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 4° for 20 minutes, aliquoted into 2-mL plastic microtubes, and stored at -20° 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

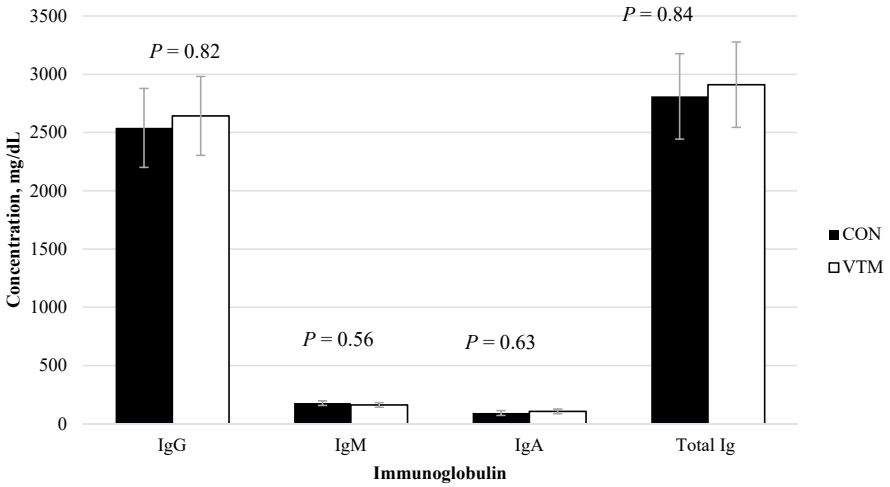

Figure 1. Concentrations of immunoglobulin (Ig) G, M and A in neonatal calf serum 24 h after consumption of dam's colostrum (Experiment 1) and total serum Ig concentrations in female calves born to beef heifers assigned to receive a basal diet (CON) or a basal diet with the addition of a vitamin/mineral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

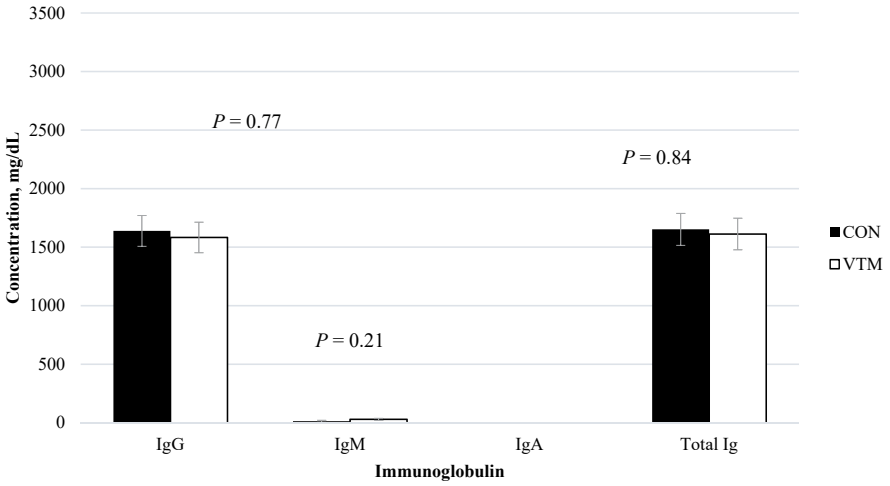

Figure 2. Concentrations of immunoglobulin (Ig) G, M and A in neonatal calf serum 24 h after consumption of colostrum replacement product (Experiment 2) and total serum Ig concentrations in female calves born to beef heifers assigned to receive a basal diet (CON) or a basal diet with the addition of 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.

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.

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.

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.

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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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