) by fall grazing with the dual grazing treatment. Only soil nitrate levels were affected (P < 0.05) by grazing management, with lower nitrate-nitrogen in the no grazing treatment compared to no rye at CREC in the spring. Spring rye ground cover was not affected (P > 0.05) by fall grazing, indicating winter rye was not negatively affected by fall grazing. While total ground cover did not differ among treatments, all rye treatments decreased (P<0.05) weed cover regardless of grazing. Under favorable fall conditions, livestock integration into winter cover crops can extend the grazing season by utilizing quality forage without inhibiting the soil benefits of a winter cover crop.

Introduction

Cover crop use has expanded greatly in North Dakota in the last decade, increasing by 89% from 2012 to 404,267 acres in 2017 (USDA-NASS, 2019). However, the potential benefits of cover crops may not be completely attained under conventional cropping management. Integrated crop livestock systems offer producers methods of cover crop utilization with the potential to expand upon the benefits of cover cropping and create an economic return from livestock grazing (Archer et al., 2020). Typical winter rye (*Secale cereale*, L.) establishment in North Dakota occurs in late August through October. Herbage produced from winter rye during the fall is often left as cover and not grazed or hayed in North Dakota. In other regions within the US, especially the Central Plains, fall grazing of winter cover crops is more common, reducing winter feeding and housing costs (Holman and Luebbe, 2011). Extending the grazing season in both the fall and spring can increase the benefits of livestock integration and produce an additional economic return on the investment of cover cropping through a forage crop. The objective of this project was to investigate the effects of integrated livestock grazing with winter rye management on soil health, livestock performance, soybean production, and economics.

Procedures

A two-year project investigating the effects of integrating livestock grazing with winter rye management on soil health, livestock performance, soybean production, and economics was established in the fall of 2022. Two locations were selected in central North Dakota: one at the NDSU Central Grasslands Research Extension Center (CGREC) located 7 miles northwest of Streeter, N.D., and a second location at the NDSU Carrington

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Research Extension Center (CREC) located four miles north of Carrington, N.D. An approximately 30- to 40-acre block of cropland was identified at each location and divided into nine plots, of approximately 4.4 acres at CGREC and 3.3 acres at CREC. The plots were randomly assigned one of three treatments that were replicated three times: seeded to winter rye and dual (fall and spring) grazed, seeded to winter rye and spring grazed, and no grazing using a randomized block design. The no graze treatment was split to include two sub-plots using a split-plot design, with one sub-plot seeded to rye and one sub-plot receiving no rye and no grazing. The sub-plot with no rye and no grazing represented a traditional soybean cropping system and was used as the control.

Following harvest of the previous cash crop at each location, German millet (*Setaria italica*, L.) at CGREC and wheat (*Triticum aestivum*, L.) at CREC, fields were no-till seeded with winter rye. Prior to fall grazing, high-tension electric fencing was constructed between all plots. Water sources were provided for each grazing treatment. The fall grazing treatments grazed 5 days at CGREC with 4 bred heifers and 3 days at CREC with 5 bred heifers.

Spring grazing treatments were grazed for 16 days at CGREC by 9 open yearling heifers and 11 days by 6 open yearling heifers at CREC. All plots were treated with glyphosate following spring grazing treatments to terminate the winter rye and any weeds. Soybeans (*Glycine max*, [L.] Merrill) were no-till planted in 14-inch rows on June 9, 2023, at both locations into the remaining residue.

Soil samples were collected after winter rye seeding in fall and after soybean planting in spring. Sampling locations were stratified within the same soil series to reduce variability. Soil chemical analysis including organic matter, NO_3-N, Total N, P-Olsen, K, and total carbon was conducted across depths of 0-6 in and 6-12 in delivered to AgVise Laboratories (Northwood, N.D.) for analysis. Biological analysis, including arbuscular mycorrhizal fungi and microbial biomass carbon, was conducted across depths of 0 - 6 inches. Aggregate stability was collected as complete soil slices at 0 - 6 inches and delivered to AgVise Laboratories for analysis via automated slaking. Soil bulk density was collected at depths of 0 - 1.2 inches and 1.9-3.1 inches using an AMS (American Falls, ID) slide hammer bulk density corer. Water infiltration was conducted at two locations per plot using a Cornel sprinkle-infiltrometer. This system simulates a rain event within a 9.5-inch ring, and run-off volume is collected and used to calculate the total volume of water infiltration at field saturation.

Forage production was estimated pre- and post-grazing by clipping six 9.84-inch^2 quadrats randomly placed across each treatment with all winter rye within each frame clipped to ground level in each quadrat. Samples were dried at 60ºC for 48 hours to determine dry matter content. Pre-grazing yields were used to estimate carrying capacity and set stocking rate for the grazing period. Dried samples were composited and delivered to the NDSU Nutrition Lab for analysis of neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), and in-vitro dry matter digestibility (IVDMD). Absolute ground cover was evaluated pre- and post-grazing by visually estimating the percent cover of bare ground, residue, living rye, and/or weeds within each quadrat.

Animal bodyweights were recorded on two consecutive days and averaged for pre- and post-grazing bodyweights. Body condition score was visually conducted by two individual scorers according to the 9-point beef scoring system (Rasby et al., 2014). Body condition score was omitted during the fall season due to the short grazing period.

Results and Discussion

Winter rye production was 156 lb/acre and 198 lb/acre at the CGREC and CREC, respectively, in fall of 2022. Yields were impacted by a late planting date and dry conditions. This resulted in a short fall grazing period of 4 days and 1 head/acre at CGREC and 3 days and 1.5 head/acre at CREC. At both locations, grazing bred heifers resulted in weight loss of 2.75 lb/day and 6.28 lb/day at CGREC and CREC, respectively (Table 1).

Winter rye production was higher at CREC than CGREC due to differences in soils and precipitation between locations (Table 2). Spring production was 371 lb/acre in dual graze, 534 lb/acre in spring graze, and 406 lbs/acre in no graze at CGREC and 582 lbs/acre in dual graze, 819 lbs/acre in spring graze, and 709 lbs/acre in no graze at the CREC. While the dual grazed treatments had lower yields across locations, yields were not different ($P > 0.05$) between treatments. The grazing period was 16 days at 2.3 head/acre at the CGREC and 12 days at 1.8 head/acre at CREC. Spring performance varied greatly between locations; average daily gain was not different ($P > 0.05$) between grazing treatments at CGREC, with the dual grazing gaining 0.47 lb/day and spring grazing gaining 0.61 lb/day (Table 1). However, ADG in the dual grazing was lower ($P < 0.05$) than the dry lot treatment at CGREC. Grazing treatments at CREC grazed as blocks of three replicates rather than individual treatments due to confinement limitations in spring 2023. There was no difference ($P > 0.05$) in ADG among the three blocks, with an average loss of 1.4 lbs/day. However, all three blocks had a lower ADG than the dry lot at CREC.

Winter rye forage quality during the fall grazing period was greater ($P \leq 0.05$) than the spring grazing period, with greater CP concentration and lower NDF and ADF concentration (Table 2). Greater fall forage quality can be attributed to lower maturity of the newly established rye. Winter rye spring forage maintained CP levels throughout the grazing period at CGREC, with no changes found between the pre- and post-grazing levels. However, winter rye in dual grazing treatments was greater ($P \leq 0.05$) in CP at the end of the grazing period compared to the no graze. There was no difference ($P > 0.05$) in NDF and ADF concentrations between treatments pre- and post-grazing at CGREC. For CREC, there was no difference ($P > 0.05$) in forage quality between treatments. The higher quality observed for the grazed treatments at CGREC can be attributed to the grazing keeping the rye in a vegetative stage, which has higher forage quality than reproductive growth (Coblentz et al., 2020). This trend was not observed at CREC, as grazing was delayed, and the stocking rate was not high enough to prevent the rye from maturing during the grazing period.

Table 1. Livestock bodyweight and average daily gain (ADG) by treatment at Central Grasslands Research Extension Center (CGREC) and Carrington Research Extension Center (CREC) during the fall 2022 and spring 2023 grazing periods.

Location	Season	Treatment	Number of cattle	Grazing days	Average pre-graze bodyweight (lbs)	Average post-graze bodyweight (lbs)	ADG (lbs/day)
CGREC	Fall	Dual graze	4	5	988	974.2	-2.75
	Spring	Dual graze	9	16	693	701	0.47[a]
		Spring graze	9	16	688	698	0.61[a,b]
		Dry lot	9	16	686	706	1.28[b]
CREC	Fall[1]	Dual graze	5	3	1196	1177	-6.28
	Spring[2]	Block 1	6	11	1028	1013	-1.34[a]
		Block 2	6	11	1039	1019	-1.80[a]
		Block 3	6	11	1039	1026	-1.17[a]
		Dry lot	6	11	1035	1063	2.27[b]

[1]Animals escaped plot, ending grazing period
[2]Cattle grazed as blocked groups consisting of 3 plots per block
[a,b]Means with different letters are significantly different within column and location ($P \leq 0.05$)

Table 2. Winter rye forage yield and quality by Treatment at Central Grasslands Research Extension Center (CGREC) and Carrington Research Extension (CREC) during the fall and spring grazing periods in 2022 and 2023.

			Fall 2022[1]				Spring 2023			
Location	Treatment	Period	Forage yield (lb/ac)	Crude protein (%DM)	NDF (%DM)	ADF (%DM)	Forage yield (lbs/ac)	Crude protein (%DM)	NDF (%DM)	ADF (%DM)
CGREC	Dual	Pre-graze	156	23.43	32.87	16.25	371[a]	18.14[a]	40.44[a]	17.68[a]
		Post-graze	106	--	--	--	227[a]	20.05[a]	54.94[b]	26.66[c,b]
	Spring	Pre-graze	119	--	--	--	534[a]	16.32[a,b]	41.32[a]	18.79[a,b]
		Post-graze	--	--	--	--	304[a]	14.73[a,b]	58.39[b]	29.85[c]
	No Graze	Pre-graze	101	--	--	--	406[a]	--	--	--
		Post-graze	102	--	--	--	1618[b]	10.04[b]	62.61[b]	33.60[c]
CREC[2,3]	Dual	Pre-graze	198[a,b]	30.28	41.58	17.64	582[a]	14.13	52.30[a]	26.72[a]
		Post-graze	157[a]	--	--	--	663[a]	11.05	67.25[b]	37.5[b]
	Spring	Pre-graze	260[a,b]	--	--	--	819[a]	13.24	52.65[a]	27.23[a]
		Post-graze	--	--	--	--	1107[a]	9.33	69.87[b]	40.17[b]
	No Graze	Pre-graze	208[a,b]	--	--	--	709[a]	--	--	--
		Post-graze	294[b]	--	--	--	2105[b]	9.76	69.58[b]	40.15[b]

[1]Only grazing treatments were analyzed for Fall 2022
[2]Cattle escaped ending grazing period Fall 2022
[3]Cattle grazed as blocked groups Spring 2023
[a,b]Means with different letters are significantly different within column and location ($P \leq 0.05$)

Soil nitrate was higher ($P \leq 0.05$) in the no rye treatment compared to the no-graze treatment at CREC (Table 3). Dual grazing and spring grazing were not different ($P > 0.05$) in soil nitrate from either the no rye or no graze. There was no difference ($P > 0.05$) in soil nitrate content among treatments at CGREC. No differences were observed in all other soil chemical properties at either location. Soil bulk density was not different among treatments at either location.

Spring season ground cover was not affected by dual season grazing. All treatments containing rye provided weed suppression, having lower ($P \leq 0.05$) weed coverage than the no rye treatment across both locations. At the end of the spring grazing period, residue cover was significantly lower within the dual grazing treatment at CGREC and spring grazing treatment at CREC.

Even though climatic factors restricted winter rye performance, cattle grazing did not affect the function of rye as a cover crop. Notably, absolute ground cover was not impacted by fall or spring grazing. No rye plots at either location had greater weed cover, including yellow foxtail (*Setaria pumila*) and kochia (*Bassia scoparia*) post-grazing. The lack of effect on soil bulk density demonstrated no risk of compaction from fall or spring grazing cattle prior to cash crop planting. The continuation of the project through 2023 and 2024 may reveal other effects of cover crop management that are slow to develop over one growing season. Animal performance was low during the fall grazing season at both locations; however total animal loss of gain was minimal. Fall drought and late rye seeding slowed germination and establishment, only allowing a short grazing period which did not allow livestock to adjust, plus livestock may have had difficulty grazing a short crop. Fall grazing did not affect spring winter rye yields, which shows promise for fall grazing under more favorable fall growing conditions.

Acknowledgements

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Table 3. Soil Nutrients by Treatment at Central Grasslands Research Extension Center (CGREC) and Carrington Research Extension Center (CREC) Post-Grazing, Spring 2023.

Location	Treatment	Organic matter (%)	Total-N (%)	NO_3-N (lb/ac)	P-Olsen (lbs/ac)	K (lbs/ac)	T.C. (%)
CGREC	Dual graze	3.44	0.17	27.5	37.7	408	1.75
	No graze	3.39	0.17	17.5	21.7	391	1.75
	No rye	3.25	0.16	22.5	18.0	407	1.64
	Spring graze	2.58	0.13	24.0	34.0	392	1.37
CREC	Dual graze	2.93	0.15	24.0[a,b]	104.0	737	2.27
	No graze	2.70	0.17	16.3[a]	85.3	631	1.95
	No rye	3.23	0.17	35.3[b]	112.0	664	2.25
	Spring graze	2.68	0.15	18.3[a,b]	93.3	673	2.03

[a,b]Means with different letters are significantly different within column and location ($P \leq 0.05$)

The culturable ocular bacterial microbiota of beef cattle and its commensal members that can inhibit pinkeye-associated pathogens

Sarah M. Luecke[1], Gerald Stokka[2], Kaycie N. Schmidt[1], Garrett Havelka[2], and Samat Amat[1]

The objective of this study was to characterize the culturable fraction of the bacterial microbiota residing in the bovine eye and to investigate whether commensal members of this community could inhibit the pinkeye-associated pathogens Moraxella bovis and Moraxella bovoculi. Results indicate that the bovine eye harbors a relatively diverse culturable bacterial community, and some of these commensal species can inhibit pinkeye pathogens, suggesting the possibility to develop bacterial therapeutics based on these commensal isolates to mitigate pinkeye infections in cattle in place of antibiotics.

Summary

In this study, we cultured a wide range of bacterial species using both aerobic and anaerobic culture conditions and five different growth mediums from ocular swabs obtained from beef cattle with (n = 35) and without (n = 29; healthy control) pinkeye infections. We taxonomically identified a subset of these bacterial isolates using near-full length 16s rRNA gene sequencing and tested a subset of these isolates for their ability to directly inhibit the growth of *Moraxella bovis* and *Moraxella bovoculi*, the primary pinkeye pathogens. We identified 6 bacterial isolates that can inhibit the growth of *M. bovis* and *M. bovoculi in vitro*. Using scanning electron microscopy (SEM), we further investigated the morphological and structural damage that occurred to *M. bovis* and *M. bovoculi* cells after incubation with culture supernatants of selected isolates that demonstrated growth inhibition *in vitro*. The SEM imaging provided clear indication of damage to *Moraxella* cell structure. Together, these commensal ocular bacteria that displayed antimicrobial activity against *Moraxella in vitro* are viable candidates for the development of bacterial therapeutics to treat and prevent pinkeye in cattle.

Introduction

Pinkeye, clinically known as infectious bovine keratoconjunctivitis (IBK), is a highly contagious disease of the eye and is one of the most significant health challenges impacting producers in the Midwest (Martin et al., 2019) with an estimated $150 million in annual losses to US beef producers (Bartenslager et al., 2021). The development of pinkeye in cattle is multifactorial, and it is commonly believed that irritation to the eye from face flies, tall grass, and ultraviolet (UV) light predisposes animals to pinkeye development. However, the primary ecological agents that are known to contribute to pinkeye infection are the bacterial pathogens *Moraxella bovis* and *Moraxella bovoculi*. Currently, pinkeye vaccinations against these pathogens are limited in their efficacy, and as such, producers are left with very little protection from outbreaks. Challenges in preventing and treating pinkeye infections may be a result of the knowledge gap surrounding the ocular microbiome (Bartenslager et al., 2021). To date, there are very few studies that have investigated the bacterial community of the bovine eye using culture independent metagenomic sequencing-based techniques (Cullen et al., 2017; Bartenslager et al., 2021). Research suggests that the bovine eye does harbor bacterial communities and that they may be important in ocular health. A relatively rich and site-specific bacterial community has recently been reported in the eyes of healthy newborn calves (Luecke et al., 2023). The genera *Moraxella* was well represented in those samples, and it is currently unclear if early colonization of the eye acts to prime the newborn's immune system against pathogens or if it predisposes them to infection. Given this information, we conducted the present study to 1) characterize the ocular microbiota of healthy and pinkeye-infected beef cattle using sequencing and culturing techniques, and 2) isolate and screen commensal ocular bacterial isolates for their antimicrobial activity against *M. bovis* and *M. bovoculi*.

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Procedures

Ocular swabs from the cornea and conjunctiva of cattle exhibiting IBK symptoms (n = 35) as well as control swabs from healthy animals (n = 29) were collected from multiple herds across North Dakota as well as from the NDSU Beef Cattle Research and Teaching Center and from the NDSU Veterinary Diagnostic Laboratory (Table 1). Ocular swabs were collected using Puritan Opti-Swabs with the Liquid Amies Collection and Transport System (Puritan, Guilford, ME) and were stored on ice for transport to the lab. Once in the lab, samples were aliquoted and spread on up to five types of agar plates (Blood, Columbia Blood, De Man, Rogosa and Sharpe (MRS), Wilkins-Chalgren, and Multi-slice agar), all with various growth mediums to support the growth of a wide range of microorganisms. Plated samples were incubated both aerobically and anaerobically for 24 – 48 h. Bacterial colony growth was quantified, and unique colonies were sub-streaked onto fresh media and incubated for 24 h. Isolated bacteria were then cryopreserved (n = 658). Genomic DNA was extracted from a subset of preserved bacterial isolates (n = 351) and used for taxonomic identification by the near-full length 16S rRNA gene sequencing. Of the 351 identified isolates, 53 were tested for growth inhibitory effects against *M. bovis* and *M. bovoculi* using the agar slab method as described previously (Amat et al., 2019). Following the agar slab experiments, a selection of candidate bacteria that exhibited relatively strong inhibition of *Moraxella* growth were used to evaluate changes to cell morphology of *Moraxella* by inoculating *Moraxella* into the cell free supernatant of the candidate bacteria, incubating for 14 h, and observing changes using scanning electron microscopy (SEM) as described previously (Amat et al., 2019).

Results and Discussion

The 351 bacterial isolates identified using near-full length 16s rRNA gene sequencing were represented by 6 different bacterial phyla and 61 different bacterial genera. Bacterial phyla included Bacillota (44%), Firmicutes (23%), Actinomycetota (13%), Pseudomonadota (13%), Actinobacteria (5%), and Proteobacteria (2% Figure 1A). Of the 61 bacterial

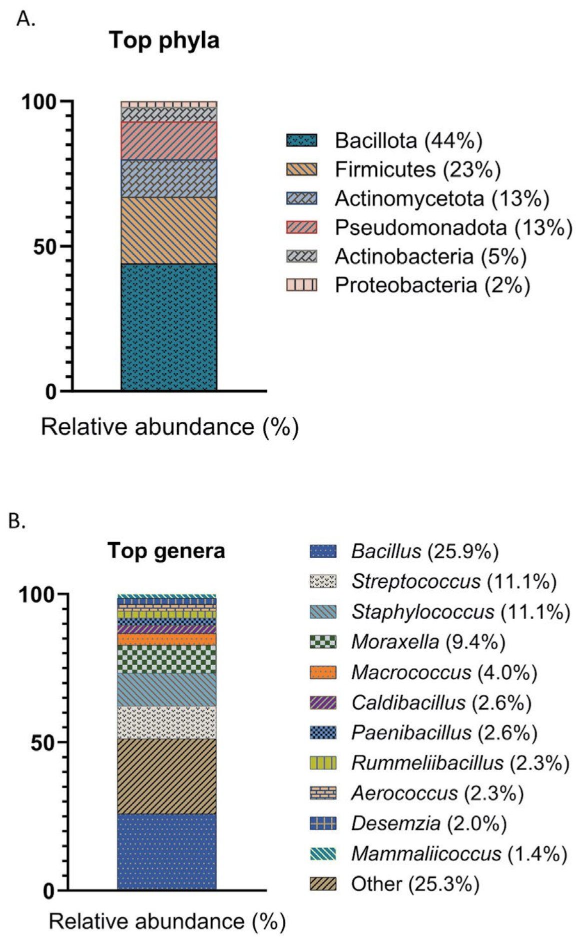

Figure 1: Proportion of bacterial phyla (A) and genera (B) representing a subset of the bacterial isolates isolated from ocular swabs of healthy and pinkeye affected beef cattle (n = 351 isolates).

Table 1: Number of swabs collected and total number of isolated bacteria that were cryopreserved.

Sources	4 ND Veterinary Clinics, NDSU Beef Herd, NDSU VDL					No. of Summer Swabs				43
						No. of Winter Swabs				21
Swab Type	Total Number of Swabs	Aerobic Isolates				Anaerobic Isolates				Total Isolate Number
		MP	CB	Blood	MRS	MP	Blood	WC	CB	
Control	29	30	61	30	43	14	11	74	18	281
Pinkeye	35	41	37	108	67	12	10	80	22	377
Subtotal	64	71	98	138	110	26	21	154	40	658

genera, *Bacillus* (26%), *Streptococcus* (11%), *Staphylococcus* (11%), *Moraxella* (9%), and *Macrococcus* (4%) were the most prevalent (Figure 1B). A total of 33 *Moraxella* isolates were identified, and they consisted of *M. bovis* and *M. bovoculi*. Of the 53 isolates tested for inhibition against Moraxella using the agar slab method (Figure 2), 6 isolates showed zones of inhibition ranging from an average of 13 mm to 25.7 mm (Table 2). *Weizmannia coagulans* (43Y MRS-C), *Lactobacillus fermentum* (ATTC 9338), and *Paenibacillus polymyxa* (42G WC-F) showed relatively strong inhibition against *Moraxella*, while *Alkalihalobacillus rhizosphaerae* (25F CB-B) and *Lentilactobacillus buchneri* (23D MRS-A) showed medium growth inhibition and *Weissella paramesenteroides* (23D MRS-F) displayed weak growth inhibition. *Weizmannia coagulans* (43Y MRS-C), *Lactobacillus fermentum* (ATTC 9338), and *Lentilactobacillus buchneri* (23D MRS-A) cell-free culture supernatants were incubated with *M. bovis* and *M. bovoculi* for 14 h and prepared for SEM imaging. The *W. coagulans* and *L. fermentum* isolates exhibited the greatest amount of cell damage to *M. bovoculi*. Complete cell lysis was observed, indicating that *W. coagulans* and *L. fermentum* effectively inhibit the growth of *M. bovoculi*. *Lentilactobacillus buchneri* exhibited only minor cell damage to *M. bovoculi*, with few structural damages to the *M. bovoculi* cells (Figure 3). When the cell-free culture supernatant of *W. coagulans* and *L. fermentum* was incubated with *M. bovis*, noticeable cell damage occurred, but it was not to the extent of the damage that occurred to *M. bovoculi* (Data not shown). Irregular cell shape and damages to the cell wall of *M. bovis* were observed, which indicates that *W. coagulans* and *L. fermentum* may be viable candidates for the development of bacterial therapeutics against *M. bovis*.

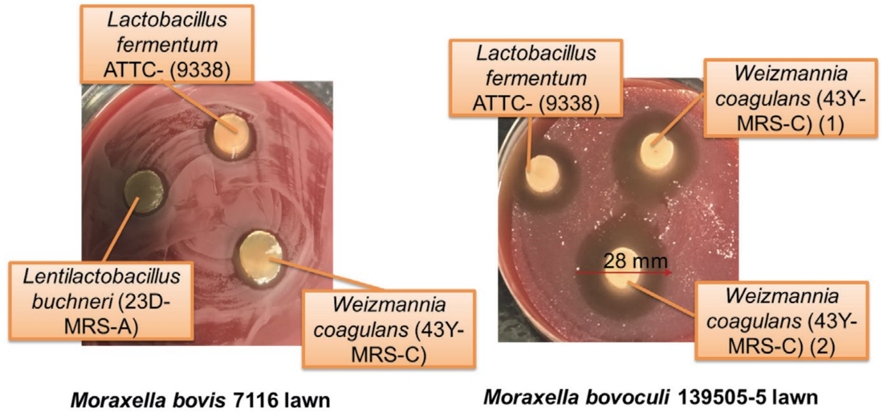

Figure 2: Example of the agar slab method. This method allows for visualization of antimicrobial activity of bacteria by placing a small agar slab (10 mm in diameter) containing a bacterial strain of interest on the surface of a plate containing a fresh inoculation of *M. bovis* or *M. bovoculi*. After co-incubation, growth inhibition of *M. bovis* or *M. bovoculi* can be observed by the formation of a zone of inhibition surrounding the agar slab containing the bacteria of interest.

Table 2: Six bacterial isolates that exhibited antimicrobial activity against *M. bovis* and *M. bovoculi* when tested using the agar slab method.

Isolate ID	Species	Average ZOI (mm)
43Y MRS-C	*Weizmannia coagulans*	25.7
ATTC 9338	*Lactobacillus fermentum*	18.5
42G WC-F	*Paenibacillus polymyxa*	17.2
25F CB-B	*Alkalihalobacillus rhizosphaerae*	16.4
23D MRS-A	*Lentilactobacillus buchneri*	14.1
23D MRS-F	*Weissella paramesenteroides*	13.0

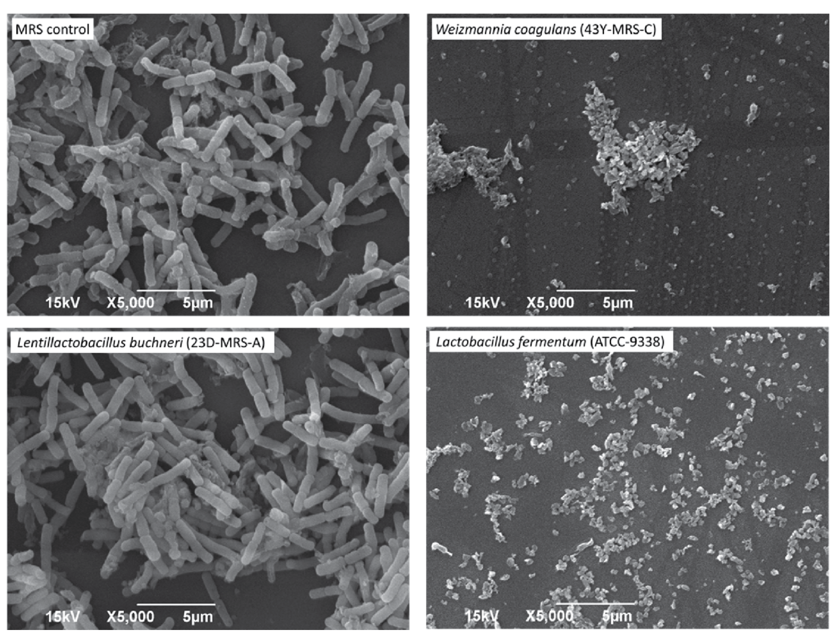

Figure 3: Scanning microscopy imaging (SEM) images of *Moraxella bovoculi* 139505-5 after incubation with cell-free culture supernatants of screened bacterial strains originated from the bovine ocular swab. Bacteria were incubated with cell-free culture supernatants before fixation and microscopy. MRS control represents untreated (incubated with MRS broth only) *Moraxella bovoculi* 139505-5 cells.

These results indicate that the bovine oculus harbors relatively diverse culturable bacteria. In addition, some of the commensal bacterial isolates can inhibit the growth of *M. bovis* and *M. bovoculi*, potentially through the production of antimicrobial agents that can damage the cell structure and cell morphology of the pathogens. This information adds to the current understanding of the bovine ocular microbiota and indicates that commensal bacterial species within the ocular microbiota may be able to be harnessed to combat against pinkeye pathogens and modulate ocular microbiome-mediated eye health in cattle.

Acknowledgments

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Effects of an intranasal essential oil spray on respiratory pathogens, nasopharyngeal microbiota, and animal performance in feedlot steers

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We recently identified five essential oils (EOs) that have the potential to be used as antibiotic alternatives to mitigate bovine respiratory pathogens. This study further tested the efficacy of the intranasal EO spray consisting of these selected EOs in feedlot steers. A single dose of EO spray applied intranasally resulted in the reduction of the abundance of bovine respiratory disease (BRD) associated genera Mannheimia and modulation of the nasopharyngeal microbiota, while showing no negative effects on animal performance and feeding behavior.

Summary

Bovine respiratory disease (BRD) remains one of the costliest diseases impacting the North American feedlot industry. BRD prevention in feedlot cattle often relies on the use of antimicrobial metaphylaxis at the time of feedlot arrival. Despite use of metaphylaxis, the incidence of BRD in feedlot cattle continues to increase, and this is partially due to the emergence and spread of antimicrobial resistance in bovine respiratory pathogens against those classes of antibiotics used as metaphylaxis. Thus, there is an impetus to develop antimicrobial alternatives to mitigate BRD pathogens in feedlot cattle. Five EOs were previously characterized *in vitro* and identified as candidate EOs for the development of an intranasal EO spray against BRD pathogens as an alternative to antibiotics. The present *in vivo* study evaluated the effects of a single intranasal dose of EO spray on bovine respiratory pathogens, nasopharyngeal microbiota, and animal performance in feedlot steers. Study results suggest the possibility of using intranasal EOs to modulate nasopharyngeal microbiota and mitigate BRD pathogens in feedlot cattle.

Introduction

Calves arriving at the feedlot are often exposed to a number of stressors, such as stresses associated with weaning, transportation, and comingling at the auction market. As a result, calves experience suppressed immunity and altered respiratory microbiota equilibrium, which predisposes the calves to the development of BRD (Peel, 2020). Antibiotic metaphylaxis is, therefore, used at feedlot arrival by most commercial feedlots across the US and Canada to mitigate respiratory bacterial pathogens and prevent BRD. However, due to the increased antimicrobial resistance in respiratory pathogens, BRD incidence in feedlots is increasing (Timsit et al., 2017). To develop alternatives to metaphylactic antibiotics, we set out to explore the potential use of EO-based intranasal spray to mitigate BRD pathogens and modulate the nasopharyngeal microbiome for improved respiratory health. Five EOs – ajowan, thyme, fennel, cinnamon leaf, and citronella – were selected as candidates for an intranasal spray application based on their *in vitro* antimicrobial activity against respiratory bacterial and viral pathogens and commensal species, as well as immunomodulatory and antibiofilm activities (Amat et al., 2022). The objectives of the present pilot study were to evaluate the effects of a single intranasal dose of EO spray comprised of these 5 selected EOs on respiratory bacterial pathogen abundance, nasopharyngeal microbiota, animal performance, feeding behavior, and immune response of feedlot steers.

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Procedures

Forty crossbred Angus steer calves born between April and June 2021 (7 - 8 months old, initial body weight = 624.8 ± 11 lbs [SE]) were assigned for this study. Calves were transported 40 miles from the Ekre Grassland Preserve to the NDSU beef cattle facility after weaning. During the trial, calves were separated into 4 pens based on weight and housed in partially covered pens at the NDSU Beef Cattle Research Complex (BCRC). All calves were individually fed a high-concentrate diet with the Insentec BV feeding system (Hokofarm Group, Marknesse, the Netherlands), which is on a cement pad.. Twenty calves were randomly assigned either to the EO or the control groups. The EO group received an intranasal spray of 5 EOs (ajowan, thyme, fennel, citronella, and cinnamon leaf) with a final concentration of 0.025% (v/v) of each EO diluted in phosphate-buffered saline (PBS), while the control group received an intranasal spray with only PBS. Weights were recorded and nasopharyngeal swabs were collected on days -1 (24 h before treatment application), 1, 2, 7, 14, 28, and 42. Blood was collected on days -1, 2, 7, 28, and 42, and complete blood cell counts were determined by the Veterinary Diagnostic Laboratory at Texas A&M University. Feeding behavior was determined by the number of visits (times that an animal used the feed bunk), meals (a combination of visits within a 7-minute interval) and eating rate (how much time was spent eating). Additionally, the amount of feed ingested was determined by the difference in weight before and after each visit. Genomic DNA was extracted from nasopharyngeal swabs, the bacterial 16S rRNA gene was sequenced, and the SILVA SSU release 138.1 database was used to classify bacteria based on taxonomy (up to the genus level). The relative abundance of bacterial taxa and the microbiota composition were evaluated based on the treatment group and days on experiment.

Results and Discussion

Overall, none of the animals showed any signs indicative of BRD throughout the course of the experiment. A single intranasal EO spray application did not affect body weight, average daily gain, or dry matter intake of steers (*P* > 0.05) for the 42-day period of this study (Figure 1). Overall, no significant effect of EO spray on animal feeding behavior was observed (*P* > 0.05; Table 1). As for the impact of EO spray on the nasopharyngeal microbiota, noticeable but subtle changes were observed in the community structure, microbial richness, and diversity (Figure 2). Overall beta diversity of the nasopharyngeal microbiota was distinct between EO and control steers (*P* < 0.05; Figure 2A). The EO group had increased species richness and diver-

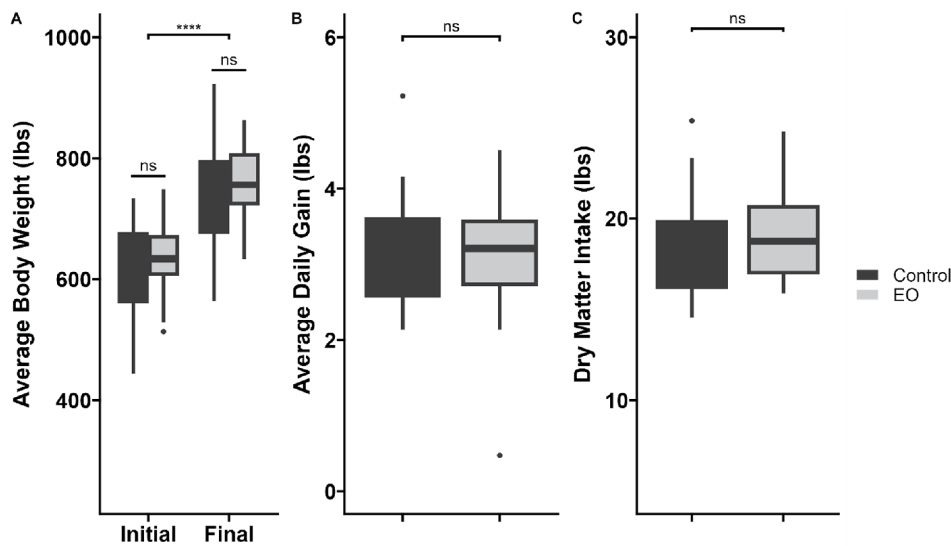

Figure 1. Animal performance parameters of steer calves that received either an intranasal essential oil (EO; n = 18) spray or phosphate-buffered saline (control; n = 20) over 42 days. A) initial and final average body weight (lbs), B) Average daily gain (lbs), and C) dry matter intake (lbs). NS = no significant difference between treatments *P* > 0.05; ** = *P*<0.0001.**

Table 1. Feeding behavior of steer calves that received either an intranasal essential oil (EO) spray or phosphate buffered saline (control) over 42 days.

	EO	Control	SEM	P-value
Event, per day				
Visits	17.8	20.2	2.04	0.20
Meals	7.4	7.8	0.39	0.31
Time eating, min				
Per visit	6.8	5.3	0.74	0.05
Per meal	12.3	10.2	0.94	0.03
Per day	90.5	79.3	5.25	0.04
Eating rate, lbs				
Per visit	1.7	1.4	0.18	0.13
Per meal	3.2	2.8	0.22	0.12
Per min	0.3	0.3	0.44	0.66

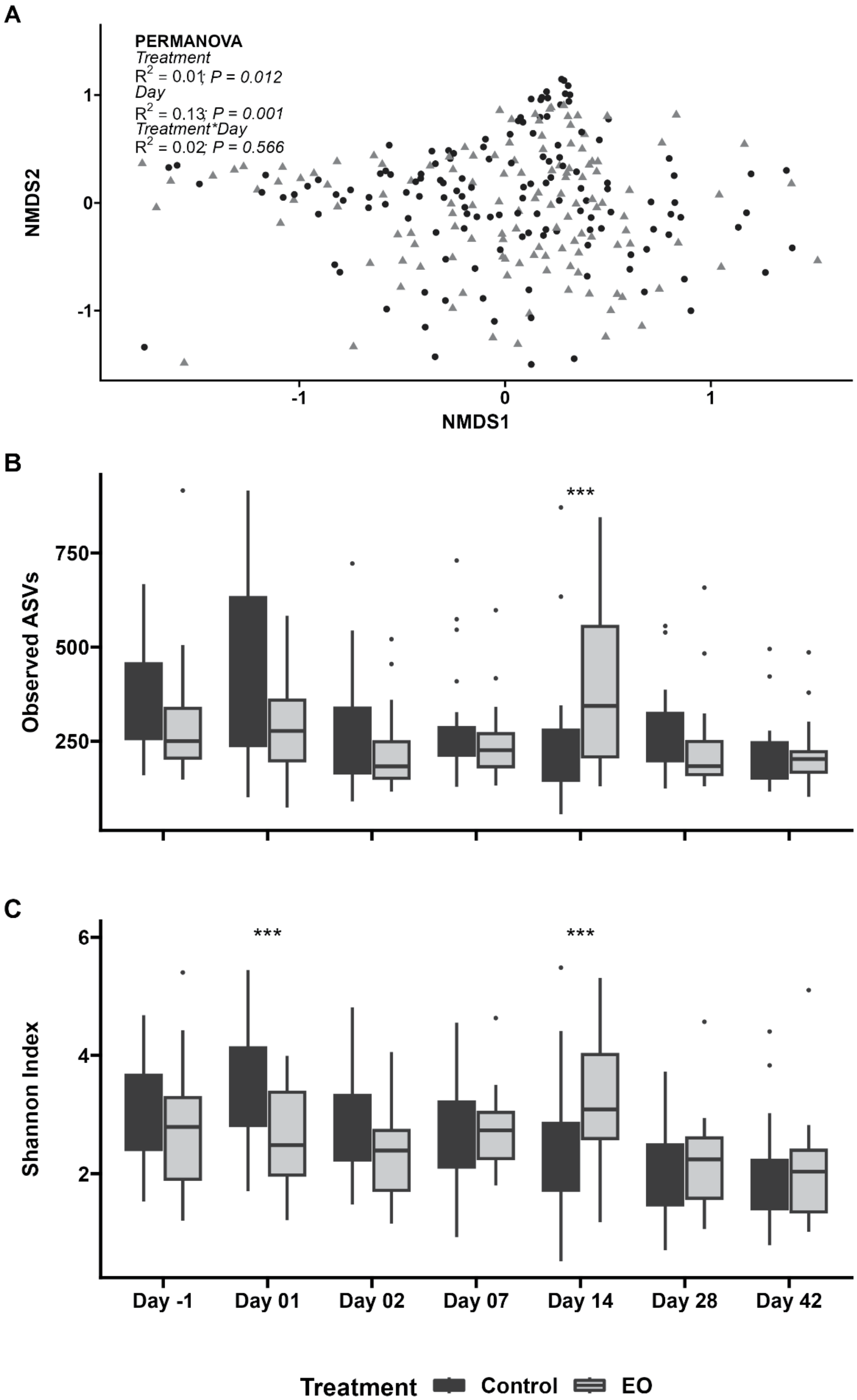

Figure 2. Beta and alpha diversity of the nasopharyngeal microbiota in steer calves that received either an intranasal essential oil (EO; n = 18) spray or phosphate-buffered saline (control; n = 20). A) Nonmetric multidimensional scaling (NMDS) plots of the Bray–Curtis dissimilarities (beta diversity), B) number of observed amplicon sequencing variants (ASVs; microbial richness), and C) Shannon diversity index.. * = *P* < 0.05.**

sity on d 14 compared to the control group while having reduced diversity on d 1 (24 h after EO application *P* < 0.05; Figure 2B). The relative abundance of the BRD-associated genus *Mannheimia* increased by 3.9-fold (from 2.66% to 10.4%) in control animals from d -1 (24 h pre-EO treatment) to d 2 when compared to EO calves (*P* > 0.05; Figure 3). The overall relative abundance of the BRD-associated pathogenic genus *Pasteurella* did not differ between the EO and control groups (data not shown). Furthermore, complete blood cell counts were similar (*P* > 0.05; data not shown) for both animal groups, indicating that intranasal application of an EO blend did not trigger any short- or long-term (up to 42 days) inflammatory and immune responses in feedlot cattle. Additional research is needed to further explore the use of EOs in feedlot cattle production systems.

Acknowledgments

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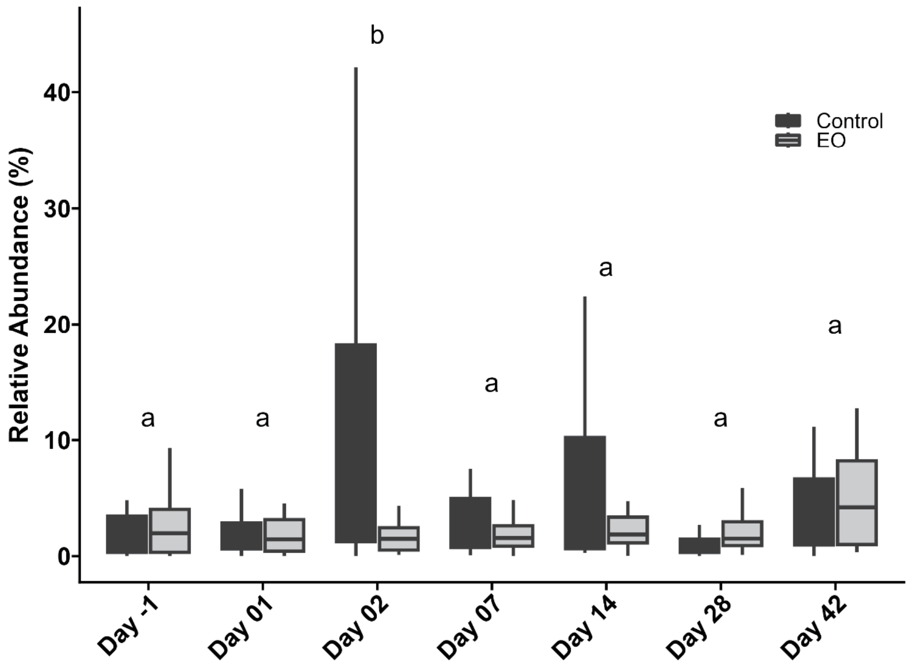

Figure 3. Relative abundance of the genus *Mannheimia* in nasopharyngeal swabs collected from beef steer calves that either received an intranasal essential oil (EO) or a phosphate saline buffer (control) application on day 0. Different letters represent significantly different relative abundances.

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Estrogen's role in the induction of parturition and fetal maturation in periparturient ewes

Bethania J. Dávila Ruiz[1], Chutikun Kanjanaruch[1], Carl R. Dahlen[1], Pawel P. Borowicz[1], Alan J. Conley[2], and Lawrence P. Reynolds[1]

The objective of this study was to obtain a better picture of estrogen's role in the control of parturition and fetal maturation in periparturient Rambouillet ewes through the evaluation of the relationship between systemic estradiol (E2) levels and 1) the timing of parturition, lamb's birth weight, and lamb vigor, and 2) the uterine progestogenic responsiveness and progesterone (P4) plasma levels. Results suggest that estradiol may downregulate myometrial P4 receptor protein expression, leading to myometrial contraction-inducing parturition; however, it does not seem to affect lamb birth weight or vigor.

Summary

The incidence of livestock death due to premature birth is approximately 10% in the US, which results in a large economic loss for farmers and ranchers. Therefore, the prevention of premature birth and the understanding of underlying mechanisms of parturition and fetal maturation in preparation for birth are problems that need to be addressed. Parturition requires activation of myometrial contractility, which may be driven by a withdrawal of progesterone (P4) accompanied by a rise in estrogen levels. However, these relationships are unclear, as estradiol (E2) can induce parturition without P4 withdrawal. This experiment was designed to obtain a better picture of estrogen's role in the control of parturition in periparturient Rambouillet ewes through the evaluation of the relationship between E2 levels and 1) the timing of parturition, lamb birth weight, and lamb vigor and, 2) uterine progestogenic responsiveness and systemic plasma P4 levels. Two experiments were conducted. In experiment 1, ewes were treated and allowed to deliver. The hours from treatment until delivery, and live lamb birth weight and vigor were recorded. In experiment 2, ewes were treated and slaughtered 26 h later for tissue collection. At slaughter, carotid blood was collected to measure hormone levels, and samples of the utero-placenta were formalin-fixed and immunofluorescently stained for P4 receptors. The same treatment was used for both experiments. The ewes were randomly assigned to either E (4 Silastic implants of 50 mg of E2; 200 mg/ewe; Exp 1 n = 5, Exp 2 n = 6) or C (4 empty implants; Exp 1 n = 5, Exp 2 n = 6) groups. All treatments began at d 139 to 142 of gestation. Results showed that in experiment 1, the hours from treatment to delivery were less in E compared with the C group (64.1 ± 75.64 vs 374.4 ± 75.64 h, $P = 0.01$), the live birth weight tended to be less in lambs from the E group (4.12 ± 0.23 vs 4.77 ± 0.21 kg. $P = 0.07$), but there was no difference between groups for lamb vigor (2 ± 0.39 vs 1 ± 0.48 [4-point scale with 0 being the best], $P = 0.13$). In experiment 2, E2 treatment downregulated P4 receptor protein expression in the myometrium of E vs C groups (27.02 ± 36.68 vs 42.0 ± 3.68 intensity units, $P = 0.01$), but there was no difference in systemic plasma levels of P4 in E vs C (6.50 ± 1.42 vs 8.99 ± 1.42 ng/mL, $P = 0.24$), while E2 concentration in systemic blood was less in C compared with E (30.61 ± 11.73 vs 149.21 ± 55.93 pg/mL, $P = 0.01$). These results suggest that in late pregnant ewes, E2 downregulates myometrial P4 receptors and thus progestogenic responsiveness of the myometrium which leads to activation of the myometrium, earlier delivery, and thus lower live lamb weight at delivery without a decrease in P4 systemic blood levels.

Introduction

Livestock death due to premature birth in the US is approximately 10%, resulting in a significant economic loss for farmers and ranchers. Therefore, addressing the problem of premature birth and understanding the mechanisms behind parturition and fetal maturation is crucial. Maintaining pregnancy and giving birth to offspring is a complex process involving multiple fetal and maternal

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hormones and biochemical factors, but steroids are the protagonist. Three key events must take place to ensure a successful birth: (1) the maturation of fetal organs in preparation for extra-uterine life, (2) the delivery of the fetus, and (3) the delivery of the placenta (Kota et al., 2013). The main reason behind the difficulty of defining the fundamental mechanisms that underly the initiation of parturition and fetal organ maturation is the variation between species and the limited number of mammalian species that have been studied regarding pregnancy steroidogenesis. Length of gestation, the number of fetuses, and the timing of parturition differ, and even though several hormones involved are well conserved, the tissues involved in hormone synthesis, the controlling mechanisms, and mechanisms of action differ widely among species (Conley et al., 2014; Rokas et al., 2020).

The delivery of the fetus is driven by myometrial contractions and cervical ripening, which is known to be triggered by a decrease in P4 (the pro-gestational hormone) and an increase in E2 levels. The first theory proposed for the parturition mechanism in sheep in 1973 by G. C. Liggins indicated that the fetal lamb could signal its own birth through the activation of the fetal hypothalamic-pituitary-adrenal (HPA) axis. This model postulated that when the fetus becomes stressed, possibly due to a lack of nutrients or space at the end of pregnancy, the HPA axis is activated, leading to the release of cortisol by the fetal adrenal cortex that will be transported to the placenta and will stimulate the steroidogenic enzymes involved in the conversion of P4 into estrogens, leading to the withdrawal of P4 and myometrial activation (Liggins et al., 1973). However, previous studies have demonstrated that the relationship between these hormones is unclear for many reasons: 1) P4 concentration is much greater than that of estrogen at late gestation (ng/ml vs pg/ml) meaning that even if some P4 were converted into E2, it still would not result in a reduction in P4 levels (Hamon et al., 1990); 2) There is a compartmental expression of steroidogenic enzymes: in humans, bovine, and ovine, the conversion of 17OHP4 to A4 in the Δ4 pathway is very inefficient (Conley et al., 2012); and 3) E2 can induce parturition independently of P4 withdrawal (Wu et al., 2004). Therefore, the objective of this study was to obtain a better picture of estrogen's role in the control of parturition in periparturient Rambouillet ewes through the evaluation of the relationship between systemic E2 levels and 1) the timing of parturition, lamb birth weight, and lamb vigor, and 2) the uterine progestogenic responsiveness and P4 plasma levels.

Experimental Procedures

Two experiments were conducted performing the same treatment. Multiparous ewes were randomly assigned to either E (4 Silastic implants of 50 mg of E2; 200 mg/ewe; Exp 1 n = 5, Exp 2 n = 6) or C (4 empty implants; Exp 1 n = 5, Exp 2 n = 6) groups. All treatments began at d 139 to 142 of gestation. Implants were subcutaneously inserted in the axillary region of the ewe and were removed 2 days after parturition (experiment 1) or at slaughter (experiment 2).

In experiment 1, ewes were treated and their delivery time after treatment, live lamb birth weight, and vigor were recorded. Lamb vigor was assessed using a scale ranging from 0 to 4, where 0 represents extreme activity and vigor with the lamb standing on all four feet, 1 indicates high activity with the lamb standing on its back legs and knees, 2 represents moderate activity with the lamb active on its chest and holding its head up, 3 indicates weakness with the lamb lying flat but still able to hold its head up, and 4 indicates severe weakness with the lamb unable to lift its head and showing minimal movement.

In experiment 2, ewes were treated and slaughtered 26 h later for tissue collection. At slaughter, carotid blood was collected, and P4 and E2 plasma concentrations were measured by LC-MS and radioimmunoassay. Also, cross-sections of the uterus were collected, formalin-fixed and immunofluorescent stained for P4 receptors using DAPI counterstaining. Confocal imaging of myometrium was generated for image analysis of the receptor expression with Image-Pro Plus. Statistical significance ($P < 0.05$) was assessed using the MIXED procedure of SAS for both experiments.

Results and Discussion

In experiment 1, the hours from treatment to delivery were less in E compared with the C group (64.1 ± 75.64 vs 374.4 ± 75.64 h, $P = 0.01$). This indicates that the E group had an average day of gestation (DOG) at lambing of approximately d 142 ± 3, while the C group had an average DOG of approximately d 154 ± 3. In a more recent study (Davila-Ruiz, Reynolds, Conley et al., unpublished) we found with that a similar treatment with E2 on days 139 to 142 of gestation resulted in an average delivery day of 143 ± 1 compared with an average delivery day of 147 ± 1 in control ewes. The average gestation period in Rambouillet ewes typically falls around 147 days. Furthermore, lamb weight tended to be lower in the E group compared to the C group (4.12 ± 0.23 vs 4.77 ± 0.21 kg, $P = 0.07$). This observation can be rationalized as the induction of earlier delivery may result in slightly lower birth weights for the lambs. Also, the presence of both single and twin pregnancies included in the experiment can impact the birth weight of the lambs, as single pregnancies typically result in higher birth weights compared to twin pregnancies. No difference in lamb vigor was found between the E and C groups (2 ± 0.39 vs 1 ± 0.48, $P = 0.13$). Several factors may contribute to the lack of differences in lamb vigor. 1)

The timing of lamb vigor assessment conducted a few hours after birth may have not captured initial differences that could have emerged in the following days. In fact, a couple of days later, two lambs in the E group experienced sudden death, while no death was reported in the lambs of the C group. 2) Despite the E group experiencing parturition around 10 days earlier than the C group, both groups were likely at a similar stage of lung maturity. This suggests that the timing of parturition alone may not determine lamb vigor.

In experiment 2, a significant increase in E2 systemic levels was found in the E group compared with C group (149.21 ± 55.93 pg/mL vs 30.61 ± 11.73, P = 0.01), which suggests that E treatment effectively increased E2 levels. Estradiol has been related with the promotion of myometrial contractility and initiation of parturition. Together with the results in experiment 1, this finding suggests that a higher concentration of E2 could drive earlier delivery. A downregulation of myometrial P4 receptor protein expression was observed in the E group compared to C group (27.1 ± 36.7 vs 42.0 ± 3.68 intensity units, P = 0.01; Figure 1). This finding could have an important implication in the control of parturition, as P4 receptors play a crucial role in maintaining the inhibitory effects of P4 on uterine contractility promoting uterine quiescence during pregnancy. Therefore, the fact that the number of myometrial P4 receptors decreases with higher estrogen levels making the cells less responsive could potentially contribute to the initiation of parturition. No differences were found in P4 systemic plasma levels in E vs C (6.50 ± 1.42 vs 8.99 ± 1.42 ng/mL, P = 0.24), which together with the results in experiment 1, suggest that local changes in myometrial P4 receptors, rather than systemic P4 levels, might be more critical in regulating myometrial activation.

The findings of both experiments highlight the complex interplay between myometrial P4 receptor expression, systemic P4 and E2 concentrations, and the timing of parturition. Overall, these findings indicate that E2 concentrations have a notable effect on the timing of parturition and may contribute to slight differences in birth weight, but its impact on fetal maturation, as assessed by lamb vigor after birth, appears to be limited. Therefore, it can be concluded that E2 concentrations primarily affect the timing of parturition rather than directly influencing fetal maturation and that the downregulation of myometrial P4 receptor protein expression with the increase of E2 levels supports the important role of E2 in initiating labor. However, future research is needed to clarify the precise mechanism of parturition and fetal maturation to enhance reproductive management strategies in livestock.

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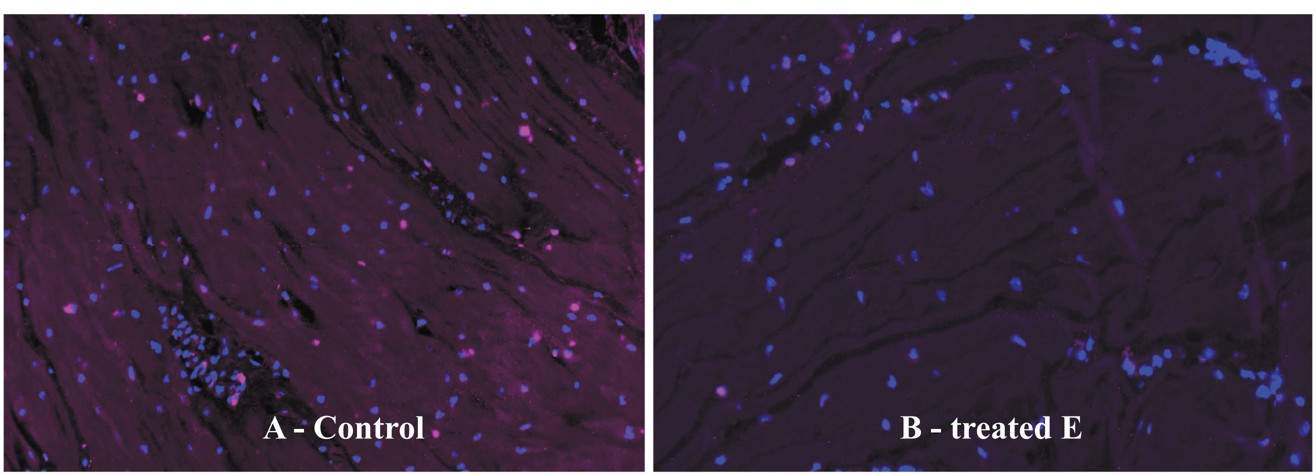

Figure 1. Staining for PR in the myometrium (200X). Comparison of the strong nuclear staining (reddish pinkish) in the Control (A) vs. the Estrogen-treated (B) myometrium. Bluish staining represents DAPI-stained nuclei.

Divergent planes of nutrition in mature rams influences birth characteristics of offspring but not growth performance or ewe reproductive productivity

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The objective of the current study was to characterize the effects of divergent planes of nutrition in mature rams on lambing and weaning rates, as well as offspring postnatal characteristics. While sire nutritional status prior to conception did not influence lambing or weaning rates and growth in offspring, birth weight and several body measurements were impacted, suggesting an effect of paternal diet on in utero development.

Summary

Twenty-four mature Rambouillet rams (initial mean body weight [BW] = 183.0 ± 6.4 lb) were randomly assigned to be managed on either a positive (gain 12% of initial BW; POS), maintenance (maintain initial BW; MAINT), or negative (lose 12% of initial BW; NEG) plane of nutrition over 84 days. Following the feeding period, rams were placed with 10 ewes each for a 28-day breeding season. Ewes were managed similarly throughout gestation. At lambing, birth weights and body measurements were recorded. Weights, body measurements, and scrotal circumference were recorded at weaning (approximately 60 days of age). All lambs were raised similarly throughout the growth period and final weights were recorded at approximately 220 days of age. Adjusted weaning weights and pre- and post-weaning average daily gain (ADG) were calculated. Lambing and weaning rates, as well as the number of lambs born and weaned per ewe lambed, were similar among treatments ($P > 0.34$). Lambs sired to NEG rams had greater birth weights, chest circumference, and shoulder-hip length than MAINT lambs ($P < 0.04$). These differences were not observed at weaning ($P > 0.23$), and pre-weaning ADG and adjusted weaning weights were similar among sire treatments ($P > 0.40$). While male offspring weighed more at day 160 and had a greater post-weaning ADG compared to female offspring ($P < 0.001$), no effects of sire treatment were observed for growth performance or scrotal circumference ($P > 0.36$). These findings provide insight on the effects of paternal nutrition on reproductive performance and offspring physiology, which could contribute to improved long-term managerial decisions for producers.

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Introduction

There are dramatic changes in body weight and plane of nutrition that occur throughout the production year for sires in livestock species as a result of differences in nutrient availability and workload. Previous research has demonstrated a link between male fertility and nutrition, representing an opportunity to optimize reproductive performance. Inadequate nutrition (both over- and undernutrition) has been associated with poor reproductive performance in bulls and rams, including reduced sperm production and motility, hormone concentrations, and libido (Brown, 1994). Based on producer preferences and available feedstuffs, there is variation in the rate of gain for sires leading up to the breeding season, which may not only affect reproductive performance, but also offspring development.

Recent studies in humans and mice have shown that changes in paternal nutrition prior to conception is linked to differences in offspring development and physiology and may contribute to metabolic diseases such as obesity and type II diabetes (Fullston et al., 2013). This occurs due to exposure of the developing sperm to altered concentrations of hormones and nutrient availability. This can result in sperm with alterations in nucleic acid composition and structure (known as epigenetic modifiers [i.e., DNA methylation patterns, histone modifications, RNA transcripts, etc.]), which are transferred to the embryo at the time of fertilization. The developing embryo and subsequent fetus may then experience differences in growth and development during pregnancy, leading to potential alterations in postnatal outcomes. Understanding the effects of paternal programming has several implications for improving livestock efficiency, thus the objective of this study was to characterize the effects of paternal plane of nutrition on ewe reproductive productivity, offspring body measurements and growth performance.

Procedures

A summary of procedures and characterization of the model are described by Bochantin et al., (2022). Briefly, mature Rambouillet rams (n = 24; BW = 183.0 ± 6.4 lb) from the Hettinger Research Extension Center (HREC; Hettinger, ND) were transported to NDSU (Fargo, ND) for this study. Rams were individually housed and randomly assigned to one of three treatments; a positive (gain 12% of initial BW [**POS**]; n = 8), maintenance (maintain initial BW [**MAINT**]; n = 8), or negative (lose 12% of initial BW [**NEG**]; n = 8) plane of nutrition. The feeding period was 84 days, corresponding to the length of two spermatogenic cycles in rams and ensuring that all sperm developed during the experimental period were exposed to the dietary treatment. Rams were fed a common diet and weighed on a weekly basis, after which dietary allotments were adjusted to achieve the targeted BW. The subsequent changes in body weight, composition, hormone and metabolite concentrations, and semen characteristics in response to divergent planes of nutrition are summarized by Bochantin et al. (2022).

Following the feeding period, rams were transported to HREC and each ram was placed in a pen with 10 ewes of similar age and body weight for a 28-day breeding season. After breeding, ewes were turned out to graze mixed native prairie pasture and managed similarly throughout gestation. Two weeks prior to lambing, ewes were brought to the lambing facilities and fed a common diet (Table 1). Lamb sex, birth type (singleton, twins, etc.), birth weight, lamb vigor, and body measurements at approximately 6 to 12 hours after birth were recorded. Body measurements included: crown-rump length (**CRL**; cm), shoulder-hip length (**SHL**; cm), chest circumference (**CC**; cm), and biparietal distance (**BPD**; cm; Table 2). Ewe and lamb cohorts were managed similarly through weaning, which occurred at approximately 60 days of age. Body weight and measurements, as well as scrotal circumference (cm), were recorded at weaning, and pre-weaning average daily gain (ADG) was calculated. Throughout the growth period, all lambs were fed a starter diet, consisting of a commercially available starter pellet (70%) and oat hay (30%). End weights were recorded at approximately 220 days of age and used to calculate post-weaning ADG. Scrotal circumference was also measured for ram lambs.

Data were analyzed with the MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC), with ram serving as the experimental unit. Differences among treatments were considered significant at $P \leq 0.05$ and tendencies at $0.05 < P \leq 0.10$.

Results and Discussion

Sire treatment did not influence the proportion of ewes that lambed, nor the number of lambs born per ewe exposed or per ewe lamb ($P >$ 0.77; Table 3). Additionally, there were no differences among sire treatments in the total weight of lamb birthed per ewe exposed or per ewe lambed ($P >$ 0.34; Table 3). In terms of ewe productivity variables before weaning, there were no differences among sire treatments, including the number of lambs weaned per ewe exposed nor per ewe lambed ($P > 0.54$). Additionally, the weight of lambs weaned per ewe exposed and per ewe lambed were not affected by sire treatment ($P > 0.54$), which also was observed at the end timepoint ($P > 0.65$). Collectively, sire dietary treatment did not affect the number of ewes bred or offspring born, indicating minimal effects on ram reproductive performance; however, the number of ewes per ram in the current experiment is lower than that of typical commercial production, so further evaluation is needed to better understand the extent of sire nutrition on reproductive performance.

There were no treatment × sex interactions observed for any of the variables recorded through the experiment. Interestingly, birth weight was influenced by sire treatment and sex of the lamb ($P < 0.03$). While male offspring weighed more than females ($P < 0.001$), lambs sired by NEG rams had greater birth weights than

Table 1. Ingredient list and inclusion rate of ingredients fed to gestating/lambing ewes and lamb offspring.

Ingredient, % DM	Inclusion, %	CP, %	TDN, %
Gestating & lambing ewes			
Ground hay	80.0	15.0	63.1
Oats	20.0	13.0	75.0
Lambs prior to weaning			
Creep feed	100.0	18.0	80.0
Lambs after weaning			
Grower pellet	75.0	16.0	80.0
Oats	25.0	13.0	75.0

Table 2. Weight and body measurements at lambing and weaning of offspring sired by rams managed on divergent planes of nutrition.

	Treatment[1]				Sex			*P*-value[3]		
Item	**POS**	**MAINT**	**NEG**	**SEM**	**Male**	**Female**	**SEM**	**TRT**	**Sex**	**TRT × Sex**
Birth Measurements										
Weight, lb	8.6^{x}	8.4^{ax}	9.3^{by}	0.22	9.2b	8.5^{a}	0.17	0.03	0.001	0.98
CRL, cm	45.9	45.9	46.7	1.81	46.3	46.0	1.79	0.18	0.36	0.91
CC, cm	37.6^{ab}	37.4^{a}	38.4^{b}	0.41	37.9	37.7	0.35	0.05	0.34	0.80
SHL, cm	20.2^{ab}	19.9^{a}	20.7^{b}	1.73	20.2	20.4	1.72	0.04	0.43	0.89
Hip Width, mm	53.9	53.5	53.9	0.53	54.4^{b}	53.2^{a}	0.45	0.72	0.001	0.94
BPD, mm	58.9^{x}	59.3^{xy}	60.1^{y}	2.06	60.1^{b}	58.8^{a}	20.4	0.09	< 0.001	0.86
Weaning Measurements										
Weight, lb	26.0	27.1	28.4	7.01	27.1	26.9	6.94	0.40	0.93	0.90
Pre-Weaning ADG, lb/d	0.24	0.26	0.24	0.08	0.24	0.26	0.08	0.58	0.40	0.99
CRL, cm	70.5	70.6	70.7	4.51	70.1	71.1	4.48	0.98	0.23	0.62
CC, cm	53.7^{a}	54.8^{ab}	56.1^{b}	4.09	54.4	55.3	4.06	0.04	0.23	0.75
SHL, cm	31.8	31.9	31.6	2.50	31.6	31.9	2.50	0.89	0.52	0.66
BPD, mm	72.7	72.1	72.9	3.05	72.1^{x}	73.0y	3.03	0.57	0.08	0.15
Scrotal circumference, cm	11.2	11.6	11.2	0.33	-	-	-	0.66	-	-
Post-Weaning Measurements										
End weight, lb	111.6	114.4	116.1	3.39	125.9^{b}	102.1^{a}	2.93	0.36	< 0.001	0.44
Post-weaning ADG, lb/d	0.46	0.49	0.49	0.02	0.53^{b}	0.39^{a}	0.02	0.41	< 0.001	0.31
Scrotal circumference, cm	30.9	31.1	30.7	1.00	-	-	-	0.88	-	-

[1]Rams were managed on one of three treatments: to gain 12% of initial BW (POS), maintain initial BW (MAINT), or lose 12% of initial BW (NEG) during an 84-day feeding period.
[2]Measurements recorded included weight, crown-rump length (CRL), chest circumference (CC), shoulder-hip length (SHL), hip width, biparietal distance (BPD), average daily gain (ADG), and scrotal circumference (SC).
[3]Significance was set at $P < 0.05$ and tendency at $0.05 < P \leq 0.10$ and included the effects of sire treatment (TRT), sex, and their interaction (TRT × Sex).
[ab]Means within a row for each main effect column (TRT or Sex) lacking a common superscript differ ($P < 0.05$).
[xy]Means within a row for each main effect column (TRT or Sex) lacking a common superscript tended to differ ($0.05 < P \leq 0.10$)

Table 3. Lambing, weaning, and rearing weights of offspring sired by rams managed on divergent planes of nutrition.

	Treatment[1]				
Item	**POS**	**MAINT**	**NEG**	**SEM**	***P*-value**
Lambing[2]					
Ewes lambed per ewes exposed, %	77.3	73.2	70.1	14.2	0.88
Average day of lambing interval	12.7	12.9	12.9	3.8	0.99
No. born per ewe exposed	1.48	1.36	1.35	0.21	0.77
No. born per ewe lambed	1.78	1.81	1.79	0.09	0.96
Weight of lamb birth per ewe exposed, lb	13.9	12.3	13.2	1.57	0.78
Weight of lamb birth per ewe lambed, lb	16.5	16.8	17.9	0.68	0.34
Weaning					
No. weaned per ewe exposed	0.97	0.77	0.89	0.131	0.55
No. weaned per ewe lambed	1.14	0.99	1.14	0.114	0.54
Weight of lamb weaned per ewe exposed, lb	36.6	29.8	36.4	5.36	0.64
Weight of lamb weaned per ewe lambed, lb	42.3	37.7	44.9	4.65	0.54
Rearing					
No. at end of experiment per ewe exposed	0.86	0.70	0.79	0.12	0.65
No. at end of experiment per ewe lambed	1.00	0.90	1.02	0.113	0.71
Weight of lamb per ewe exposed, lb	94.8	80.5	90.4	13.38	0.74
Weight of lamb per ewe lambed, lb	110.0	103.2	116.4	12.48	0.76

[1]Rams were managed on one of three treatments: to gain 12% of initial BW (POS), maintain initial BW (MAINT), or lose 12% of initial BW (NEG) during an 84-day feeding period.
[2]Rams were placed in an outdoor pen facility with 10 ewes each for a 28-day breeding period following the feeding period. Lambing characteristics were calculated for each ram exposed to the 10 ewes.

MAINT-sired lambs ($P = 0.04$) and tended to have greater birth weights than lambs sired by POS rams ($P = 0.08$). Furthermore, chest circumference and shoulder-hip length, were influenced by sire treatment, where NEG lambs had greater values than MAINT lambs ($P < 0.05$). Additionally, NEG lambs tended to have greater biparietal distance than POS lambs at birth ($P = 0.09$), while male lambs exhibited a greater biparietal distance than female lambs ($P < 0.001$). Interestingly, the majority of these differences in birth measurements were not observed in the weaning measurements. At weaning, NEG lambs had a greater chest circumference than POS lambs ($P < 0.04$), while female lambs tended to have greater biparietal distance than male lambs ($P = 0.08$). There were no differences among treatments observed for body weight or pre-weaning ADG ($P < 0.40$) at weaning. Additionally, there were no differences among treatments for scrotal circumference, an indicator of potential sperm production ($P = 0.66$). At the end collection, there were no effects of sire treatment on weight, post-weaning, ADG, or scrotal circumference; however, ram lambs had a greater end weight and post-weaning ADG, as compared to ewe lambs ($P < 0.001$). These findings suggest a potential effect of paternal nutrition on *in utero* development, which resulted in different weights and body measurements at birth. While there is limited information regarding paternal programming in livestock species, these results conflict with those reported in a mouse study, in which nutrient restricted males sired offspring with reduced birth weights (McPherson et al., 2016). Additionally, overfed male mice sired offspring with not only greater birth weights than control males, but also exhibited increased weight gain and fat deposition during their growth (Fullston et al., 2013). In a study with ram lambs supplemented with rumen protected methionine, the offspring sired by treated rams weighed and had numerically smaller scrotal circumference compared to control counterparts, but minimal differences in growth patterns observed (Gross et al., 2020). Although differences in weaning measurements or growth performance were not observed in the current study, there could be influences on other physiological traits, such as nutrient metabolism, fat deposition, or reproduction, that are influenced by paternal diet.

Future studies will focus on evaluating these paternal effects in greater depth, specifically evaluating relevant metabolic indicators, such as glucose metabolism and feed efficiency. Effects of paternal nutrition on offspring reproductive potential will also be evaluated to identify influences on fertility and transfer of gamete genetic material, as transgenerational inheritance has also been reported (Fullston et al., 2013). Together, these findings support the improvement of managerial decisions for sire nutrition, as well as help better understand the long-term implications on offspring performance.

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Lamb growth trait evaluation of purebred and crossbred Royal Whites in North Dakota

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The purpose of this study was to summarize general production characteristics in weight and growth of Royal White lambs and their crosses with other hair breeds in North Dakota. This paper provides simple means and standard deviations for birth weight, weight after rearing, and average daily gain in Royal White lambs and their crosses produced in North Dakota climates.

Summary

Royal White sheep are an established composite hair breed developed initially using Dorper (DO) (black and white headed) sire lines crossed with St. Croix ewes. There is limited production data readily available on Royal White sheep, particularly in northern climates. This paper provides general summaries of purebred and crossbred Royal White (RW) lamb weights and growth from birth to end of rearing ages. The average birth weight of RW lambs was 7.62 ± 1.71 lb, and the average birthweight of crossbreds was 8.13 ± 1.61 lb overall. Four crosses were made with average birthweights of 8.09 ± 1.62 lb, 8.49 ± 1.53 lb, 8.12 ± 1.71 lb, and 7.67 ± 1.46 lb for F1 DO-RW, ¾ DO ¼ RW, F1 RO-RW, and ½ RO ¼ DO ¼ RW, respectively. Numerically, differences in birthweight based on litter size at birth was only evident in crossbred lambs. Due to study limitations, weights around weaning were inconsistent in ages. Even so, Royal White crossbred lambs averaged 0.64 ± 0.11 lb/d of gain, with similar gains found in purebred Royal White lambs.

Introduction

The Royal White (RW) breed is a composite breed developed by Bill Hoag using Dorper (DO) and St. Croix (SC) hair breeds (Registry Royal White® Sheep Association, 2018). Originally called Dorpcroix, Hoag formally had the name changed in 2003 and trademarked in 2004. A limited number of publications are available on RW sheep. These include publications from studies comparing RW-sired crossbred lambs to Rambouillet lambs for growth given natural prebiotic treatments (Campbell, 2002), pelt and leather quality (Shelly et al., 2009) and genetic resistance to prion diseases (e.g., scrapie polymorphisms; Seabury, 2004). The remainder of RW breed characterizations are based on Mr. Hoag's observations and records (Registry Royal White® Sheep Association, 2018).

The development of the RW breed was focused on arid and tropical regions of the U.S., where Hoag indicated that sheep had to be hardy and cope with unexpected weather changes that occur in West Texas across seasons (Registry Royal White® Sheep Association, 2018). Even so, no characterization has been provided in other climates. North Dakota (N.D.), in general, is described as a continental climate due to extreme shifts in temperatures because of cold winters and warm-to-hot summers (National Weather Service, 2007). The western part of N.D. is characterized as a semi-arid climate due to less precipitation and humidity, while the eastern part of N.D. is characterized as a humid, continental climate due to humid, warm-to-hot summers, and windy, cold winters. The climate of N.D. is distinctly different from the variety of climate types seen in central-to-western regions of Texas. Therefore, the purpose of this study was to summarize general production characteristics in weight and growth of RW lambs and their crosses with other hair breeds in N.D.

Procedures

Animals and Breeding

All procedures involving animals were reviewed and approved by the North Dakota State University (NDSU) Institutional Animal Care and Use committee. A flock of 60 purebred RW ewes (n = 30 spring- and 30 fall-born in 2014) were purchased by the NDSU Dickinson Research Extension Center (DREC) in February of 2015. The spring-born RW ewes were bred prior to purchase, then transported to DREC in Febru-

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ary and lambed between late April to late July as approximately one-year-old ewes. Ewe lambs born in 2015 were retained in the flock and males were castrated and sold following weaning (late August). The RW ewes were housed at the DREC ranch located near Manning, ND (47º11′37.3′′N, 102º50′20.1′′W) and managed as an early summer shed-lambing system. In 2016 and 2017, the ewes were bred to White DO rams and in 2018, ewes were randomly separated into two groups for breeding to DO and Romanov (RO) rams. Some F1 DO-RW ewe lambs (n = 50) produced in 2017 and 2018 were retained for breeding to DO and/or RO rams in 2019 as well. From 2018 to 2019, the flock was downsized due to space limitations at the ranch. In October of 2019, a subset of purebred RW (n = 23) and F_1 DO-RW (n = 17) ewes were sold to the NDSU Sheep Unit located in Fargo, ND (46º54′14.3′′N, 96º49′59.3′′W) and the remaining ewes were sold by DREC. The ewes retained at the NDSU Sheep Unit were switched to a fall pasture and shed-lambing management system, where they were next bred to a DO ram in late spring of 2020 to produce either F_1 DO-RW or ¾ DO ¼ RW offspring. In 2021 and 2022, remaining purebred RW ewes (n = 13) were used exclusively for laparoscopic artificial insemination (LAI) following the procedure described in Sathe (2018) using semen of purebred, registered RW rams. Any remaining F_1 DO-RW ewes were bred to the White DO ram to produce ¾ DO ¼ RW offspring. A purebred RW ram lamb produced in 2021 was retained and used for natural service breeding with purebred RW ewes in 2022 following LAI.

General Management Practices

At DREC, sheep were fed chopped mix hay and grains produced on DREC lands through winter months. Rotational grazing was used during summer months near ranch headquarters once plant growth was adequate. Sheep Mineral 16-8 (CHS, Inc., Sioux Falls, S.D.) and loose white salt was provided throughout the year as free choice in mineral feeders. Following weaning, lambs were provided mixed hay and a commercial growing feed (Lamb Grower Complete B30; CHS, Inc., Sioux Falls, S.D.) until they were sold or integrated back into the flock.

At the NDSU Sheep Unit, sheep were fed a blend of chopped alfalfa and grass hay or a long-stem native grass round bale hay during winter months. In spring, summer and fall, ewes were rotationally grazed on native pastures. During late gestation and lactation, ewes were fed a 16% protein complete pellet produced at the NDSU feed mill. The Shepherd's Choice Trace Mineral Premix (Premier 1 Supplies, Washington, Iowa) and salt were blended and provided throughout the year as free choice in mineral feeders. Lambs were started on a 20% protein creep pellet and transitioned to a 16% protein complete pellet until sold or retained as replacements. Both diets were produced at the NDSU feed mill.

Production Data

Lambing data were captured on all lambs during the study period. These data included date of birth, litter size at birth (LS_B), litter size based on how they were reared (LS_R), status of lambs (active, died, reasons for death if known), sex, dam, suspected or known sire, expected lamb breed type, and birth weight. Starting in 2017, weights on lambs were captured at least once when lambs were approximately 60 to 90 d old, which was typically weaning but varied based on management needs and location. Average daily gain (ADG) for each lamb was calculated as the difference between the weight captured in the 60 to 90 d timeframe minus birth weight divided by the age of the lamb (in d).

Statistical Analyses

Data was imported into R software version 4.2.3 (R Core Team, 2023) within RStudio version 2023.03.03 (Posit Team, 2023). Basic summaries statistics of lamb data were generated using the *dplyr* R package version 1.1.1 (Wickham et al., 2023) with *group_by* and *summarise* functions. Grouping variables included production year, breed type, lamb sex (male or female), litter type (LS_B and LS_R as single, twin, or triplet), age of dam (in whole years) and their interactions based on available data. Due to the unbalanced nature of available data, no additional statistical models were employed.

Results and Discussion

Royal White Lambs

Purebred RW were only produced in 2015 (n = 21), 2021 (n = 2), and 2022 (n = 11) due to challenges in purchasing purebred rams to support natural service matings. All RW ewes were the same age when producing purebred lambs, such that ewes were one, seven, and eight years old, respectively. The average birth weight of RW lambs was 7.62 ± 1.71 lb across years and 7.14 ± 1.79 lb, 9.10 ± 1.84 lb, and 8.25 ± 1.23 lb for the three years produced, respectively. Given all 2015 born lambs were from one-year old dams, the lower birth weight would be consistent with other sheep breeds (e.g., Gardner et al., 2007). Summary statistics by lamb sex and litter size (Table 1) indicate male lambs were often heavier than ewe lambs, but differences among litter sizes were not as evident.

Weights were generally collected in the 60-to-90 d timeframe, but this was not always consistent with RW lambs and did not always coincide with actual weaning across management location or years. Therefore, the weights and ADG values are described as "after rearing" to be consistent across years data were collected. In terms of RW lambs, there were only two instances that lambs were reared differently than their LSB (one twin raised as a single and one triplet raised as a single) in the two years of available data. Therefore, only LSR was considered in summary statistics (Table 1). The twin-born LAI lambs born in 2021 consisted of a male and female that averaged 79.0 ± 15.6 lb at 81 d of age with average ADG of 0.86 ± 0.17 lb/d. In 2022, six females and three male lambs were weaned and averaged 63.1 ± 11.5 lb at 100.3 ± 11.1 d of age with average ADG averaged of 0.55 ± 0.13 lb/d.

Crossbred Lambs

Most crossbred lambs were F_1 DO-RW (65.65%) followed by ¾ DO ¼ RW (18.35%), ½ RO ¼ DO ¼ RW (9.18%), and F1 RO-RW (6.82%; Table 2). The majority of crossbred lambs (85.18%), including all RO-influenced lambs, were produced from 2017 to 2019 at the DREC (averaged 121 lambs per year) with the remainder produced at the NDSU Sheep Unit (averaged 21 lambs per year). This was simply due to the larger flock size accommodated at the DREC.

The average birthweight of crossbreds was 8.13 ± 1.61 lb overall and 8.09 ± 1.62 lb, 8.49 ± 1.53 lb, 8.12 ± 1.71 lb, and 7.67 ± 1.46 lb for F_1 DO-RW, ¾ DO ¼ RW, F1 RO-RW, and ½ RO ¼ DO ¼ RW, respectively. Summary statistics by breed type for lamb sex and litter size (Table 3) indicate that when RO was the highest percentage, birth weights of lambs were lower than other crosses, particularly for triplets. Litter size, in general, was particularly impactful for single-born lambs in all crosses compared to twin- and triplet-born lambs (Table

Table 1. Means and standard deviations of Royal White lamb weights and average daily gain from birth to end of rearing grouped by lamb sex, litter size (LS), or their interaction.[1]

		Birth		After Rearing			
Sex	LS	n	BW, lb	n	WT, lb	Age, d	ADG, lb/d
Overall	S	24	7.55 ± 1.75	6	66.7 ± 7.5	96.0 ± 11.3	0.61 ± 0.09
	TW	4	7.55 ± 2.24	2	79.0 ± 15.6	81.0 ± 0.0	0.86 ± 0.17
	TR	6	7.93 ± 1.43	3	56.0 ± 16.5	109.0 ± 0.0	0.45 ± 0.14
Female	Overall	19	7.25 ± 1.78	7	64.0 ± 15.9	102.0 ± 13.2	0.56 ± 0.21
	S	14	7.20 ± 1.72	3	63.3 ± 7.0	101.0 ± 15.1	0.54 ± 0.04
	TW	2	7.70 ± 3.82	1	90.0 ± 0.0	81.0 ± 0.0	0.98 ± 0.00
	TR	3	7.20 ± 1.31	3	56.0 ± 16.5	109.0 ± 0.0	0.45 ± 0.14
Male	Overall	15	8.08 ± 1.55	4	69.5 ± 6.2	88.2 ± 5.2	0.69 ± 0.06
	S	10	8.04 ± 1.76	3	70.0 ± 7.6	90.7 ± 2.3	0.68 ± 0.06
	TW	2	7.40 ± 0.57	1	68.0 ± 0.0	81.0 ± 0.0	0.74 ± 0.00
	TR	3	8.67 ± 1.33	0	--	--	--

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Litter size through rearing was based on being reared a single (S), as a twin (TW), or as a triplet (TR). Birth weights were collected over three years, whereas weights after rearing were only collected in two years. Dams were all the same age per year. The n per group level is the total number of lambs with records within that category.

Table 2. Sample sizes of crossbred lambs with birth and rearing age records produced overall as well as by location and year.[1]

		Crossbred type n for birth / rearing records				
Location	Year	F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW	Total
NDSU DREC	2017	116 / 103	--	--	--	116 / 103
	2018	112 / 104	--	--	--	112 / 104
	2019	30 / 26	36 / 31	29 / 26	39 / 35	134 / 118
NDSU Sheep Unit	2020	17 / 17	8 / 7	--	--	25 / 24
	2021	3 / 3	17 / 16	--	--	20 / 19
	2022	1 / 1	17 / 17	--	--	18 / 18
Total		279 / 254	78 / 71	29 / 26	39 / 35	425 / 386

[1]Locations included the North Dakota State University (NDSU) Dickinson Research Extension Center (DREC) ranch near Manning, ND and NDSU Sheep Unit in Fargo, ND. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F_1 (true first crosses) were 50% of each breed.

3). Purebred Romanov lamb birth weight is commonly reported to be about 5.5 lb (e.g., Khattab et al., 2021) due to the prolific nature of the breed. The higher average F_1 RO-RW birth weight in this population would certainly indicate some level of heterosis is present, however a balanced cohort of purebred and crossbred lambs would be needed to determine the exact level. Additional statistical comparisons are warranted to prove litter size differences exist. Furthermore, heavier birthweights of DO x RW crosses compared with purebred RW indicate heterosis still may occur between the two breeds (Table 1 and 3) even though DO influenced RW in breed development.

Weights taken following rearing were more consistent during the 60-to-90 d timeframe for all crossbreds. The overall average was 57.1 ± 11.2 lb at 76.9 ± 10.3 d of age with an ADG of 0.64 ± 0.11 lb/d (Table 4). Given all four types were only present in 2019, Table 5 provides summary statistics by breed type for lamb sex, litter size, and their interaction. Weights and ADG were within the realm of what has been reported in other sheep breeds at the given ages and weights.

Lambs derived from RW genetics, either purebred or crossbred, reached breed comparable weights to medium-framed wool sheep at 53.9 to 66.9 lb after rearing and growth rates of 0.62 to 0.68 lb/d. This early growth meets production expectations indicating that RW-influenced progeny can be effectively marketed after a short backgrounding period for the growing lightweight market. Further research on post-weaning growth and utilizing RW for commercial lambs is warranted.

Table 3. Means and standard deviations of Royal White crossbred lamb birthweights grouped by lamb sex, litter size (LS), or their interaction within breed type.[1]

		Crossbred type			
Sex	LS	F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW
Overall	S	9.32 ± 1.57	9.19 ± 1.73	9.33 ± 1.04	8.63 ± 0.98
	TW	7.91 ± 1.45	7.90 ± 1.08	8.79 ± 1.48	7.33 ± 1.36
	TR	7.48 ± 1.74	8.13 ± 0.93	7.04 ± 1.56	6.50 ± 2.29
Female	Overall	7.88 ± 1.65	8.21 ± 1.81	7.77 ± 1.82	7.50 ± 1.55
	S	9.25 ± 1.19	8.87 ± 2.14	9.00 ± 0.00	8.08 ± 0.80
	TW	7.55 ± 1.55	7.46 ± 1.08	8.50 ± 1.47	7.44 ± 1.66
	TR	7.47 ± 1.74	9.20 ± 0.00	6.50 ± 1.84	4.50 ± 0.00
Male	Overall	8.26 ± 1.58	8.70 ± 1.26	8.41 ± 1.61	7.77 ± 1.43
	S	9.40 ± 1.91	9.50 ± 1.23	9.50 ± 1.41	9.17 ± 0.88
	TW	8.19 ± 1.31	8.19 ± 1.00	9.07 ± 1.54	7.28 ± 1.24
	TR	7.48 ± 1.77	7.60 ± 0.14	7.43 ± 1.34	7.50 ± 2.12

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.

Table 4. Means and standard deviations of Royal White crossbred lamb weights and growth by end of rearing produced from 2017 to 2022 grouped by breed type.[1]

		Crossbred type			
Trait	Group	F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW
WT, lb	All	53.9 ± 9.8	62.4 ± 11.2	60.4 ± 8.7	66.9 ± 12.1
	2019-born	54.2 ± 11.5	57.1 ± 12.6	*	*
Age, d	All	72.7 ± 7.3	85.2 ± 13.6	83.4 ± 5.8	86.3 ± 4.0
	2019-born	75.0 ± 9.2	76.9 ± 6.6	*	*
ADG, lb/d	All	0.63 ± 0.11	0.64 ± 0.12	0.62 ± 0.10	0.68 ± 0.13
	2019-born	0.61 ± 0.11	0.63 ± 0.14	*	*

[1]Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.
*Values are the same as the All group.

Table 5. Means and standard deviations of 2019-born Royal White crossbred lamb weights by end of rearing grouped by lamb sex, litter size (LS), or their interaction within breed type.[1]

Sex	LS	Crossbred type			
		F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW
Overall	S	66.8 ± 9.2	64.7 ± 10.5	70.0 ± 6.7	76.2 ± 11.7
	TW	54.4 ± 9.7	50.1 ± 8.5	61.6 ± 7.2	63.6 ± 7.1
	TR	45.0 ± 9.9	34.0 ± 0.0	50.8 ± 3.4	51.5 ± 7.7
Female	Overall	52.9 ± 12.1	54.4 ± 8.8	57.9 ± 6.9	61.4 ± 9.8
	S	63.7 ± 8.3	59.3 ± 8.5	69.0 ± 5.7	66.0 ± 7.4
	TW	51.9 ± 10.9	48.9 ± 5.4	56.6 ± 4.2	62.2 ± 7.8
	TR	41.0 ± 11.3	--	51.5 ± 2.1	45.0 ± 1.4
Male	Overall	55.4 ± 11.2	61.4 ± 16.4	62.2 ± 9.6	70.6 ± 12.2
	S	76.0 ± 0.0	73.7 ± 6.6	71.0 ± 9.9	85.0 ± 5.8
	TW	57.0 ± 8.1	52.2 ± 13.0	65.4 ± 6.6	64.2 ± 7.0
	TR	47.0 ± 10.2	34.0 ± 0.0	50.5 ± 4.2	58.0 ± 2.8

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.

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Does feeding high Oleic soybeans (TruSoya) in a swine finishing ration impact meat and carcass quality characteristics?

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Dietary sources of fatty acids present in swine diets will be represented in their muscle and lipid tissues, which may influence carcass and quality traits. In this study, replacing traditional soybean meal or conventional extruded soybeans with extruded high-oleic acid soybeans (TruSoya) during the finishing phase did not affect carcass composition, meat quality, or shelf-life of pork, but did modify the fatty acid profile of subcutaneous fat.

Summary

Seventy-two crossbred pigs (Landrace x Yorkshire, Duroc x Landrace x Yorkshire) were allotted to 18 pens and randomly assigned to one of three finishing diets: traditional control soybean-meal (CTRL), extruded conventional soybean (CONV), or extruded high-oleic acid soybean, TruSoya (TRU). Upon reaching 260 pounds, pigs were harvested, and compositional carcass measurements and pork quality traits were collected. A shelf-life study was performed to determine differences in pork chops to assess color change associated with diet. Subcutaneous fat samples were obtained to evaluate changes in fatty acid profile. Diet affected final live weight, and pre-rigor carcass weight (HCW), but did not impact fresh pork water holding capacity, pH, or color. Shelf-life evaluation found no differences for dietary impact or interaction with day of storage and (or) slaughter date. Minolta L* (lightness whereby 100 = white and 0 = black) increased, while a* (redness) and b* (yellowness) decreased over time in retail display across all diets. Most notably, TRU increased the percentage of oleic acid in subcutaneous fat; however, the increased presence of this monounsaturated fat did not impact belly firmness compared to other diets.

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Introduction

Diet composition can modify the balance of fatty acids in pork lean and fat depots. Dietary rations have been created to improve the content of the beneficial fatty acids (such as oleic, linoleic, and linolenic) in pork. However, changes in fatty acid concentration may be detrimental to palatability and technological characteristics (Fanalli et al., 2022). Oleic acid is the major monounsaturated fatty acid (MUFA) found in pig fat. Increased consumption of MUFA has been associated with reduced risk of stroke in humans and can improve dietary lipid deposition and physiological utilization. That said, it may impact color, marbling, and cooked flavor, and alter technological characteristics such as firmness, fat cohesiveness, and oxidative stability (Bee et al., 2002; Navarro et al., 2021).

TruSoya soybeans contain a higher content of oleic acid and lower content of saturated fatty acids compared to traditional or conventional soybeans. However, there is limited data evaluating the impact of soybeans possessing enhanced fatty acid composition on pig carcass traits and pork quality. Therefore, the objective of this experiment was to determine if a swine finishing ration that included a high concentration of TruSoya soybeans will impact carcass composition and meat quality characteristics.

Experimental Procedures

Crossbred pigs (Landrace x Yorkshire, Duroc x Landrace x Yorkshire; N = 72) were sorted by weight (initial weight 172 ± 20 pounds) and sex, then distributed within 18 pens. Each pen was randomly assigned to one of three experimental diets: traditional control soybean-meal (CTRL), an extruded conventional soybean (CONV), or an extruded high oleic acid soybean (TRU) as the main protein source. The diets were offered during the finishing period until reaching 260 (± 6) pounds. Six slaughter groups were created, harvesting 12 animals/group to ensure uniformity of finishing weight. Thus, animals were retained on test for 34, 37, 41, 42, 48, or 50 days. Animals were humanely harvested at the NDSU meat laboratory.

Final live weight, pre-rigor carcass weight (HCW) and dressing percent were recorded at harvest. After a 24-hour chill (36°F), loin eye depth, loin eye area, subcutaneous fat depth, loin eye color, and marbling scores were taken at the 10th/11th rib interface. The right-side carcass was fabricated into primal cuts (ham, belly, loin, boston butt, and picnic shoulder), which were weighed and expressed as percentage of chilled side weight. A one-inch-thick boneless pork chop was obtained adjacent to the 10th rib for shelf-life analysis. An additional chop was obtained adjacent the 11th rib, vacuum packaged, aged for seven days (36°F), and frozen (10°F) for later analysis. Subcutaneous fat samples were obtained adjacent to the first thoracic vertebra, frozen at 10°F, and saved for fatty acid analysis. Fresh belly firmness was determined by the belly flop test, which consisted of measuring the distance between caudal and cranial ends in a suspended belly on a V-shaped smokehouse stick. Shelf-life was evaluated in a simulated retail display for six days. Pork chops were overwrapped with a plastic film and placed in a retail cooler at 40°F. Minolta L*, b*, and a* measures were recorded daily using a Konica Minolta CR-400 Chroma Meter (Konica Minolta Inc. Ramsey, NJ) as indicators of pigment degradation and spoilage. Pork chops thawed for quality analysis were evaluated for pH, drip loss, subjective marbling, color score, cook loss, and tenderness. Color was recorded from pork chops after 30 minutes exposure to oxygen to allow surface "color blooming." Raw chop weight was obtained prior to cooking on clamshell grills until reaching an internal temperature of 140°F. The chops were then cooled to room temperature and re-weighed to determine cook loss. Tenderness was evaluated by Warner-Bratzler Shear Force (WBSF). Five round cores (0.5-inch diameter) were removed directionally parallel to the muscle fibers (AMSA, 2016). Each core was sheared by a V-notched cutting blade attached to the WBSF instrument (PPT Group UK Ltd, Slinfold, UK) to record the maximum force to cut through the sample. All data were analyzed using the MIXED procedure of SAS (SAS 9.4, SAS Institute Inc., Cary, NC). Repeated measures were used to analyze shelf-life. Differences were considered significant at $P \leq 0.05$ with pen as experimental unit.

Results and Discussion

Animals fed TRU had higher body weights, HCW, and dressing percentage compared to the other diets (Table 1). In contrast, loin eye area and depth, fat depth and the primal cut weights were not affected by the diet. The belly flop test suggested that bellies from the animals fed CONV were softer than CTRL and TRU (higher percentage change = softer belly).

Diet did not affect meat quality but differences for drip loss, L*, b*, and pH variation were associated with slaughter group (Table 2). No significant interactions were found between slaughter group, diet, or retail day during the shelf-life evaluation. However, numerical differences were found in L* and a* values. Pork chops from the TRU treatment were lighter (higher L*) and less red (lower a*) over time (Figure 1). Slaughter group and day of retail display influenced color change and rate of acceptable retail decline regardless of diet, showing a typical degradation curve for all treatments.

Fatty acid analysis revealed that TruSoya soybeans resulted in a greater percentage of subcutaneous oleic acid and less linoleic and saturated fatty acids (Figure 2). It is important to note that this modification did not affect belly firmness. Slaughter group

Table 1. Compositional carcass traits for pigs fed traditional soybean meal (CTRL), extruded conventional soybean (CONV), or extruded high-oleic acid soybean (TRU).

	Experimental diet*				*P* - value[1]				
Carcass trait	CONV	CTRL	TRU	SEM	Diet	Sex	Slaughter group	Slaughter group x diet	Slaughter group x sex
Final live weight, lb	260.84^{ab}	255.97^{a}	262.65^{b}	1.98	0.035	0.109	<0.001	0.012	0.028
HCW, lb	205.96^{ab}	202.36^{a}	208.37^{b}	1.82	0.034	0.108	<0.001	0.029	n.s
Dressing %	79.00	79.00	79.26	0	0.614	0.821	0.006	n.s	n.s
Loin eye depth, inch	2.62	2.60	2.63	0.08	0.894	0.016	0.027	n.s	0.012
Loin eye area, sq. inch	7.88	7.65	7.8	0.24	0.546	0.088	0.019	n.s	n.s
Fat depth 10th rib, inch	0.85	0.82	0.87	0.04	0.713	0.005	0.005	n.s	n.s
Cold Right carcass, lb	99.04	98.46	100.25	1.41	0.481	0.037	0.003	n.s	n.s
Ham, %	26.78	26.66	26.90	0.65	0.795	0.189	<0.001	n.s	n.s
Belly, %	15.85	16.15	15.89	0.59	0.746	0.609	0.001	n.s	n.s
Loin, %	22.57	23.31	22.83	0.58	0.349	0.663	0.001	n.s	n.s
Boston butt, %	7.59	7.15	7.25	0.38	0.304	0.936	0.075	n.s	n.s
Picnic shoulder, %	14.06	13.73	14.15	0.35	0.672	0.864	0.008	n.s	n.s
Belly flop, % of initial	73.47^{a}	59.95b	67.70^{ab}	2.55	0.007	0.038	0.079	n.s	n.s

[1]Values are significant at $P \leq 0.05$. n.s = non-significant for the interaction.
*Values with different letter indicate significance of the diet at $P \leq 0.05$

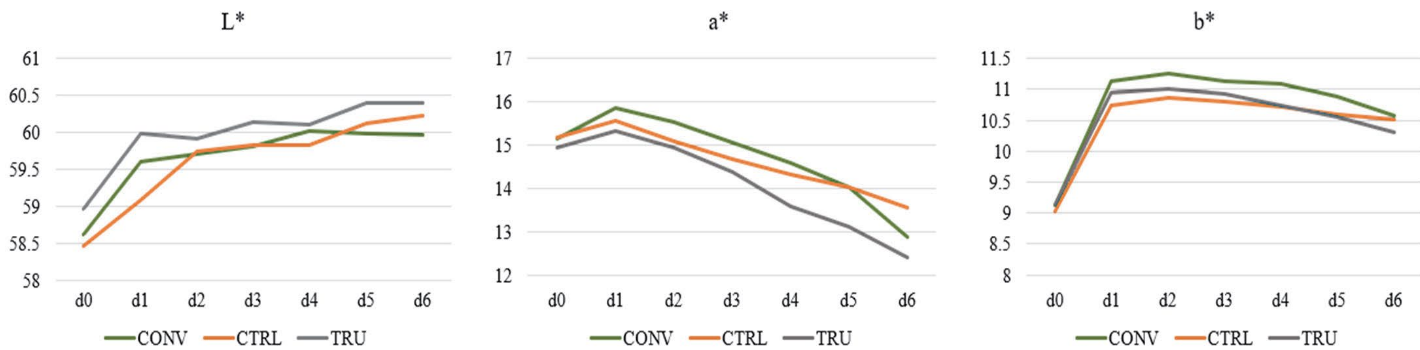

Figure 1. Shelf-life results for pigs fed traditional soybean meal (CTRL), extruded conventional soybean (CONV), or extruded high-oleic acid soybean (TRU).

Table 2. Pork quality traits of pigs fed traditional soybean meal (CTRL), extruded conventional soybean (CONV), or extruded high-oleic acid soybean (TRU).

	Experimental diet				*P* - value[1]		
Quality trait	CONV	CTRL	TRU	SEM	Diet	Sex	Slaughter Group
Drip loss, %	3.99	4.17	3.45	0.39	0.41	0.36	0.003
Cook loss, %	16.08	17.53	16.80	0.72	0.26	0.74	0.74
L*	56.02	56.79	56.20	1.42	0.67	0.02	0.007
a*	14.07	14.24	13.80	0.33	0.59	0.50	0.21
b*	9.974	10.36	10.20	0.58	0.55	0.02	0.007
Color score	2.5	2.4	2.5	0.2	0.71	0.67	0.09
Marbling score	2.1	2.1	2.2	0.2	0.79	0.23	0.20
pH	5.49	5.47	5.50	0.04	0.43	0.87	0.004
WBSF, N	21.32	20.78	23.10	1.35	0.19	0.68	0.10

[1]Values are significant at $P \leq 0.05$

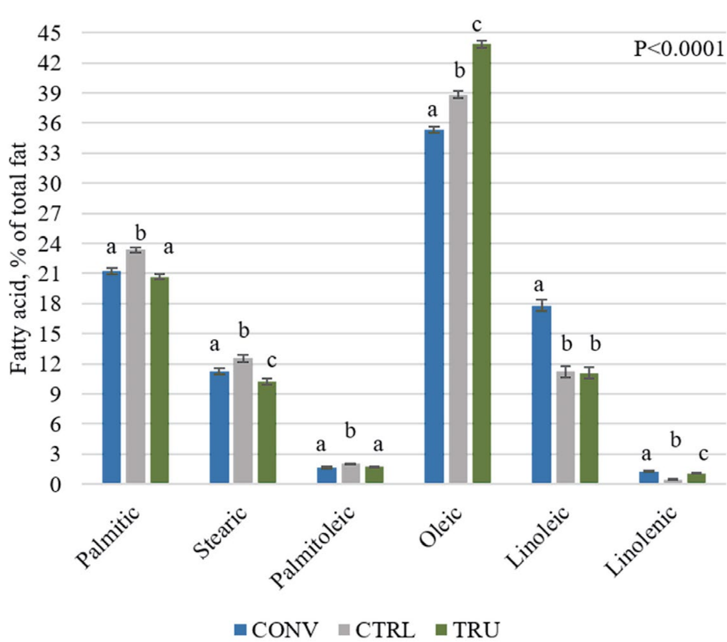

Figure 2. Fatty acid profile of pork subcutaneous fat from pigs fed traditional soybean meal (CTRL), extruded conventional soybean (CONV), or extruded high oleic acid soybean (TRU).

and sex had greater impact on carcass and quality traits than diet. For this reason, TruSoya soybeans could be considered as a dietary alternative to modify the fatty acid profile in pork, while keeping similar carcass and quality traits when fed during the finishing period.

Acknowledgements

This project was supported by the Minnesota Soybean Research and Promotion Council. The authors would like to express their appreciation for the contributions of the North Dakota State University's swine unit personnel, NDSU meat lab, Sebastian Gutierrez, the Northern Crops Institute personnel, and the swine extension program of the South Dakota State University.

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Determining lamb carcass benchmarks and value attributes for producers in the Northern Plains region

Matthew Chaney[1] and Travis Hoffman[1,2]

The objective of this study was to evaluate individual lamb carcass measurements from producers in the region to determine if improvements in benchmarks surpassed outdated carcass baselines which could lead to the development of regional standards to provide a more uniform American Lamb product. We present the Northern Plains benchmarks of 12th rib backfat (0.27 in); body wall thickness (1.02 in); ribeye area (2.58 in^2); hot carcass weight (69.73 lbs.); and percent boneless closely trimmed retail cuts (45.57%).

Summary

In attempt to promote a more uniform American Lamb product, the assessment of carcass benchmarks will be instrumental in promoting a higher quality product with less variability. Currently, the large variation in sheep flocks and production systems have accentuated concerns of variability within the American Lamb end product. To encourage unity on all fronts, the promotion of regional benchmarks can help ensure the quality of the product being raised. For the time being, sheep producers are missing out on the opportunity to make production and carcass improvements because of the inability to assess how their sheep grade. For the producers in the Northern Plains region, a set of regional benchmarks may help guide production decisions and ultimately advance carcass quality. These newly defined regional benchmarks are 12th rib backfat (0.27 in); body wall thickness (1.02 in); ribeye area (2.58 in^2); hot carcass weight (69.73 lbs.); and percent boneless closely trimmed retail cuts (45.57%).

Introduction

In relation to other proteins, lamb is comparatively more expensive, only further validating the need for continuous improvement (Hoffman, 2015). Presently, it is a challenge to make improvements without benchmarking data for producers to use when making breeding, management, and feeding decisions.

The American lamb and sheep industry is very diverse with numerous breeds and production styles that have generated inconsistencies in product uniformity that resulting in U.S. lamb quality being inconsistent. Variation of diets, harvest endpoint (age, weight, body composition), and breed composition influence product consistency and can impact eating experience. These differences in production systems, breeds and finishing diets can impact the degree of fatness, tenderness and flavor of lamb. The use of carcass benchmarks gives producers a targeted goal to strive toward in producing lean, muscular lamb carcasses of desired weights. These targets may help producers create a more consistent, uniform product. Understanding carcass benchmarks may help improve nationwide carcass uniformity and end product.

Lamb producers should strive to place a strategic emphasis on quality attributes identified in this research to ensure lamb quality by limiting variability. In pursuing quality and uniformity, opportunities are now obtainable in reaching a broader consumer range due to promoting positive eating satisfaction and uniform lamb flavor. With the help of you, the producer, we can strive to produce lamb with product authenticity attributes requested by retail and foodservice sectors, and inevitably American lamb consumers stamped with consistent quality. The objectives were to define carcass benchmarks for lamb in the Northern plains region.

Procedures

The development of Northern Plains 2018/2019 carcass benchmarks builds on prior carcass baselines performed in 2016/2017 by Dr. Held and Dave Olilla in South Dakota. Carcass measurements assessed were 12th rib backfat, body wall thickness, ribeye area, hot carcass weight (HCW) and percent boneless closely trimmed retail cuts (%BCTRC). A total of 1,180 lambs were shipped to Superior Farms, Denver, Colorado from 58 producers located in the Northern Plains region (Minnesota, Iowa, South Dakota and Nebraska). Car-

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cass measurements were recorded by trained NDSU personnel. Aggregated data was used to outline benchmarks using the MEANS procedures of SAS (SAS Institute, Inc., Cary, NC).

Results and Discussion

The benchmark averages gathered from the aggregated years in this study are shown in Table 1. The numerical difference between prior baselines set in 2016/2017 can be located in Table 2 along with each individual year and aggregated data. From the prior study (2016) performed on 365 lambs from 19 producers from South Dakota, Dr. Held and Dave Ollila found that lambs had an average HCW of 69.84 lbs., 12th rib backfat of 0.32" and a ribeye area of 2.36 in^2, which factored into a %BCTRC of 45.33%. When compared to new updated carcass benchmarks, lambs in the Northern Plains region were heavier muscled but were trimmer, and had a similar HCW. Differences were 0.05" decrease in 12th rib backfat (½ of a USDA Yield Grade) and an increase of ribeye area by 0.17 square inches greater than previous regional standards. Granted, there was an increase in body wall thickness which we hypothesize is due to sampling variability between personnel. It is also important to recognize that while lambs were from the same region, producer repeatability was not the target of this research from the two studies. This reiterates that comparisons of carcass benchmarks utilizing different states provides informative understanding and not direct comparisons.

Producers in the Northern Plains region have been able to push the industry norms in a positive direction by understanding and utilizing past benchmarks from states in the northern Midwest. There is room for continued improvement as producers and the American Sheep Industry strive to raise a uniform product of lean, muscular lambs for the supply chain. Reinforcement of carcass benchmarks may result in positive changes of trimmer and heavier muscled lambs. These changes along with opportunistic marketing approaches, should help the sheep industry succeed in the United States. Across large contemporary groups the indicated progression provides opportunities toward a future of carcass yield objectifiable characteristics, especially considering the industry push for value-based marketing.

As information continues to be gathered and released, the strive to provide accurate data and results from carcass traits will only solidify the progression of what the industry is currently doing correctly. Improvements in future flock production and marketing advancements should result in improve quality and consistency of American Lamb.

Table 1. 2018/2019 Northern plains region lamb carcass benchmarks.

	LSMeans	Standard Deviation	Minimum	Maximum
12th rib backfat* (in)	0.27	0.03	0.20	0.35
Body wall thickness (in)	1.02	0.14	0.76	1.60
Ribeye area (in^2)	2.58	0.16	2.27	2.88
Hot carcass weight (lbs)	69.73	3.74	61.14	79.38
% BCTRC	45.57	0.73	43.24	47.29

Least square means pulled from 1180 lambs harvested from 58 different producer lots.
*USDA YG 1 = BF 0.06 - 0.15; YG 2 = BF 0.16 – 0.25; YG 3 = BF 0.26 – 0.35; YG 4 = BF 0.36 – 0.45; YG 5 = BF 0.46 – 0.55

Table 2. Mean averages for 2016/2017, 2018 and 2019 followed by 2018/2019 lamb carcass benchmarks.

	2016/2017[1]	2018[2]	2019[3]	2018/2019[4]
12th rib backfat* (in)	0.32	0.27	0.26	0.27
Body wall thickness (in)	0.86	1.07	0.76	1.02
Ribeye area (in^2)	2.36	2.60	2.27	2.58
Hot carcass weight (lbs)	69.84	70.91	61.14	69.73
% BCTRC	45.33	45.35	45.76	45.57

1Statistics display the mean carcass values recorded for 2016/17 data taken from (Held et al., 2016) for 365 lambs harvested from 19 South Dakota producers.
[2]Least square means from 558 lambs harvested from 27 different producer lots.
[3]Least square means from 622 lambs harvested from 31 different producer lots.
4Least square means aggregated from 1180 lambs harvested from 58 different producer lots.
*USDA YG 1 = BF 0.06 - 0.15; YG 2 = BF 0.16 – 0.25; YG 3 = BF 0.26 – 0.35; YG 4 = BF 0.36 – 0.45; YG 5 = BF 0.46 – 0.55

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Exploring lamb sausage marketability in North Dakota

Matthew Chaney[1], Anuradha Vegi[2], Kasey Maddock-Carlin[1], and Travis Hoffman[1]

The objective of this study was to explore whether lamb sausage could be accepted by consumers with enhancement from unique and flavorful ingredients. We tested whether consumers were accepting of distinct flavor profiles and would be inclined to purchase uniquely seasoned lamb sausage based on each recipe's flavor. We found a minimum of 88% of consumers sampled would be inclined to purchase lamb sausage and that each recipe averaged from a "moderate" to a "like very much" score for overall liking.

Summary

Ground lamb is an underutilized and undervalued product of a lamb carcass. The objective of this study was to use lamb trim in the form of a ground lamb sausage mixed with distinct seasonings and culturally specific spice profiles to assess consumer appeal to target new markets. We introduced a series of 6 unique lamb sausage flavor profiles (Greek, Italian, Moroccan, Sicilian, Irish-style banger, and Mexican Chorizo). In experiment 1, consumers (n = 186) evaluated flavor intensity, amount of flavor, and overall liking, and ranked each based on preference. The response to lamb sausage flavors were rated high using LSMEANS results. Lamb sausage flavors were then ranked, and the order was Greek, Italian, Sicilian, and Moroccan. In the preference ranking test (n=41) in experiment 2, the highest-ranked Greek profile was compared with two new flavors, Irish-style banger and Mexican Chorizo, and results indicated that the ranking was Irish-style banger followed by Greek, and then Mexican Chorizo lamb sausage.

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Introduction

Beyond COVID-19, the current market share of small lamb producers and processors has expanded with new sales of lamb as consumers are increasing lamb consumption (Sartin, 2021). As COVID-19 progressed, North Dakota sheep producers and processors remained diligent to fill the supply chain inefficiencies at retail cases while improving the transparency from producer to consumer. Consequently, to fill the void and/or capitalize on the request for local meat, farmer's markets and producers across the state were providing consumers with either whole lamb carcasses or individual cuts. As a result, the vast majority of producers, processors, and consumers are currently missing out on value-added options for lamb trim produced from fabrication of the carcass. Ground lamb can be made and merchandised, but there are limited options to create unique lamb sausage flavors to increase marketing options. Despite the potential for increasing market share of processed lamb, current available recipes are not easily sourced, creating a lapse in value-added lamb products.

The increased shift of locally and regionally produced food to the marketplace (Pretty, 2020) has resulted in producers and retail chains having to adapt to the perceptions and attitudes from a changing consumer group. For consumers to willingly purchase and consume a product, their perceptions of the product must be positive. This is reinforced by the findings of Pethick et al. (2010), who described the importance of consumer awareness to consistently deliver meat that will satisfy consumer demands for quality and eating experience. By improving the appearance and sensory properties and marketing strengths of lamb, improvements to the current marketplace demand can be achieved.

Procedures

Lamb trim purchased from the NDSU meat lab was mixed and weighed into seven 30-pound batches (Figure 1). Ingredients were measured and mixed by hand and allowed to meld together for 24 hours. Upon refrigeration, the mixed batches were

Figure 1. Scan for Lamb Sausage Recipe Cards which were provided at the conclusion of each consumer sensory panel.

stuffed using a fresh collagen casing and forming links of approximately 6 inches. Sausages were then vacuum packaged and frozen for three weeks until used for taste panel evaluation.

Flavor and preference ranking data were collected from taste panels at the Red River Valley Fair in Fargo, North Dakota, as well as a second taste panel at a sheep producer educational event in Carrington, North Dakota. Panelists scored each lamb sausage for flavor intensity, amount of flavor, and overall flavor liking. Panelists were also asked to indicate "yes" or "no" to if they would purchase the product based on product flavor. The GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) was used to assess consumer acceptance for each questionnaire response. The MEANS procedure was used to generate mean averages for each treatment along with the ANOVA procedure to determine flavor differences.

Results and Discussion

In catering to many consumer taste palates within North Dakota, we aimed to take advantage of the uniqueness of flavor styles in the creation of the value-added lamb sausage tested in this experiment. Consumer acceptance on the flavor intensity, amount of flavor, and overall liking showed significant differences between each treatment sausage type for each variable along with means for flavor and overall liking. The overall difference in flavor intensity was different for each sausage type (Table 1). Moroccan had the highest flavor intensity at 51.30. The Italian lamb sausage was second. The Sicilian lamb sausage ranked third with a moderate to strong presence of flavor intensity and lastly, consumers found the Greek lamb to have the least flavor. There were also significant differences for the amount of flavor between each recipe. (P = 0.05). Moroccan-style sausage had the highest amount of flavor value with the Italian lamb sausage ranked second with a slightly above the median scale descriptor of just-about-right. The Sicilian lamb sausage ranked third, and ranking with the least amount of flavor was the Greek lamb sausage. However, for overall flavor liking, the Greek and Italian recipes was liked more than the Sicilian and Moroccan.

These differences also coincided with preference. Within the preference ranking tests, the Sicilian and Moroccan were less preferred than the Italian and Greek lamb sausage (Table 2). The most popular lamb sausage at the Red River Valley Fair was Greek and therefore was utilized in the proceeding experiment. In experiment 2, the preference ranking test of Greek and Mexican Chorizo were similarly less preferred than the Irish-style lamb banger (Table 3). Another key takeaway is that the amount of flavor and overall flavor liking were influenced by the stronger flavors of the Moroccan lamb sausage, which

Table 2. Preference ranking analysis using a One-way ANOVA (n=179/treatment) of four lamb sausage recipes (Greek, Italian, Sicilian, and Moroccan).

Treatment	MEANS[2]	P-value	TUKEY'S HSD
Greek and Italian	2.26	0.76	0.0335[b]
Greek and Moroccan	2.47	0.0002	0.4693[a]
Greek and Sicilian	2.51	<0.0001	0.5363[a]
Italian and Moroccan	2.49	0.0002	0.4358[a]
Italian and Sicilian	2.53	<0.0001	0.5028[a]
Moroccan and Sicilian	2.74	0.58	0.0670[b]

Lamb sausages were prepared and tested at the Red River Valley Fair, Fargo, North Dakota.
*Treatment represents; lamb sausage recipes (Greek, Italian, Moroccan, and Sicilian).
[1]Values within the same Tukey's Honest Significant Difference (HSD) row without a common superscript differ at (P< 0.05).
[2]Means were calculated based on preference ranking score indicated by a 1 = First; 2 = Second; 3 = Third; and 4 = Fourth preferred lamb sausage.

Table 1. Least square means from a consumer taste panel using line affective magnitude (LAM) scaling and Just-About-Right (JAR) tests on consumer panelists (n = 186/treatment) at random.

	Flavor Intensity			Amount of Flavor			Overall Flavor Liking		
Treatment	MEANS	SEM	P-value	MEANS	SEM	P-value	MEANS	SEM	P-value
Greek	24.45[d]	1.25	<0.0001	46.29[c]	1.06	<0.0001	80.47[a]	1.42	<0.0001
Italian	39.27[b]	1.25	<0.0001	53.67[d]	1.06	<0.0001	79.24[a]	1.42	<0.0001
Moroccan	51.30[a]	1.25	<0.0001	59.95[a]	1.06	<0.0001	74.22[b]	1.42	<0.0001
Sicilian	29.74[c]	1.25	<0.0001	49.58[b]	1.06	<0.0001	75.79[b]	1.42	<0.0001

Analysis was performed on consumer panelists liking of amount of flavor, flavor intensity, and overall liking from four lamb sausage recipes (Greek, Italian, Moroccan, and Sicilian) prepared and tested at the Red River Valley Fair in Fargo, North Dakota.
[1]Least squares means (MEANS) within the same column without a common superscript differ (P< 0.05).
[2]MEANS reflect panelists answers recorded in millimeters (mm).
[3]SEM (largest) of the least squares means.

may have resulted in the least overall liking and could cause consumers to be less willing to purchase. Alternatively, the more balanced, neutral, and calmer spice profile of the Greek lamb sausage is perhaps why the recipe was the most preferred in overall liking, reinforcing consumer palate differences. The results for the final consumer response of 'Would you purchase?' question from experiment 1 can be found in Figure 2 with Italian ranking first followed by Greek and then Sicilian and lastly, Moroccan.

The use of consumer taste panels to develop distinct and unique flavor profiles showed many consumers are eager to welcome new products. In these experiments, we tested consumer acceptance and likeability of lamb sausage, and through the utilization of popular flavor profiles from around the globe, were able to determine if a value-added marketing approach for local producers and processors was feasible. Similar to the findings above, the opportunities to spark consumer interest and increase financial gain for sheep producers may be achieved as the general public does seem to like distinct and culturally diverse lamb sausage flavors.

Table 3. Preference ranking analysis using a One-way ANOVA (*n*=41/treatment) of three lamb sausage recipes (Greek, Irish-style banger, and Mexican Chorizo).

Treatment	MEANS[2]	*P*-value	TUKEY'S HSD
Greek and Irish	1.87	0.01	0.4634[a]
Greek and Mexican chorizo	2.18	0.34	0.1707[b]
Irish and Mexican chorizo	1.95	<0.001	0.6341[a]

Lamb sausages were prepared and tested at the North Dakota sheep producer meeting in Carrington, North Dakota.
*Treatment represents; lamb sausage recipes (Greek, Irish-style banger, and Mexican Chorizo).
1Values within the same Tukey's Honest Significant Difference (HSD) row without a common superscript differ at (P< 0.05).
[2]Means were calculated based on preference ranking score indicated by a 1 = First; 2 = Second; and 3 = Third preferred lamb sausage.

Figure 2. Consumer (n=176) panelist response to 'Would you purchase?' question asked proceeding sampling each lamb sausage sample.

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The influence of carcass weight and external fat thickness on chilling rate of commercial beef carcasses

Kiersten Gundersen[1], Michaella Fevold[2], Robert Maddock[1], Zachary Carlson[1], and Kasey Maddock Carlin[1]

The study evaluated beef carcass weight classes (thin, medium, and heavy) and 12th rib external fat depth classes (thin, average, fat) on the rate of temperature decline of the deep portion of the beef round during the initial 24 hours of carcass chilling and subsequent impacts on tenderness and water holding capacity. Carcass weight had the biggest influence on the rate of temperature decline where fat depth measured at the 12th rib only impacted temperature decline during early chilling. Meat quality differences were limited to water holding ability. The slower temperature decline in higher weight carcasses with more fat allowed for decreased purge loss in the sirloin, thus preventing yield loss during storage.

Summary

The objectives of this study were to; 1) evaluate carcass weight and external fat depth on the rate of temperature decline of the round on commercial beef carcasses and 2) analyze the impact of carcass weight and external fat depth on meat tenderness and water-holding capacity. Commercial beef carcasses (n = 60) were selected based upon carcass weight (light = less than 800 lbs.; medium = between 801 lbs. and 900 lbs.; and heavy = over 901 lbs.) and 12th rib external fat depth (thin = less than 0.4 in.; average = 0.5 in. and 0.69 in.; and fat = over 0.7 in.). The results indicated that heavy and fat carcasses took longer to cool than other classed carcasses. Fat depth also influenced ($P = 0.05$) the pH values after 24 hours of chilling. There was a carcass weight × external fat depth interaction for cook loss ($P = 0.007$) on top round steaks where medium-average carcasses and medium-fat weight carcasses had more cooking loss percentage than other classed carcasses. There was also a carcass weight × fat depth interaction for purge loss ($P = 0.01$) in sirloin where medium-fat weight carcasses and heavy-average carcasses, and heavy-fat carcasses had the least amount of purge.

Introduction

In the U.S., over the past several decades, carcass weights have increased by at least 90 pounds (Maples et al., 2018) and fat thickness measured at the 12th rib has increased by 0.20 in. These changes have initiated questions on the influence of weight and fat depth on the rate of carcass chilling, meat quality, and the consistency of beef products.

Research has established that trim and light weight carcasses can be susceptible to cold shortening which happens when muscles are cooled too quickly before rigor mortis (Davey and Gilbert, 1974) causing a contraction or shortening of muscle fibers and subsequent reduction in tenderness. Conversely, an increased fat thickness has been indicated in insulating muscles from cooling, which can also result in decreased tenderness due to loss of protein functionality (Aalhus et., 2001) which lessens the ability of beef to age.

Limited data is available on how carcass weight and fat thickness influences the rate of chilling and meat quality characteristics of beef products. Therefore, the objectives of this study were to evaluate if carcass weight and fat depth impacted temperature decline in the beef round and to determine subsequent impacts on tenderness and water-holding capacity.

Experimental Procedures

At a large, commercial midwestern packing plant, beef carcasses (n = 60) were selected prior to entering the cooler after harvest based upon a 3 × 3 factorial scheme with three levels of carcass weight (thin, medium, and heavy) and three levels of 12th rib external fat depth (thin, average, and fat).

Carcasses were probed with a temperature logger (ThermoWorks THS-294-933, ThermoWorks, American Fork, UT) into the cushion of the round. The probe was angled towards the deep portion of the round and temperature points were recorded every 15 minutes for 24 hours while carcasses were in the chill cooler prior to grading and fabrication.

24 to 36 hours after cooling, carcasses were ribbed, and data was collected by USDA personnel. The data

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consisted of hot carcass weight (HCW), 12th ribeye area, kidney, pelvic, and heart fat (KPH). Loin pH was measured by NDSU personnel between the 12th and 13th rib before entrance to the carcass cooler, and after 24 hours of chilling.

After grading, carcasses were fabricated into primal cuts. Beef top rounds (Institutional Meat Purchase Specification {IMPS} 169) and top sirloin butts (IMPS 184) were vacuum packaged and transported back to North Dakota State University's Meats Laboratory. The primal cuts were stored at approximately 35°F for 14 days (sirloins) and 21 days (rounds). Primal cuts were weighed with and without packaging, using the weight differences to calculate the percentage of purge. Each primal cut was measured for external fat depth and fabricated into 1-inch-thick steaks (IMPS 1169 and 1184) for cook loss and Warner-Bratzler shear force analysis.

Steaks were equilibrated to room temperature (68°F) prior to cooking and raw weight was collected. Steaks were cooked on an electric clam-shell grill (Cuisinart Electric Griddler GR5BP1, Cuisinart, Stamford, CT) preheated to 350°F to an internal temperature of 145°F. The internal temperature of the steaks was monitored with a thermocouple probe (Omega KHSS-18G-RSC-12, Omega Engineering, Inc., Norwalk, CT) placed in the center of each steak connected to a handheld thermometer (Omega HH801B, Omega Engineering, Inc., Norwalk, CT). Steaks were removed from the grill and allowed to cool for a minimum of 5 minutes. After the initial cooling period, cooked steaks were weighed and cooking loss percentage calculated. Warner-Bratzler shear force was conducted from a minimum of six cores (0.5 in. diameter) were removed from the center of each steak parallel with the muscle fibers. Each core was placed in the middle of a V-notched (60-degree-angle) cutting blade. All cores were perpendicularly sheared to the muscle fibers at the shear force machine (Tallgrass Solutions GF-151, Tallgrass Solutions, Inc., Manhattan, KS).

Statistical Analysis

Data collected were analyzed using the PROC MIXED procedures of SAS (SAS 9.4, SAS Institute Inc., Cary, NC) with the main effects of carcass weight and 12th rib external fat depth, and their interaction with carcass as the experimental unit. Least square means was separated using the PDIFF option in SAS 9.4. Significance levels were set at $P \leq 0.05$.

Results and Discussion

The rate of temperature decline was affected by carcass weight ($P < 0.05$; Figure 1a) where in the second hour of chilling, the heavy carcasses were cooling at a slower rate than the light carcass weights, and by the ninth hour, the heavy carcasses were chilling more slowly than the medium weight carcasses. These temperature differences were still apparent for the heavy carcass weights when the probes were removed at 24 hours. It is important to note that the inside rounds were not fully cooled at 24 hours and temperature was still decreasing. There was a tendency ($P < 0.10$; Figure 1b) for fat carcasses to have a higher temperature than thin carcasses between the second and seventh hour in the cooler but that tendency was not sustained beyond those times, which may be due to the lower number of thin carcasses in the analysis.

There were differences in KPH% for carcass weight and fat depth ($P < 0.001$; Table 1) which were expected outcomes due to selection criteria and the connection between weight, muscling, and fat. The interaction of carcass weight and 12th rib fat depth for REA was further investigated in Figure 2a. Light-thin and medium-thin carcasses had the smallest REA. As carcasses became heavier and developed more fat, the REA became larger. These results were expected due to the relationship with the development of weight, muscling, and fat. Loin pH was lower in the thin carcasses versus the average and fat after 24 hours ($P = 0.04$). The location of pH measurements was similar to the location of fat depth measurement, which allow a direct connection between fat depth and pH. The pH was not evaluated in the same muscle as temperature, making a connection between temperature and pH more difficult. However, Fevold et al. (2021) showed that the loin did cool more quickly than the top round, and light carcasses were colder than heavy carcasses at four hours into chilling.

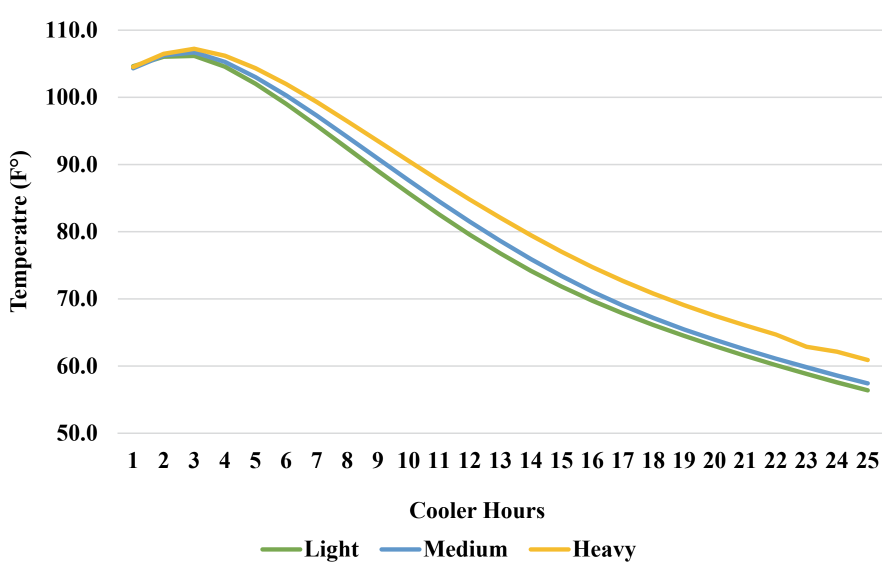

Figure 1a. Influence of carcass weight class on the rate of temperature decline.

Weight classes represents; Light = less than 800 lbs., Medium = 801 lbs. to 901 lbs., and Heavy = over 901 lbs.

McKenna et al. (2005) reported that the gluteus muscle and the semimembranosus muscle had similar pH values, which were lower than the pH in the longissimus.

Purge loss, cook loss, and shear force outcomes for top rounds and top sirloin butts are found in Table 1 and Figures 2b and 2c. For top rounds, carcass weight and 12th rib fat depth influenced cook loss ($P < 0.01$) where medium-average and heavy-fat carcasses had more cook loss than light-average. Top sirloin butts showed significant differences for purge loss ($P = 0.01$) based upon the interaction of carcass weight × fat depth, where medium-fat carcasses, heavy-average carcasses, and heavy-fat carcasses had the least amount of purge. Based on these results, fat depth plays an important role in water-holding ability within the sirloin. In the sirloin, the

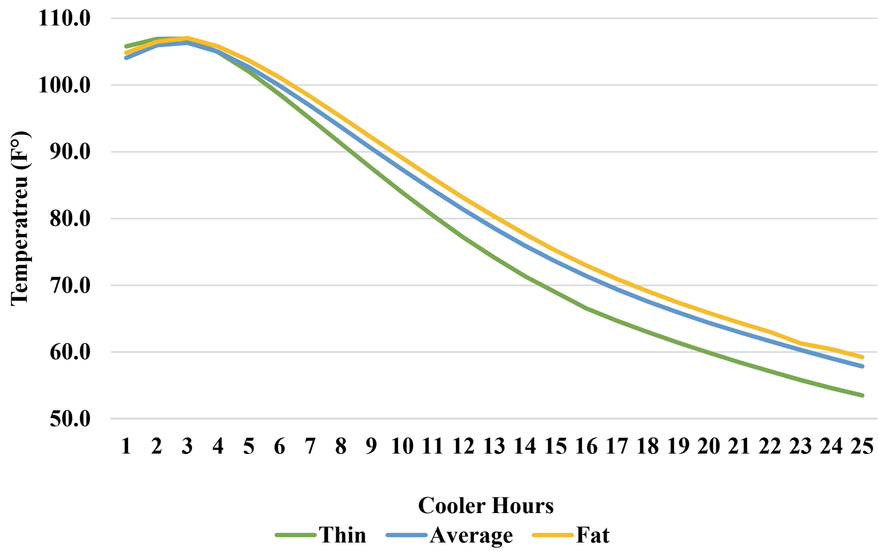

Figure 1b. Influence of 12th rib fat depth class on the rate of temperature decline.

Fat depth classes represents; Thin = less than 0.4 in., Average = 0.5 in. to 0.69 in., and Fat = over 0.7 in.

Table 1. Influence of carcass weight class, fat depth class, and weight class × 12th rib fat depth class interaction on carcass and meat quality

	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Carcasses (n)	21	15	24		6	20	25				
HWC (lbs.)	758[c]	851[b]	991[a]	9.4	779	864	891	39.5	<0.001	0.708	0.625
12th Rib BF	0.57	0.67	0.70	0.03	0.45[c]	0.60[b]	0.88[a]	0.03	0.11	0.002	0.378
REA (in.^{2})	12.83[c]	13.97[b]	15.03[a]	0.27	13.15	14.13	13.93	0.36	<0.001	0.464	0.027
KPH (%)	2.14[a]	2.13[a]	1.83[b]	0.05	1.54[b]	1.91[ab]	2.10[a]	0.09	<0.001	<0.001	0.314
pH Before Cooling	6.68	6.74	6.73	0.05	6.78	6.76	6.67	0.07	0.653	0.293	0.808
pH After 24 hours	5.83	5.77	5.79	0.05	5.68[b]	5.87[a]	5.74[a]	0.07	0.950	0.038	0.535
Top Rounds	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Rounds (n)	18	14	21		5	22	26				
Purge (%)	1.63	1.66	1.58	0.17	2.04	1.41	1.77	0.21	0.750	0.115	0.321
CL (%)	24.20	28.24	27.90	1.26	27.10	26.03	27.47	1.79	0.735	0.978	0.007
WBSF (kg)	2.46	2.50	2.43	0.09	2.27	2.47	2.47	0.13	0.574	0.548	0.062
Sirloins	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Sirloins (n)	18	14	21		5	22	26				
Purge (%)	1.01[a]	0.82[b]	0.82[b]	0.09	0.96	0.94	0.83	0.13	0.049	0.302	0.012
CL (%)	18.79	19.06	18.24	1.52	19.59	18.40	18.82	2.93	0.950	0.945	0.917
WBSF (kg)	2.34	2.54	2.16	0.18	1.29	2.40	2.29	0.34	0.305	0.321	0.840

Means with different subscripts with a category within each row are significantly different ($P \leq 0.05$)
Carcass abbreviations; HWC = hot carcass weight, BF = backfat, REA = ribeye area, KPH = kidney, pelvic, and heart fat, CL = cook loss, and WBSF = Warner-Bratzler shear force.

combination of fat and weight appear to have different impacts depending on class as the medium weight carcasses had the least purge when fattest and the heavy weight carcasses had the least purge with average fat cover, indicating a moderate temperature decline is more ideal than either extreme. Heavier carcasses with more fat have a slower rate of temperature decline than lighter thinner carcasses. These differences appear to influence water-holding ability of cuts from the round and sirloin. Based on these outcomes, further comparisons should be completed on carcass weight and fat depth on other economically important cuts. This preliminary data indicate that carcass weights and fat depths do influence meat quality outcomes due to temperature decline differences. It may be possible to mitigate these temperature differences by making changes during the carcass chilling process through carcass sorting and cooler modifications.

Acknowledgments

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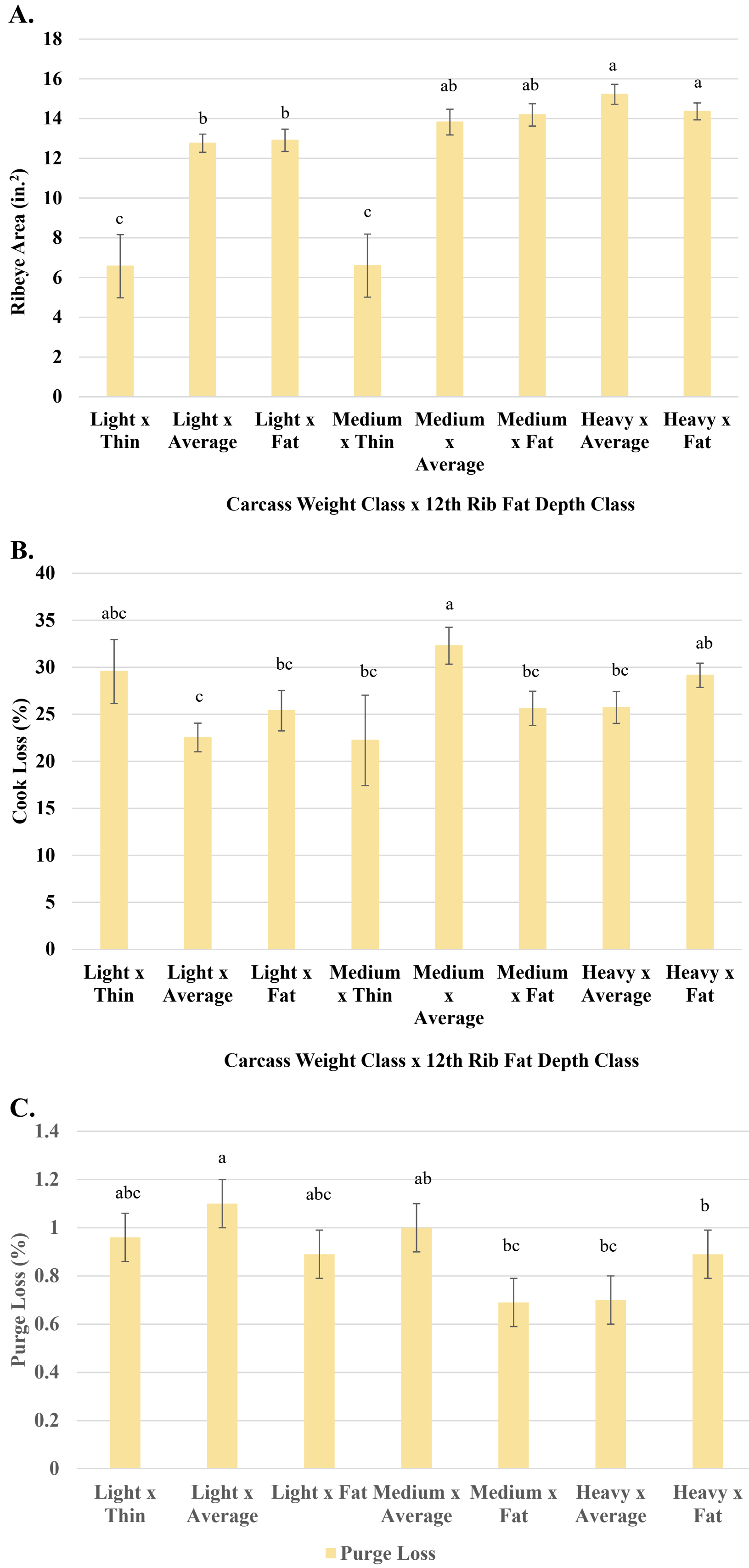

Figure 2. Interactive means ($P < 0.05$) of carcass weight x 12th rib fat depth on carcass ribeye area (A), round steak cook loss % (B), and sirloin purge loss % (C).

Means with different subscripts are significantly different ($P \leq 0.05$). Weight classes represents; Light = less than 800 lbs., Medium = 801 lbs. to 901 lbs., and Heavy = over 901 lbs. Fat depth classes represents; Thin = less than 0.4 in., Average = 0.5 in. to 0.69 in., and Fat = over 0.7 in.

Local meats Extension outreach in North Dakota

Travis W. Hoffman, Isaac D. Brunkow, Carl R. Dahlen, and Adam A. Marx

The public wants to know "where their food comes from." As NDSU Extension, we have the opportunity and responsibility to assist with regulatory interpretation, tell the production story, and improve communication and expectations of consumers regarding the meat we produce in North Dakota livestock operations. NDSU Extension personnel and efforts reached producer to consumer audiences and provided interactive webinars and timely, relevant resources across the livestock/meat supply chain.

Summary

Consumer interest in local meats has been increasing with emphasis on farmers markets, direct marketing, and the desire of consumers to have a better understanding of their family's protein choices. This has resulted in NDSU developing an Extension program to provide resources and guidance to producers wishing to pursue locally-driven marketing systems. Outreach focus has included online webinar series, in-person lectures/seminars, publications, and conference presentations to provide information, determine appropriate current and future approaches, and develop tools that match clientele requests.

Introduction

There often is a disconnect between producers and consumers. However, it is apparent, particularly during and post-pandemic, that we have an increased need to connect our producers with resources on how to provide safe and high-quality meat from the purchase of an animal for consumption. Additionally, there is an increase in North Dakota meat processing plants, resulting in a need for improved outreach and resources for our livestock producers to succeed with merchandising local foods. The North Dakota Department of Agriculture has led efforts to build farmers market acceptance and increase consumer and producer awareness of the benefits of fresh, locally grown products. Outreach accomplished by NDSU Extension by Travis Hoffman and Isaac Brunkow continued dialogue for producer/consumer education that spans the livestock supply chain.

Procedures

In order to develop appropriate vision for Extension programming, a needs assessment survey was distributed via several producer organizations in North Dakota and Minnesota and through NDSU affiliated social media accounts. The goal of the survey was to collect data on topics, questions, and concerns producers have over marketing locally produced meat. The research participants (n = 12) identified primary emphasis topics: 1) navigation of regulations; 2) marketing strategies; 3) how to get started; and 4) potential profitability of direct marketing systems.

In 2022 and 2023, Local Meats Webinar Series were conducted online via Zoom involving a wide variety of panelists. The topics and panelists were organized and coordinated by Hoffman and Lindy Berg. The 2022 panelists covered topics including Getting Livestock Ready for Harvest, Retail Meats and Inventory Management, Meat and Poultry in Farmer's Markets and Farm to School, Poultry Meat and Egg Production, and Building Your Consumer Relationships for Success (Table 1). These garnered a live audience ranging from 10 to 28 with a total of 95 attendees over the duration, and a total of 881 views as of August 1, 2023 from our NDSU Extension's YouTube page. A summary of the topics and panelists are provided below.

Getting Livestock Ready for Harvest –May 3, 2022 (27 attendees; 389 YouTube views)

Summary: Initial discussion was striving for appropriately finished animals to direct market livestock. Meeting consumer expectations can be species specific for market weight and timing. Underfeeding can lead to detrimental quality, while over-finished animals result in decreased yield and lamb quality challenges. Too light or too much market weight and finish can be extremely detrimental to the end product. The panelists also stressed that finishing and time to finish is breed and purpose dependent and that each operation needs to cater to its best timetable for their production goals.

Meat and Poultry in Farmers Markets and Farm to School – May 10, 2022 (16 attendees; 107 YouTube views)

Summary: Local foods are a great alternative to heavily processed

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and packaged foods, and schools have implemented local fruits and vegetables into their menus. Opportunity exists for livestock producers to build demand for their meat and poultry products through schools and farmers markets. The panelists detailed experiences facilitating their product through the supply chain to local farmers markets and school lunch programs.

Retail Meats and Inventory Management – May 17, 2022 (14 attendees; 140 YouTube views)

Summary: With many modern supermarkets running short of items, it can seem like a hassle and a huge struggle to manage a stocked inventory when first starting out direct marketing meat. With the advent of some services, technology, and organizational strategies, many of the headaches can be prevented or alleviated. Our panelists analyzed strategies and technologies that they utilize to keep themselves organized and how to best keep their customers stocked with locally grown meat.

Building Your Consumer Relationships for Success – May 24, 2022 (28 attendees; 102 YouTube views)

Summary: With the increased adoption of social media, it is more important than ever that animal agriculture create a trusting relationship with consumers and the public. Face-to-face interactions are still important, especially if direct marketing products off your operation. The panelists discussed how they cultivate producer-customer relationships that not only benefit their operations but help to educate consumers about the positive aspects associated with animal agriculture.

Poultry Meat and Egg Production – May 31, 2022 (10 attendees; 143 YouTube views)

Summary: One of the easiest and most efficient livestock species to start with is poultry production. Poultry can be housed in a much smaller environment when compared to cattle, sheep, goats, and swine. Food safety, environmental impact, and overall health and welfare are the principal areas of concern when it comes to any livestock species but is especially emphasized

Table 1. NDSU Extension 2022-2023 Local Meats Webinar Series; titles, dates and presenters.

2022 Local Meats Webinar Series, led by Travis Hoffman and Lindy Berg		
Getting Livestock Ready for Harvest	May 3, 2022	Lisa Pederson, NDSU Extension CJ and Calli Thorne, Triangle M Ranch and Feedlot Daryl Lies, 6 in 1 Meats
Meat and Poultry in Farmer's Markets and Farm to School	May 10, 2022	Jan Stankiewicz, NDSU Extension Kristine Kostuck, North Dakota Department of Agriculture Deb Egeland, North Dakota Department of Public Instruction
Retail Meats and Inventory Management	May 17, 2022	Ron and Beth Wolff, Wolff Suffolks Joana Friesz, Friesz Livestock Isaac Brunkow, Brunkow Family Lamb Spencer Wirt, 6 in 1 Meats
Building Your Consumer Relationships for Success	May 24, 2022	Annie Carlson, Morning Joy Farm Isaac Brunkow. Brunkow Family Lamb
Poultry Meat and Egg Production	May 31, 2022	Penny Nester, NDSU Extension Wayne Martin, UMN Extension Julie Garden-Robinson, NDSU Extension Adam and Apryl Mawby, Garden Dwellers Ranch
2023 Local Meats Webinar Series, led by Isaac Brunkow and Travis Hoffman		
Regulations	May 2, 2023	Nathan Kroh, North Dakota Department of Agriculture Rhonda Amundson, North Dakota Department of Public Instruction
Building a Contractual Relationship with a Locker	May 9, 2023	Ron and Beth Wolff, Wolff Suffolks Trish Feiring, Feiring Cattle Company Spencer Wirt, general manager, 6 in 1 Meats
Finding Your Niche Market/ Starting a Farmer's Market	May 16, 2023	Simone Wai, Red River Farmers Market Ron and Beth Wolff, Wolff Suffolks Kelsey Krapp, The Bison Ranch Ashley Bruner, Dakota Angus Beef
Inventory Management	May 23, 2023	James Maiocco, Barn2Door Glenn Brunkow, Brunkow Family Lamb Shane Wendel, Wendel Livestock

with poultry production. Our experts provided information on the regulations, resources, and experiences they had with poultry meat and egg production.

Our NDSU Extension webinar series resulted in a wide variety of discussion occurring with several thought-provoking questions directed from the online audience that were answered in real time by the panelists. A deliverable was a solid reference for livestock producers, and development of a network of people with common goals to adhere to regulations and build consumer satisfaction with locally-produced proteins.

In 2023, another series of webinars was conducted building off the 2022 inaugural outreach. Topics evolved from the previous year with new panelists offering fresh insight or covering new topics that had potential benefit for North Dakota producers. Discussion was advantageous for producers looking to expand their operations to include a local meat marketing strategy. The topics and panelists were organized and coordinated by Brunkow under the direction of Hoffman (Table 1).

Regulations – May 2, 2023
(74 YouTube views)

Summary: The first of this year's webinar series started off delving into the regulatory stipulations to adhere to for selling locally produced meat. This is a necessity to ensure health and safety regulations are followed. The panelists provided insight into the various levels of inspection, differences in poultry, and how to get involved with providing locally produced meat to schools.

Building a Contractual Relationship with a Locker – May 9, 2023
(49 YouTube views)

Summary: It is paramount to have a working relationship with your processor when setting up a local meats marketing operation. The panelists discussed struggles and techniques they have developed when working with processors, how to navigate management change, and provided insight from a processor's viewpoint.

Finding Your Niche Market/Starting a Farmers Market – May 16, 2023
(27 YouTube views)

Summary: Standing out from the crowd can be the difference between success and failure. In addition, having a market to sell through can create new opportunities to advertise and merchandise product. The panelists explained what makes their operations successful, their experiences with farmers markets, and what goes into managing a large farmers market like the Red River Farmers Market in Fargo, North Dakota.

Inventory Management – May 23, 2023 (59 YouTube views)

Summary: Managing meat product inventory can be a challenge, and if done improperly can be detrimental to customer relationships and unsafe to public health. Our panelists discussed strategies they have utilized, management software and technologies they have used, and the importance of being able to branch out their product lines for retail and foodservice.

The 2023 webinar series included perspectives from parties not directly involved with processing or producing livestock, such as those involved in organizing marketplaces (i.e., Red River Farmers Market and Barn2Door online marketplace). While numbers were over 50 attendees for online presentations, 209 views on YouTube have been documented as of August, 2023.

Educational outreach in North Dakota increased through efforts conducted with our local meats research and Extension program at NDSU. A post-webinar summary was conducted to evaluate "overall usefulness of the 2022 Local Meat Production — Farm to Market Webinar Series to your work" in September 2022. A mean rating of 4.02 out of 5 (n = 59) was aggregated corresponding to webinar participants considered the webinars Very Useful. Directly following webinars, attendees were asked to respond with their agreement to "I learned information on Local Meats from today's webinar," with a mean of 4.0 (agree) out of 5 (n = 32); and "I will make changes to my operation based on information learned from today's webinar," with a 3.5 out of 5 (n = 32) response indicating a response between neutral and agree. The four-month post-survey respondents were asked, "since attending the 2022 Local Meat Production - Farm to Market Webinar Series, have you made any changes to your operation or marketing based upon information you obtained from the topics presented during the workshop?" A total of 59% (n = 44) responded that they have made changes in marketing or to their operation, showing transformational change through the implementation of new ideas.

With addition to the aforementioned two successful series of online seminars, further accomplishments include the creation of a beef carcass model curriculum and factsheets benefiting producers, processors, and consumers in North Dakota. Brunkow attended conferences and provided presentations to augment dissemination of information representing NDSU Extension. Future NDSU sponsored workshops to provide continuing education to our food supply chain may focus on producer marketing strategies, economic viability of direct marketing, retail and foodservice cuts for livestock species, consumer focused preparation, and meat quality education. Further future deliverables include a custom-exempt focused beef carcass pricing model and research on lamb feeding economics to benefit marketing and operation finances. The NDSU Extension YouTube channel and NDSU Extension Livestock Facebook page include more information about Local Meats Outreach.

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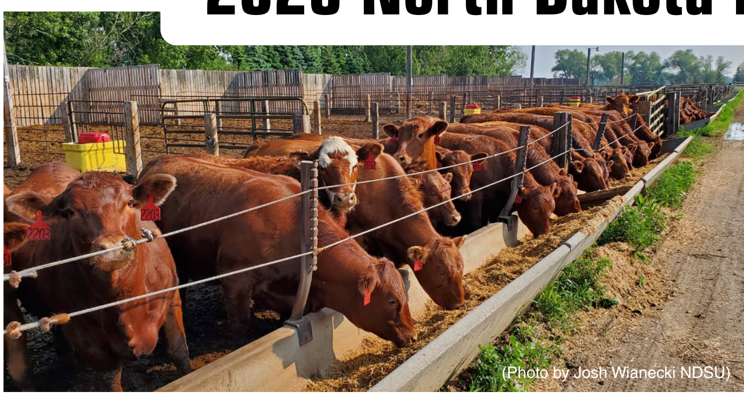
(Photo by Karl Hoppe, NDSU)

2023 North Dakota Livestock Research Report



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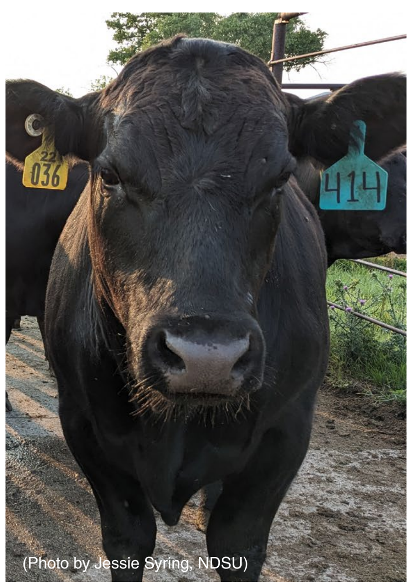

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