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Effects of rumen-protected EFA supplementation to late-gestating beef cows on performance and physiological responses of the offspring

R. S. Marques,* R. F. Cooke,*[1] M. C. Rodrigues,*† A. P. Brandão,* K. M. Schubach,* K. D. Lippolis,* P. Moriel,‡ G. A. Perry,§ and D. W. Bohnert*

*Oregon State University - Eastern Oregon Agricultural Research Center, Burns, OR 97720; †UNESP - Faculdade de Medicina Veterinária e Zootecnia, Botucatu/SP 18168-000, Brazil; ‡University of Florida - Range Cattle Research and Education Center, Ona, FL 33865; and §South Dakota State University - Department of Animal Science, Brookings, SD 57007

ABSTRACT: This experiment compared performance and physiological responses of the offspring from cows supplemented with a rumen-protected EFA or SFA + MUFA source during late gestation. Ninety-six multiparous, non-lactating, pregnant Angus × Hereford cows were stratified by BW and BCS, and divided into 24 groups of 4 cows/group at the end of their 2nd trimester of gestation (d -7). All cows became pregnant during the same estrus-synchronization + AI protocol, with semen from a single sire. Groups were randomly assigned to receive (as-fed basis) 454 g/cow daily of soybean meal in addition to 1) 200 g/cow daily of rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids or 2) 200 g/cow daily of rumen-protected SFA + MUFA mix based on palmitic and oleic acids (CON). Groups were maintained in 2 pastures (6 groups of each treatment/pasture), and received daily 10.9 kg/cow (as-fed basis) of grass-alfalfa hay. Groups were segregated and offered treatments 3 times/week from d 0 until calving. Cow BW and BCS were recorded, and blood samples were collected on d -7 and within 12 h after calving. Calf BW was also recorded within 12 h of calving. Calves were weaned on d 280 of the experiment, preconditioned for 45 d (d 280 to 325), transferred to a growing lot on d 325, and moved to a finishing lot on d 445 where they remained until slaughter. At calving, EFA-supplemented cows had greater ($P < 0.01$) proportion (as % of total plasma fatty acids) of PUFA including linoleic, linolenic, arachidonic, docosapentaenoic, and docosahexaenoic acids. At weaning, calves from CON-supplemented cows were older ($P = 0.03$), although no treatment differences were detected ($P = 0.82$) for calf weaning BW. During both growing and finishing phases, ADG was greater ($P \leq 0.06$) in calves from EFA-supplemented cows. Upon slaughter, HCW and marbling were also greater ($P \leq 0.05$) in calves from EFA-supplemented cows. Collectively, these results suggest that supplementing EFA to late-gestating beef cows stimulated programming effects on postnatal offspring growth and carcass quality. Thus, supplementing late-gestating beef cows with a rumen-protected EFA mix appears to optimize offspring productivity in beef production systems.

Key words: beef cows, EFA, offspring, pregnancy, supplementation
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INTRODUCTION

Maternal nutrition is a major extrinsic factor programming nutrient partitioning and consequent development of fetal organ systems associated with health, production, and reproduction (Funston et al., 2010). Hence, nutritional management of late-gestating beef cows has been shown to directly impact performance of the subsequent offspring via fetal programming effects (Marques et al., 2016a). However, the majority of research conducted to date within this subject focused on energy and CP nutrition, and little is known about the potential impacts of supplementing EFA to gestating cows on offspring productivity.

In humans and livestock species, ω-3 and ω-6 fatty acids (**FA**) are considered essential by playing critical roles in several body functions but cannot be synthesized by the body; hence, EFA must be

[1]Corresponding author: reinaldo.cooke@oregonstate.edu

consumed through the diet (Hess et al., 2008). During gestation, dietary EFA become available in the circulation and are transferred to the fetus via the placenta (Garcia et al., 2014). In humans, supplementing pregnant women with EFA is considered critical for optimal fetal and early-life child development, including growth, nervous, and immune responses (Greenberg et al., 2008). Accordingly, research with swine reported that supplementing pregnant sows with EFA benefited piglet vitality, as well as pre- and post-weaning growth (Tanghe and De Smet, 2013).

Based on these research, we hypothesized that supplementing EFA to late-gestating beef cows will increase postnatal offspring productivity. Nevertheless, EFA should be supplement to cattle and other ruminant livestock as rumen-inert sources to prevent extensive ruminal biohydrogenation (Hess et al., 2008). Hence, this experiment evaluated the effects of rumen-protected EFA supplementation to beef cows during the last trimester of gestation on performance and physiological responses of the offspring.

MATERIALS AND METHODS

This experiment was conducted at the Oregon State University – Eastern Oregon Agricultural Research Center (Burns station). The animals utilized were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the Oregon State University, Institutional Animal Care and Use Committee (#4758).

Cow-calf management and dietary treatments.

Ninety-six multiparous, non-lactating, pregnant Angus × Hereford cows (BW = 586 ± 4 kg, age = 7.5 ± 0.2 yr, BCS = 5.01 ± 0.03 according to Wagner et al., 1988) were assigned to this experiment at the end of their 2nd trimester of gestation. Cows were pregnant to fixed-time AI using semen from a single Angus sire (d 195 of gestation on d 0).

Prior to the beginning of the experiment (d -7), cows were stratified by BW and BCS, and divided into 24 groups of 4 cows/group. Groups were then randomly assigned to receive (as-fed basis) 454 g of soybean meal per cow daily in addition to 1) 200 g/cow daily of rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (100 g of Prequel + 100 g of Strata; Virtus Nutrition LLC., Corcoran, CA) or 2) 200 g/cow daily of rumen-protected SFA + MUFA mix based on palmitic and oleic acids (**CON**; 200 g of EnerGII; Virtus Nutrition). Supplement treatments were iso-nitrogenous, iso-lipidic, and isocaloric (Table 1). Groups were maintained in 1 of 2 meadow foxtail pastures (12 groups/pasture, being 6 groups/treatment in each pasture) beginning on d -7. Grass-alfalfa hay was provided daily at 10.9 kg/cow (as-fed basis), and cows had ad libitum access to water and a commercial mineral + vitamin mix.

TABLE 1. Ingredient composition and nutrient profile of diets containing a rumen-protected SFA + MUFA mix (CON) based on palmitic and oleic acids, or a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids

Item	CON	EFA
Ingredients, kg/day (as-fed basis)		
Grass-alfalfa hay	10.9	10.9
Soybean meal	0.454	0.454
EnerGII [1]	0.200	-
Prequel [1]	-	0.100
Strata [1]	-	0.100
Nutrient profile [2] (DM basis)		
DM	93.5	93.5
TDN, %	61	61
NEm, Mcal/kg	1.29	1.28
CP, %	10.2	10.2
Fat, %	3.52	3.49
Palmitic acid (16:0), %	0.88	0.49
Oleic acid (18:1), %	0.91	0.61
Linoleic acid (18:2), %	0.44	0.69
Linolenic acid (18:3), %	0.92	0.97
Eicosapentaenoic acid (20:5n-3), %	0.00	0.13
Docosahexaenoic acid (22:6n-3), %	0.00	0.11

[1]Ca salts by Virtus Nutrition LLC (Corcoran, CA).

[2]Values obtained via wet chemistry analysis (Dairy One Forage Laboratory, Ithaca, NY).

From d 0 of the experiment until calving, cows were gathered 3 times weekly and groups were sorted into 1 of 12 drylot pens. Groups were offered treatments individually (6.08 kg of supplement treatment/feeding per group; as-fed basis) Diets (hay + treatments) were formulated to meet or exceed nutrient requirements for energy, protein, minerals, and vitamins of late-gestating beef cows (NRC, 2000). Immediately after calving, cow-calf pairs were removed from their pasture, and assigned to the general management of the research herd that did not include rumen-inert EFA or SFA + MUFA supplementation (Marques et al., 2016a).

Calf management

Preconditioning (d 280 to 325). Calves were weaned on d 280 of the experiment and transferred to a 6-ha meadow foxtail pasture for a 45-d preconditioning period as a single group (Marques et al., 2016b). During preconditioning, calves received mixed alfalfa-grass hay (12% CP, 57% TDN; DM basis), water,

and commercial mineral and vitamin mix for ad libitum consumption.

Growing (d 325 to 445) and finishing (d 445 until slaughter). On d 325, all calves were loaded into a commercial livestock trailer and transported for 480 km to the growing lot (Top Cut; Echo, OR), where they remained for 120 d and managed as a single group. On d 445, calves were moved to an adjacent finishing lot (Beef Northwest; Boardman, OR), where they continued to be managed as a single group until slaughter at a commercial packing facility (Tyson Fresh Meats Inc., Pasco, WA). Growing and finishing diets, which did not contain rumen-protected EFA or SFA + MUFA, were fed ad libitum as described in Marques et al. (2016b).

Sampling

Feedstuffs. Two samples of all dietary ingredients fed to late-gestating cows were collected before the beginning of the experiment and analyzed for nutrient content by a commercial laboratory (Dairy One Forage Laboratory, Ithaca, NY). Feed samples were also analyzed for FA profile.

Cows and newborn calves. Individual cow BW and BCS were recorded and a blood sample was collected prior to the beginning of the experiment (d -7). Within 12 h after calving, cow BW, cow BCS, calf birth BW and calf gender were recorded, and blood was collected from each cow.

Preconditioning. Cow BW and BCS were recorded at weaning (d 280). Calf BW was recorded and blood samples were collected on d 280, 282, 285 and 288 of the experiment. During the 45 d of preconditioning, calves were observed daily for bovine respiratory disease (**BRD**) signs and treated when signs were observed.

Growing and finishing. Calf BW was recorded upon arrival at the growing lot (d 325) and the finishing lot (d 425). Calves were observed daily for BRD signs and received medication according to the management criteria of the growing and finishing yards. At the commercial packing plant, carcass traits were collected upon slaughter.

Blood analysis

All blood samples were collected via jugular venipuncture, centrifuged at 2,500 × *g* for 30 min for plasma collection, and stored at -80°C on the same day of collection. Samples from cows (d -7 and after calving) were analyzed for FA profile (Garcia et al., 2014). Samples collected from calves from d 280 to 288 were analyzed for haptoglobin and cortisol concentrations (Marques et al., 2016b).

Statistical analysis

All cow and calf variables were analyzed with group as the experimental unit, and group(treatment × pasture), cow(group), and pasture as random variables. Quantitative data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), and binary data were analyzed using the GLIMMIX procedure of SAS (SAS Inst. Inc.). All data was analyzed using gestation days receiving treatment as an independent covariate, and Satterthwaite approximation to determine the denominator degrees of freedom for tests of fixed effects. Model statements for cow-related responses included the effects of treatment. Analysis of cow plasma FA profile at calving also included results from d -7 as independent covariate. Model statements for calf-related responses analysis included the effects of treatment, calf gender as independent covariate, as well as day and treatment × day interaction for plasma haptoglobin and cortisol analyses. Finishing lot and carcass variables analyses also included days on feed as an independent covariate. The specified term used in the repeated statement for plasma haptoglobin and cortisol was day, the subject was cow(group), and the covariance structure used was autoregressive, which provided the best fit for these analyses according to the lowest Akaike information criterion. Results are reported as covariately-adjusted least square means, and separated using LSD. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and ≤ 0.10.

RESULTS AND DISCUSSION

Nutrient composition and profile of diets offered to EFA- and CON-supplemented cows are described in Table 1. Both diets were formulated to represent a typical forage-based diet with limited fat content, and provided adequate amounts of energy and CP based on the requirements of pregnant cows during last trimester of gestation (NRC, 2000). It is important to note that both diets included the same amount of rumen-protected fat, which were based on Ca salts but differed in FA profile. The CON treatment was included to serve as an iso-lipidic, iso-caloric, and iso-nitrogenous control treatment to EFA. Hence, results from this experiment should not be associated with differences in total nutrient or FA intake, but with potential fetal programming effects of supplemental ω-3 and ω-6 EFA.

Cow parameters

As designed, initial cow BW and BCS (d -7) were similar ($P \geq 0.75$) among treatments (Table 2). No treatment effects were detected ($P \geq 0.20$) for any of the subsequent BW and BCS parameters evalu-

ated (Table 2). These outcomes were expected given EFA- and CON-supplemented cows consumed similar amounts of energy and CP during late gestation, and were managed as a single group from calving until weaning. Cows assigned to the EFA and CON supplements had similar ($P \geq 0.11$) proportion (as % of total plasma FA) of all plasma FA on d -7 (data not shown), indicating similar FA profile before treatment administration. At calving, EFA-supplemented cows had greater ($P < 0.01$) proportion of plasma vaccenic, linoleic, linolenic, arachidonic, docosapentaenoic, and docosahexaenoic acids, as well as total PUFA, ω-3, and ω-6 compared with CON-supplemented cows (Table 3). Cows supplemented CON had greater ($P < 0.01$) proportion of plasma palmitic, stearic, oleic, eicosapentaenoic, and lignoceric acids, as well as total SFA and MUFA compared with EFA-supplemented cows at calving (Table 3). Overall, these results are in accordance with the FA content and intake of treatments, given that plasma profile reflects intake and intestinal FA flow (Hess et al., 2008).

TABLE 2. Performance of beef cows receiving diets supplemented with a rumen-protected SFA + MUFA mix (CON) based on palmitic and oleic acids (n = 12), or a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (n = 12) during the last trimester of gestation[1]

Item	CON	EFA	SE	*P* =
Days receiving diets, d	87.0	88.8	0.6	0.02
Initial (d -7)	584	589	15	0.75
Calving	616	614	11	0.90
BW change	31	25	4	0.20
Weaning (d 280)	575	567	10	0.63
BW change	-41	-45	12	0.43
BCS				
Initial (d -7)	5.01	5.02	0.05	0.89
Calving	5.41	5.46	0.06	0.59
BCS change	0.41	0.42	0.07	0.88
Weaning (d 280)	5.08	5.00	0.08	0.38
BCS change	-0.33	-0.47	0.10	0.26

[1]CON = cows received (as-fed basis) 200 g/cow daily of rumen-protected fatty acid mix based on palmitic and oleic acids (EnerGII; Virtus Nutrition, LLC, Corcoran, CA); EFA = cows received (as-fed basis) 200 g/cow daily of rumen-protected essential fatty acids mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (100 g Prequel + 100 g of Strata; Virtus Nutrition). Treatments were provided from d 0 until calving.

Calf birth and weaning parameters

No treatment effects were detected ($P \geq 0.16$; Table 4) for any of the calving and weaning parameters evaluated. Others have also reported similar birth and weaning BW in calves from cows supplemented or not with EFA during gestation (Hess et al., 2008). Collectively, calving and weaning results indicate that supplementing late-gestating beef cows with EFA did not impact offspring growth during gestation, as well as growth from birth to weaning compared with CON-supplemented cohorts.

Calf preconditioning parameters

No treatment effects were detected ($P = 0.20$) herein for plasma cortisol, which increased (day effect; $P < 0.01$) for both treatments upon weaning (28.5, 31.7, 32.7, and 28.4 ng/mL on d 280, 282, 285, and 288, respectively; SEM = 1.2). A treatment × day interaction was detected ($P = 0.05$) for plasma haptoglobin concentrations, which also increased for both treatments upon weaning (day effect; $P < 0.01$) but was greater ($P = 0.05$) in calves from CON-supplemented cows on d 282 (1.70 vs. 1.51 mg/mL, respectively; SEM = 0.07). These outcomes suggest that EFA supplementation to late-gestating cows did not impact the steroidogenesis required to cope with the stress of weaning procedures in the offspring, but altered the resultant plasma haptoglobin protein response (Araujo et al., 2010). During the 45-d preconditioning period, no treatment effects were detected ($P \geq 0.23$) for incidence of calves that required treatment for BRD, calf mortality, ADG, and BW at the end of preconditioning period (Table 4). Hence, calf preconditioning responses were not impacted by treatments despite differences detected for plasma haptoglobin concentration, which has been negatively associated with performance and health parameters in weaned cattle (Araujo et al., 2010).

Calf feedlot and carcass parameters

During the growing lot phase, no treatment effects were detected ($P \geq 0.52$) for initial growing lot BW and proportion of calves treated for BRD symptoms. Calves from EFA-supplemented cows had greater ($P = 0.05$) ADG and tended to be heavier ($P = 0.09$) at the end of the growing lot phase compared with calves from CON-supplemented cows (Table 5). During the finishing lot, the proportion of animals treated for BRD symptoms, days on feed (Table 5), % of calves slaughtered, and % of male calves slaughtered (data not shown) were also similar ($P \geq 0.16$) among treatments. Calves from EFA-supplemented cows tended to have greater ($P = 0.06$) ADG and were heavier ($P = 0.05$) at the end of the finishing phase compared with calves from CON-supplemented cows (Table 5). Upon slaughter, HCW and marbling were greater ($P \leq 0.05$) whereas LM area and % Choice carcasses tended to be greater ($P \leq 0.10$) in calves from EFA-supplemented vs. CON-supplemented cows (Table 5). No treatment differences were detected ($P \geq 0.38$) for the remaining carcass traits evaluated (Table 5).

TABLE 3. Plasma fatty acid profile (g/100 g of plasma fatty acids) at calving of beef cows receiving diets supplemented with a rumen-protected SFA + MUFA mix (CON) based on palmitic and oleic acids (n = 12), or a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (n = 12) during the last trimester of gestation[1]

Item	CON	EFA	SE	*P* =
Palmitic (16:0)	26.7	17.9	1.7	<0.01
Stearic (18:0)	25.8	18.7	2.4	<0.01
Oleic (18:1)	13.5	7.0	0.2	<0.01
Vaccenic (18:1 trans-11)	0.55	0.79	0.02	<0.01
Linoleic (18:2 n-6)	19.5	38.7	3.1	<0.01
Gamma-linolenic (18:3 n-6)	0.20	0.12	0.08	0.15
Linolenic (18:3 n-3)	2.01	3.73	0.59	<0.01
CLA (18:2 n-6 isomers)	0.08	0.11	0.02	0.14
Arachidonic (20:4 n-6)	0.55	2.08	0.19	<0.01
Eicosapentaenoic (20:5 n-3)	0.10	0.01	0.03	<0.01
Behenic (22:0)	0.60	0.40	0.17	0.10
Docosapentaenoic (22:5 n-3)	0.10	0.44	0.06	<0.01
Docosahexaenoic (22:6 n-3)	0.01	0.57	0.05	<0.01
Lignoceric (24:0)	0.07	0.04	0.01	<0.01
Total SFA	58.8	41.6	4.2	<0.01
Total MUFA	17.8	11.9	0.3	<0.01
Total PUFA	22.6	44.9	4.1	<0.01
Total ω-3	2.2	4.8	0.6	<0.01
Total ω-6	20.4	41.1	3.4	<0.01

[1]CON = cows received (as-fed basis) 200 g/cow daily of rumen-protected fatty acid mix based on palmitic and oleic acids (EnerGII; Virtus Nutrition, LLC, Corcoran, CA); EFA = cows received (as-fed basis) 200 g/cow daily of rumen-protected essential fatty acids mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (100 g Prequel + 100 g of Strata; Virtus Nutrition). Treatments were provided from d 0 until calving. Blood samples were collected from all cows (n = 48 per treatment) within 12 h after calving.

TABLE 4. Calving, weaning, and preconditioning outcomes from beef cows receiving diets supplemented with a rumen-protected SFA + MUFA mix (CON) based on palmitic and oleic acids (n = 12), or a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (n = 12) during the last trimester of gestation[1]

Item	CON	EFA	SE	*P* =
Calving results				
% of male calves born	46.8	56.8	7.5	0.34
Calf birth BW, kg	40.9	41.7	0.6	0.44
Adjusted calf birth BW, [2] kg	41.3	42.0	0.6	0.42
Weaning results				
% of male calves weaned	46.8	56.8	7.5	0.34
Calf weaning BW, kg	241	242	3	0.82
205-d adjusted weaning BW,[2] kg	258	259	3	0.86
Preconditioning results				
Treated for BRD symptom, %	6.8	3.8	3.8	0.55
Calf mortality, %	0.0	2.2	1.6	0.36
Preconditioning ADG, kg/d	0.43	0.50	0.05	0.31
End of preconditioning BW, kg	261	265	3	0.29

[1]CON = cows received (as-fed basis) 200 g/cow daily of rumen-protected fatty acid mix based on palmitic and oleic acids (EnerGII; Virtus Nutrition, LLC, Corcoran, CA); EFA = cows received (as-fed basis) 200 g/cow daily of rumen-protected essential fatty acids mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (100 g Prequel + 100 g of Strata; Virtus Nutrition). Treatments were provided from d 0 until calving.

Maternal nutrition impacts fetal muscle development via hyperplasia and hypertrophy, resulting in permanent effects on postnatal growth and performance (Du et al., 2010). During late-gestation, however, only muscle hypertrophy and adipocyte development are significantly influenced in the fetus by maternal nutritional status, with direct consequences on life-long growth and i.m. fat deposition (Du et al., 2010). Corroborating the treatment differences reported herein for ADG, HCW, LM area, and carcass marbling, EFA have been shown to impact muscle and adipocyte function in developing tissues. Hiller et al. (2012) reported that ω-3 FA positively regulates the expression of genes associated with muscle development and function, but reduced expression of genes regulating lipogenesis and FA accumulation in the LM to favor metabolism of muscle cells. On the other hand, ω-6 FA has been shown to have adipogenic effects by increasing the expression of PPARγ in muscle tissues; a key promoter of adipocyte differentiation and marbling in cattle (Moriel et al., 2014). Hence, the improvement in feedlot growth and carcass quality in calves from EFA-supplemented cows should be attributed to the combination of supplemental ω-3 and ω-6, whereas the specific role of each EFA deserves further investigation. By providing these EFA during late gestation, it can be speculated that accumulation of these FA into fetal tissues were increased, enhancing development of muscle and adipose cells, which translated into increased carcass growth and marbling when offspring was provided high-energy anabolic feedlot diets (Harper and Pethick, 2004).

IMPLICATIONS

Supplementing forage-fed beef cows during late gestation with a rumen-protected EFA mix based on equivalent amounts of ω-3 and ω-6 FA did not impact cow performance during gestation, calving rate, or calf birth BW. At calving, proportion of plasma ω-3 and ω-6 FA were greater in EFA-supplemented vs. CON-supplemented cows. No major differences in offspring performance, health, and immune parameters from birth to weaning and subsequent 45-d preconditioning. However, after being exposed to a high-energy feedlot diet, HCW was 16 kg heavier and carcass marbling increased from small to modest when comparing calves from EFA vs. CON-supplemented cows. These

TABLE 5. Feedlot performance and carcass characteristics of feeder cattle from beef cows receiving diets supplemented with a rumen-protected SFA + MUFA mix (CON) based on palmitic and oleic acids (n = 12), or a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (n = 12) during the last trimester of gestation[1]

Item	CON	EFA	SE	*P* =
Growing lot performance				
Initial growing lot BW, kg	248	250	3	0.68
Respiratory disease signs, %	38.3	31.8	7.1	0.52
Growing lot ADG, kg/d	1.12	1.22	0.03	0.05
Final growing lot BW, kg	383	397	6	0.09
Finishing lot performance				
Days on feed, d	127	126	1	0.34
Treated for BRD symptoms, %	2.2	2.2	2.2	0.94
Final finishing lot BW, kg	621	646	9	0.05
Finishing lot ADG, kg/d	1.87	1.98	0.04	0.06
Carcass characteristics				
HCW, kg	391	407	6	0.05
Backfat, cm	1.74	1.82	0.09	0.38
LM area, cm^2	89.6	92.3	1.2	0.10
KPH, %	2.15	2.13	0.07	0.85
Marbling	489	539	16	<0.01
Yield grade	3.50	3.56	0.11	0.63
Retail product, %	48.6	48.4	0.3	0.56
Choice, %	93.5	100.0	2.7	0.09

[1]CON = cows received (as-fed basis) 200 g/cow daily of rumen-protected fatty acid mix based on palmitic and oleic acids (EnerGII; Virtus Nutrition, LLC, Corcoran, CA); EFA = cows received (as-fed basis) 200 g/cow daily of rumen-protected essential fatty acids mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids (100 g Prequel + 100 g of Strata; Virtus Nutrition). Treatments were provided from d 0 until calving.

results are suggestive of programming effects on postnatal offspring growth and health resultant from EFA supplementation to late-gestating cows. Hence, supplementing gestating beef cows with a rumen-protected EFA mix based on eicosapentaenoic, docosahexaenoic, and linoleic acids might be a feasible alternative to optimize offspring productivity and carcass quality in beef production systems.

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