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Comparison of winter cow feeding strategies on offspring carcass characteristics and meat quality

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Objective

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

Study Description

Angus-based cows from 2 sources [n = 129 from SDSU (Experiment 1) and n = 70 from North Dakota State University (Experiment 2)] were stratified by body weight and age and placed into two treatment groups at a drylot facility during mid- and late-gestation: Concentrate (dams fed a concentrate-based diet) or Forage (dams fed a forage-based diet). Calves were finished and carcass data was collected. Striploins were collected for meat quality evaluation.

Take Home Points

In Experiment 1, offspring carcasses from the concentrate treatment tended to have more ribfat (P = 0.06) than the offspring from the forage treatment and tended to have higher (P = 0.08) yield grades. In Experiment 2, maternal treatment did not influence (P > 0.05) any carcass traits. Offspring from the concentrate treatment had increased (P < 0.05) juiciness and tended (P = 0.08) to have increased tenderness ratings compared to offspring from the forage treatment. Maternal prepartum dietary energy source during mid and late gestation did not significantly alter offspring carcass merit or meat quality.

Introduction

Recent advances in fetal programming research have shown that altering maternal nutrition during the fetal stage can result in lasting postnatal effects on offspring productivity measures, including growth, feed intake, feed efficiency, muscle development, and meat quality (Funston et al., 2012). Development of marbling, or intramuscular fat, is of great economic importance to the beef industry. Adipogenesis (fat cell development) is initiated around the fourth month of gestation, partially overlapping with the second wave of myogenesis (muscle cell development). Both muscle and fat cells are derived from a common pool of mesenchymal stem cells. Du et al. (2010) suggested this stage of development represents a major opportunity for maternal nutrition to positively or negatively affect stem cell differentiation and ultimately influence body composition. Since the number of mesenchymal stem cells decrease as cattle mature, strategies to increase marbling during early life could be more effective than later in life. After 250 d of age, marbling is primarily enhanced only through the growth of preexisting fat cells and nutritional influences have little impact on fat cell development (Du et al., 2010). Smith and Crouse (1984) reported that different regulatory processes control

fatty acid synthesis in intramuscular (marbling) and subcutaneous adipose tissue (backfat), indicating that it may be possible to increase marbling without proportional increases in backfat that could negatively impact yield grade. Thus, the fetal stage may be of key importance to overall carcass quality of offspring.

Volatile fatty acids (VFA) are the main products of the digestion of feed by bacteria in the rumen and provide greater than 70% of the ruminant animal's energy supply by serving as substrates for synthesis of glucose and fat (Ferrell et al., 1982; Bell and Bauman, 1997). Major VFA produced by rumen microorganisms include acetate, propionate, and butyrate (Bell and Bauman, 1997). Various dietary energy sources ferment in the rumen to yield differing proportions of specific short- and long-chain fatty acids. Forage-based diets result in VFA composition of approximately 65-70% acetate, 15-25% propionate, and 5-10% butyrate (Penner et al., 2009). Grain-based diets high in readily fermentable carbohydrate (starch) reduce acetate by 10-15% and increase propionate by 20-25% (Penner et al., 2009). Propionate is the only VFA that contributes directly to the net synthesis of glucose, which is a major energy substrate utilized by uterine and placental tissues for fetal growth (Ferrell et al., 1982). Typically, beef cattle are finished on high concentrate diets that result in fermentation of propionate and increased glucose production. Glucose plays an important role in intramuscular fat cell proliferation and growth that ultimately determines the amount of marbling in the carcass. Therefore, it seems plausible that diets based on nonstructural carbohydrates (starch) rather than structural carbohydrates (fiber) could influence fetal development and subsequent carcass composition. Others have evaluated dietary energy source during late gestation (Radunz et al., 2012; Wiedmeier et al., 2012), but to date literature concerning the effects of maternal dietary energy source (forage vs. concentrate) during mid- and late-gestation on offspring performance and meat quality traits is limited. We hypothesized that variations in the proportion of volatile fatty acids produced in the rumen of the gestating cow during mid- and late- gestation will differentially influence fetal development and offspring composition, leading to differences in carcass characteristics and meat quality of offspring.

Experimental Procedures

Cow Management

All animal care and experimental protocols were approved by the South Dakota State University (SDSU) Animal Care and Use Committee (approval number 18-081E). Mature, Angus-based, spring-calving cows from the SDSU Antelope Range and Livestock Research Station (n = 131) and the North Dakota State University (NDSU) Hettinger Research Extension Center (n = 70) were evaluated for pregnancy in the fall of 2017 and assigned to dietary treatments based on cow age and BCS. Groups were randomly assigned to forage-based or concentrate-based dietary treatments and allotted to four pens based on source and treatment [SDSU Forage (n = 64), SDSU Concentrate (n = 65), NDSU Forage (n = 35), NDSU Concentrate (n = 35)]. Dietary composition for the treatment diets is provided in Table 1. Feed intake was controlled so that cows in both treatments consumed equal levels of protein and energy. Cows were provided the treatment diets beginning at approximately day 94 of gestation and continuing until approximately 30 days prior to calving. Both diets were formulated to maintain cow body condition. At the end of the treatment period, cows were returned to native range pastures and managed as a common group through weaning.

Offspring Management

At weaning, a subset of 96 calves (n = 48 heifers, n = 48 steers) from the SDSU cows and 40 calves (n = 20 heifers, n = 20 steers) from the NDSU cows closest to the mean weaning weight of each source group were selected and followed through the backgrounding and finishing portions of the study. Calves were fed a common receiving diet consisting of grass hay and dried distillers grains with solubles during an 83-d backgrounding period. During backgrounding, calves were treated for external and internal parasites and vaccinated against clostridia, Haemophilus somnus, and Mannheimia haemolytica bacteria and IBR-BVD-BRSV-PI3 viruses. At the conclusion of the backgrounding phase, all calves were transported to Brookings, SD for the finishing phase of the study. The SDSU calves were finished in the Insentec monitoring system (Insentec, Marknesse, the Netherlands) at the SDSU Cow-Calf Education and Research facility (CCERF) to monitor individual feed intake. Steers and heifers were separated into two pens. The NDSU calves were stratified by sex and initial body weight into group pens (4 pens/treatment with 5 head/pen) and finished at the

SDSU Ruminant Nutrition Center (RNC). Because the calves from each source location were finished in different systems, the SDSU calves will be referred to as Experiment 1 and the NDSU calves as Experiment 2. Finishing diets for each group of cattle are provided in Table 2. Following a step-up period, calves were administered an initial growth promoting implant on d 23 of the finishing period containing 100 mg trenbolone acetate and 14 mg estradiol (Synovex-Choice, Zoetis Inc., Parsippany, NJ). Cattle were re-implanted with 100 mg trenbolone acetate and 14 mg estradiol (Synovex-Choice, Zoetis Inc., Parsippany, NJ) on d 80 of the finishing period and an ultrasound image was captured to predict harvest date. The harvest target for each source × treatment group was determined when the predicted group average was 0.5 inches of rib fat (RF), resulting in three harvest dates at d 131, d 145, and d 180 of the finishing period. Cattle were shipped 146 miles to a commercial packing facility.

Carcass Evaluation and Sample Collection

All cattle were tracked individually through the slaughter process. Following carcass chilling (approximately 24 hours), hot carcass weight (HCW), ribeye area (REA), RF, USDA Yield Grade (YG), marbling score, carcass maturity, USDA Quality Grade (QG), and objective color measurements (L*, a*, and b*) were recorded for each individual carcass. A striploin (IMPS #180) was collected from each carcass and transported to the SDSU Meat Science Laboratory and portioned into 1-inch steaks. Four steaks were aged for either 3, 7, 14, or 21 days for evaluation of Warner-Bratzler shear force (WBSF). Additional steaks were utilized to determine fatty acid profile using Fatty Acid Methyl Ether (FAME) synthesis, crude fat percentage using ether extraction, and consumer palatability of 14 d aged samples using a trained sensory panel.

Warner-Bratzler shear Force

Steaks designated for WBSF determination were thawed for 24 hours at 39°F then cooked on an electric clamshell grill (George Foreman, Model GRP1060B, Middleton, WI) to an internal temperature of 160ºF. A thermometer (Model 35140, Cooper-Atkins Corporation, Middlefield, CT) was used to record the peak internal temperature. Cooked steaks were cooled at 39ºF for 24 hr before removing 6 cores (0.50-inch in diameter) parallel to the muscle fiber orientation (AMSA, 2015). A single, peak shear force measurement was obtained for each core using a texture analyzer (Shimadzu Scientific Instruments Inc., Lenexa, KS, Model EZ-SX) with a Warner-Bratzler attachment. Measurements of the peak shear force value were averaged to obtain a single WBSF value per steak.

Ether Extract

At 3 d postmortem, the anterior face of each striploin was removed during fabrication and frozen at -4ºF and later used to determine percent crude fat using the ether extract method outlined by Mohrhauser et al. (2015). Steaks were thawed slightly and all exterior fat, epimysial connective tissue, and additional muscles were removed from the longissimus muscle. Samples were minced, immersed in liquid nitrogen, and powdered for 15 seconds using a Waring commercial blender (Waring Products Division, Model 51BL32, Lancaster, PA). Homogenized samples were weighed in duplicate 5-gram samples into dried aluminum tins, covered with dried filter papers, and dried in an oven at 212ºF for 24 hr. Dried samples were then placed into a desiccator and were reweighed after cooling. Samples were extracted using petroleum ether in a side-arm Soxhlet extractor (Thermo Fischer Scientific, Rockville, MD) for 60 hr followed by drying at room temperature and subsequent drying in an oven at 212ºF for 4 hr. Dried extracted samples were placed into a desiccator for 1 hr and were cooled and then reweighed. Crude fat was calculated by subtracting the pre-extraction weight from the post-extraction sample weight and expressed as a percentage of the pre-extraction sample weight.

Fatty Acid Composition

A sub-sample of 30 steaks per treatment was selected closest to the mean marbling score from Experiment 1 (30 per treatment from the SDSU offspring) to evaluate composition of individual fatty acids using direct FAME synthesis. Steaks were thawed slightly and external fat, epimysial connective tissue, and additional muscles were trimmed from the longissimus muscle. Samples were minced, immersed in liquid nitrogen, and powdered for 15 seconds using a Waring commercial blender (Waring Products Division, Model 51BL32, Landcaster,

PA). Duplicate 1 g samples were weighed and processed to generate FAMEs according to procedures of O'Fallon et al. (2007).

Trained Sensory Panel

An eight-member trained sensory panel evaluated samples according to standards set by AMSA (2016). Striploin samples were evaluated for juiciness (1 = extremely dry; 18 = extremely juicy), tenderness (1 = extremely tough; 18 = extremely tender), and beef flavor (1= extremely bland; 18 = extremely intense) on an anchored unmarked line scale. Steaks were cooked on an electric clamshell grill (George Foreman, Model GRP1060B, Middleton, WI) to an internal temperature of 160ºF. After cooking, steaks were rested for five minutes and then cut into 1 x 0.5 x 0.5-in samples. Two cubes were placed into a prelabeled plastic cup, covered with a plastic lid in order to retain heat and moisture, and held in a warming oven (Metro HM2000, Wilkes-Barre, PA) at 140ºF until served. Ten samples were evaluated in each session, one session per d, for a total of 10 sessions. Samples evaluations were alternated by treatment to reduce first and last order bias. Samples were served to panelists in a randomized fashion, in private booths, under red lights to limit observation of visual differences and evaluated for each trait on an anchored unmarked line scale.

Statistical Analyses

Response variables were analyzed using generalized linear mixed model procedures (SAS GLIMMIX, SAS Inst. Inc., Cary, NC). The intrauterine environment was considered the experimental unit. Experiment 1 was analyzed as a completely randomized design and Experiment 2 was analyzed as a randomized complete block design to determine the effects of treatment, calf sex and their interaction. For WBSF, aging period was added to the model as a repeated measure and peak cooking temperature was included as a covariate. Separation of least squares means was conducted using protected LSD with an alpha level of 0.05. Treatment by sex interactions were evaluated and are reported when significant.

Results and Discussion

The majority of fetal muscle and adipose tissue growth and development occurs during mid- and late-gestation (Du et al., 2010). Alterations to fetal development imposed by maternal stressors, such as maternal nutrient restriction have been shown to have long term impacts on offspring growth and performance (Webb et al., 2019; Mohrhauser et al., 2015; Underwood et al., 2010). From a production perspective, management decisions made in response to drought, availability of feedstuffs, or cost of feedstuffs can alter the gestational environment potentially leading to changes in fetal development. In the present study, drought conditions in 2017 resulted in limited forage availability at the SDSU Antelope Range and Livestock Research Station and the NDSU Hettinger Research Extension Center. Therefore, a management decision was made to transport a portion of these cow herds to a drylot from November 2017 through February 2018 to take advantage of lower cost feedstuffs and preserve range conditions. Based on feed prices of 2017, dams in the concentrate-based treatment were fed a diet that cost approximately $0.90/ day and the forage-based treatment were fed a diet that cost approximately $1.07/ day.

Carcass Characteristics

Experiment 1: Carcass measurements for Exp. 1 are reported in Table 3. Maternal treatment did not influence (P > 0.05) offspring HCW, REA, marbling score, L* values or the proportion of carcasses in each USDA Quality and Yield Grade category. Offspring from the forage treatment tended to have decreased (P = 0.06) 12th rib fat thickness and tended to have lower (P = 0.08) USDA Yield Grades compared to offspring from the concentrate treatment. Offspring from the concentrate treatment had increased (P < 0.05) a* and b* values. As expected, steers had heavier (P < 0.05) HCW and larger (P < 0.05) REA than heifers. Heifers had increased (P < 0.05) RF and marbling scores, as well as increased (P < 0.05) a* and b* values and tended (P = 0.07) to have higher USDA Yield Grades.

Experiment 2: Carcass measurements for Exp. 2 are reported in Table 4. Maternal treatment did not influence (P > 0.05) any carcass traits evaluated in Exp. 2. Similar to Exp. 1, steers had heavier (P < 0.05) HCW, larger

(P < 0.05) REA, decreased (P < 0.05) RF and marbling scores, and lower (P < 0.05) USDA Yield Grades compared to heifers.

The tendency for offspring from forage fed dams to have decreased rib fat and lower USDA Yield Grades in Exp. 1 was not observed in Exp. 2. Differences between the two experiments may be attributed to genetic and management differences between the source cow herds, as well as the differences in offspring finishing systems. While no direct comparisons with the present study are available in the literature other research has demonstrated that offspring fat depots may be especially sensitive to alterations in the maternal diet. When fed to a common backfat endpoint, Radunz et al. (2012) reported that offspring from dams fed a fiber-based diet (hay) in late gestation had increased marbling scores and no carcasses that graded USDA Select compared to offspring from dams fed a starch-based diet (corn). Underwood et al. (2010) reported that fat thickness and adjusted 12th rib fat thickness was greater in offspring from dams grazing improved pasture that providing more crude protein than offspring from dams grazed on native range during mid gestation. Wilson et al. (2015) observed a tendency for progeny from dams provided a distillers grain supplement during late gestation to have decreased backfat thickness compared to progeny from dams that were not supplemented. Steers from dams supplemented protein during late gestation were reported to have increased marbling scores, as well as a greater proportion of carcasses grading USDA Choice or better compared to steers from dams not supplemented protein (Larson et al., 2009). Mohrhauser et al. (2015) reported a tendency for decreased ribfat and lower USDA Yield Grades, with no influence on marbling score, in offspring from dams in a negative maternal energy status during mid-gestation compared to offspring from dams in a positive maternal energy status. Summers et al. (2015) also observed decreased 12th rib fat thickness with no differences in marbling score in progeny from dams that were supplemented a diet with low RUP in late gestation compared to progeny from dams not supplemented with RUP.

As observed in both Exp. 1 and Exp. 2, heifers had increased (P < 0.05) RF and YG compared to steers, and steers had increased (P < 0.05) HCW and REA compared to heifers. Mohrhauser et al (2015) also reported steers to have heavier HCW, reduced marbling scores, and larger ribeye areas. However, in contrast to the present study, steers were reported to have higher a* values and tended to have higher L* values compared to heifers (Mohrhauser et al., 2015). In addition, heifers in Exp. 1 also tended to have increased marbling scores compared to steers. This is consistent with other studies suggesting heifers have greater amounts of marbling when compared to steers and bulls (Park et al., 2018).

Meat Quality Characteristics

Experiment 1: Meat quality characteristics for Exp. 1 are reported in Table 5. Maternal treatment did not influence (P > 0.05) crude fat percentage, moisture content, WBSF, or sensory characteristics of steaks from offspring. Heifers had decreased (P < 0.05) moisture and increased crude fat content compared to steers. As expected, WBSF improved (P < 0.05) each aging period (4.75 ± 0.152 kg, 3.79 ± 0.112 kg, 2.98 ± 0.088 kg, and 2.65 ± 0.064 kg for steaks aged 3, 7, 14, and 21 days, respectively).

Experiment 2: Meat quality characteristics for Exp. 2 are reported in Table 6. Maternal treatment did not influence (P > 0.05) crude fat percentage, moisture content, WBSF, or flavor of steaks from offspring. However, offspring from the concentrate treatment had increased (P < 0.05) juiciness and tended to have increased (P = 0.08) tenderness compared to offspring from the forage treatment as evaluated by a trained sensory panel. Heifers had increased (P < 0.05) crude fat and decreased moisture content compared to steers, which is likely the result of heifers having greater amounts of marbling compared to the steers. As expected, WBSF improved (P < 0.05) from d 4 to 7, and from d 7 to 14, but d 14 did not differ from d 21 (4.79 ± 0.156 kg, 3.74 ± 0.156 kg, 2.91 ± 0.156 kg, and 2.63 ± 0.157 kg for steaks aged 3, 7, 14, and 21 days, respectively).

Because there were no differences in marbling scores between treatment groups the lack of difference in crude fat and moisture content is not unexpected. Other studies investigating alterations in maternal energy have evaluated WBSF and also reported no differences in this objective measure of tenderness (Radunz et al., 2012; Mohrhauser et al., 2015). However, studies investigating alterations in maternal protein levels reported steaks from offspring of dams with restricted protein intake during mid-gestation had increased WBSF values (less tender meat) compared to offspring of dams with adequate protein intake (Underwood et al., 2010; Webb

et al., 2019). In Exp. 2, steaks from the offspring of dams in the concentrate treatment were rated as juicier and tended to have improved tenderness ratings by a trained sensory panel compared to steaks from the forage treatment. The difference in sensory ratings between treatments and between Experiments in this study is unclear. Other studies investigating the effects of maternal nutrition during gestation on sensory characteristics of steaks is lacking. As no differences were observed between treatments for WBSF, crude fat, moisture content, or marbling scores more research is necessary to understand the influence of maternal dietary energy source on the sensory attributes of steaks from offspring. In both Exp. 1 and Exp. 2, heifers had increased ($P < 0.05$) crude fat and decreased moisture content compared to steers, which is likely attributed to the heifers having greater amounts of marbling compared to the steers.

Fatty Acid Composition

Fatty acid composition was only analyzed for Exp. 1 (Table 7). The concentration (mg/g) of arachidonic (C20:4n6), nervonic (C20:1n9), and docosapentaenoic (C22:5n3) acids were increased in samples from the concentrate treatment ($P < 0.05$); however, treatment did not influence ($P > 0.05$) concentration of other fatty acids. The concentration (mg/g) of capric (C10:0), myristic (C14:0), myristoleic (C14:1n5), palmitoleic (C16:1n7), and heptadecenoic (C17:1) acids were increased ($P < 0.05$) in samples from heifers compared with steers. Sex did not influence ($P > 0.05$) concentration of other fatty acids.

There is limited information on the effects of maternal diet on the fatty acid composition of meat from offspring. Webb et al. (2019) also reported that arachidonic acid was sensitive to changes in maternal diet. Offspring of dams provided adequate protein during mid-gestation produced offspring with increased concentrations of arachidonic acid compared with protein restricted dams. A study by Chail et al., (2017) evaluated the effects of finishing diet on fatty acid composition in the *gluteus medius* and *triceps brachii* and also observed increased concentration of arachidonic acid when cattle were fed a grain-based diet as compared to a forage-based diet. Results from the present study suggest that maternal diet can influence fatty acid composition of steaks from progeny and warrants further investigation.

Implications

Results from this study suggest that variation in winter cow diets during mid- and late-gestation has limited influence on progeny performance. Collectively, these data suggest a forage-based diet provided to cows during mid- and late-gestation programmed offspring to decrease deposition of subcutaneous fat without compromising marbling score, tenderness or other sensory attributes. As dams in the present study were fed to meet nutrient requirements during mid- and late-gestation, mechanisms by which energy source in mid- to late-gestation can affect growth rate of progeny might be minimized when energy needs of the cow are met. Provided that nutrient requirements are met, it appears that utilizing alternative diets for the beef cow herd does not significantly influence progeny performance and beef product quality. This provides flexibility for cow/calf producers to feed their gestating cows available energy sources during drought and/or variable growing conditions without concern for offspring performance or carcass traits.

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References

American Meat Science Association. 2016. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. AMSA, Champaign, IL.

Bell, A. W., and D. E. Bauman. 1997. Adaptations of glucose metabolism during pregnancy and lactation. Journal of Mammary Gland Biology and Neoplasia 2(3): 265-278.

Chail, A., J.F. Legako, L.R. Pitcher, R.E. Ward, S. Martini, and J.W. MacAdam. 2017. Consumer sensory evaluation and chemical composition of beef gluteus medius and triceps brachii steaks from cattle finished on forage or concentrate diets. Journal of Animal Science 95(4): 1553-1564. doi:10.2527/jas.2016.1150

Du, M., J. Tong, J. Zhao, K.R. Underwood, M. Zhu, S.P. Ford, and P.W. Nathanielsz. 2010. Fetal programming of skeletal muscle development in ruminant animals. Journal of Animal Science 88: E51-E60. doi:10.2527/jas.2009-2311

Ferrell, C. L., R.L Prior, R.K. Christenson, and S.P. Ford. 1982. Blood flow and nutrient uptake of the bovine uterus and fetus. In: Roman L. Hruska U.S. Meat Animal Research Center Report. p. 30-31.

Funston, R. N., A.F. Summers, and A.J. Roberts. 2012. ALPHARMA BEEF CATTLE NUTRITION SYMPOSIUM: Implications of nutritional management for beef cow-calf systems. Journal of Animal Science 90(7): 2301-2307. doi:10.2527/jas.2011-4568

Larson, D. M., J.L. Martin, D.C. Adams, and R.N. Funston. 2009. Winter grazing system and supplementation during late gestation influence performance of beef cows and steer progeny. Journal of Animal Science 87(3): 1147-1155. doi:10.2527/jas.2008-1323

Mohrhauser, D. A., A.R. Taylor, K.R. Underwood, R.H. Pritchard, A.E. Wertz-Lutz, and A.D. Blair. 2015. The influence of maternal energy status during midgestation on beef offspring carcass characteristics and meat quality. Journal of Animal Science 93(2): 786-793. doi:10.2527/jas.2014-8567

O'Fallon, J. V., J.R. Busboom, M.L. Nelson, and C.T. Gaskins. 2007. A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. Journal of Animal Science 85(6): 1511-1521. doi:10.2527/jas.2006-491

Park, S. J., S.H. Beak, D.J.S. Jung, S.Y. Kim, I.H. Jeong, M.Y. Piao, … M. Baik. 2018. Genetic, management, and nutritional factors affecting intramuscular fat deposition in beef cattle - A review. Asian-Australasian Journal of Animal Sciences 31(7): 1043-1061. doi:10.5713/ajas.18.0310

Penner, G. B., M. Taniguchi, L.L. Guan, K.A. Beauchemin, and M. Oba. 2009. Effect of dietary forage to concentrate ratio on volatile fatty acid absorption and the expression of genes related to volatile fatty acid absorption and metabolism in ruminal tissue. Journal of Dairy Science 92(6): 2767-2781. doi:10.3168/jds.2008-1716

Radunz, A. E., F.L. Fluharty, A.E. Relling, T.L. Felix, L.M. Shoup, H.N. Zerby, and S.C. Loerch. 2012. Prepartum dietary energy source fed to beef cows: II. Effects on progeny postnatal growth, glucose tolerance, and carcass composition. Journal of Animal Science 90(13): 4962-4974. doi:10.2527/jas.2012-5098

Smith, S. B., and J.D. Crouse. 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in intramuscular and subcutaneous adipose tissue. Journal of Nutrition 114(4): 792-800.

Summers, A. F., A.D. Blair, and R.N. Funston. 2015. Impact of supplemental protein source offered to primiparous heifers during gestation on II. Progeny performance and carcass characteristics. Journal of Animal Science 93(4): 1871-1880. doi:10.2527/jas.2014-8297

Underwood, K. R., J.F. Tong, P.L. Price, A.J. Roberts, E.E. Grings, B.W. Hess, … M. Du. 2010. Nutrition during mid to late gestation affects growth, adipose tissue deposition, and tenderness in cross-bred beef steers. Meat Science 86(3): 588-593. doi:10.1016/j.meatsci.2010.04.008

Webb, M. J., J.J. Block, R.N. Funston, K.R. Underwood, J.F. Legako, A.A. Harty, … A.D. Blair. 2019. Influence of maternal protein restriction in primiparous heifers during mid and/or late-gestation on meat quality and fatty acid profile of progeny. Meat Science 152: 31-37. doi:10.1016/j.meatsci.2019.02.006

Wiedmeier, R. W., J.J. Villalba, A. Summers, and F.D. Provenza. 2012. Eating a high fiber diet during pregnancy increases intake and digestibility of a high fiber diet by offspring in cattle. Animal Feed Science and Technology 177(3-4): 144-151. doi:10.1016/j.anifeedsci.2012.08.006

Wilson, T. B., A.R. Schroeder, F.A. Ireland, D.B. Faulkner, and D.W. Shike. 2015. Effects of late gestation distillers grains supplementation on fall-calving beef cow performance and steer calf growth and carcass characteristics. Journal of Animal Science 93(10): 4843-4851. doi:10.2527/jas.2015-9228

Tables

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

Ingredient	CONC[1]	FOR[1]
Wheat Straw	24.1 %	71.9 %
Grass/ Alfalfa Hay	---	21.8 %
Corn Silage	---	3.7 %
Suspension Supplement[2]	4.6 %	2.6 %
Corn Grain	56.6 %	---
Modified Distiller's Grain with Solubles	13.3 %	---
Limestone	1.4 %	---

[1]Diets formulated based on NRC (2000) requirements
[2]Suspension supplement: 20% Crude Protein (≤ 20% Non-protein nitrogen), 3.55-4.55% Ca, 0.20% P, 0.30% Mg, 1% K, 528.63 ppm Mn, 12.65 ppm Co, 480 ppm Cu, 5.50 ppm Se, 1440 ppm Zn, 40000 IU/lb Vit. A, 11300 IU/lb Vit. D3, 75 IU/lb Vit. E, 400 g/ton monensin.

Table 2. Dietary components and nutrient composition consumed by offspring during the finishing phase.

Ingredient	Experiment 1[1]	Experiment 2[1]
	--- % DM basis ---	
Grass Hay	11.43	---
Earlage	12.33	---
Dry Rolled Corn	55.45	30.35
Dried Distiller Grains with Solubles[2]	20.10	17.48
High Moisture Corn	---	32.50
Oatlage	---	12.90
Pelleted Melengestrol Acetate Supplement[3]	---	1.90
Suspension Supplement for Exp.1[4]	0.70	---
Suspension Supplement for Exp. 2[5]	---	4.86
	--- Nutrient composition of diet[6] ---	
DM %	72.00	70.37
CP %	14.61	14.35
ADF %	10.32	8.78
NDF %	20.74	19.47
Crude Fat %	3.74	4.34
Ash %	3.41	5.87
NEm Mcal/d	0.93	0.94
NEg Mcal/d	0.62	0.63

[1]Diets formulated based on NRC (2000) requirements for offspring fed at the Cow-calf Education and Research Facility (Experiment 1) or Ruminant Nutrition Center (Experiment 2).

[2]In experiment 1, dried distillers grains with solubles fed to heifers included melengestrol acetate (MGA, Zoetis, Parsippany, NJ) at a rate sufficient to provide 0.50 mg·hd-1·d-1; steers received dried distillers grains w/ solubles without MGA.

[3]Soybean hull based: provided MGA at a rate sufficient to provide 0.50 mg·hd-1·d-1

[4]Suspension supplement: 30.8% protein (26.6% non-protein nitrogen), 8% Ca, 0.2% P, 0.4% Mg, 7.1% K, 15.6 ppm Co, 337.6 ppm Cu, 33.8 ppm I, 723.8 ppm, Mn, 3.2 ppm Se, 1107.8 ppm Zn, 4310 IU/lb Vit A, 1080 IU/lb Vit D3, 384.6 IU/lb Vit E, 512.3 g/ton monensin.

[5]Suspension supplement: 44.03% protein (38.97% non-protein nitrogen), 11.06% Ca, 0.39% P, 7.10% K, 0.22% Mg, 0.39% S, 1.42 ppm Co, 101.47 ppm Cu, 12.18 ppm I, 116.14 ppm Fe, 309.49 ppm Mn, 2.94 ppm Se, 674.78 ppm Zn, 20294.12 IU/lb Vit A, 202.94 IU/lb Vit E, 588.24 g/ton monensin, 1.29% fat, 11.13% TSI, 52.33% Ash.

[6]All values except diet dry matter on a dry matter basis

Table 3. Least squares means for maternal prepartum dietary energy source on Experiment 1 progeny carcass characteristics, meat quality and carcass value.

	Treatment[1]			Sex			P-value[2]		
Item	**CONC**	**FOR**	**SEM[3]**	**Heifers**	**Steers**	**SEM[3]**	**Treatment**	**Sex**	**Treatment x Sex**
Hot carcass weight, lb	769	774	9.7	739	807	9.7	0.710	<0.001	0.299
Ribeye area, in^2	13.3	13.6	0.19	12.9	13.9	0.21	0.271	0.006	0.889
12th rib fat thickness, in	0.48	0.45	0.016	0.5	0.43	0.018	0.060	0.002	0.304
USDA Yield grade	3.0	2.8	0.08	3.0	2.8	0.09	0.084	0.070	0.811
Marbling score[4]	537	539	13.9	563	513	15.7	0.909	0.013	0.699
L*[5]	42.05	41.83	0.277	41.99	41.90	0.314	0.534	0.838	0.826
a*[5]	25.27	24.59	0.138	25.25	24.60	0.156	<0.001	0.002	0.921
b*[5]	10.45	10.03	0.093	10.46	10.02	0.105	<0.001	0.001	0.660
USDA Quality Grade[6]									
Prime, %	5.22	9.14	0.689	9.21	5.17	0.782	0.588	0.615	0.963
Upper 2/3 Choice, %	53.00	50.66	0.337	65.66	37.72	0.391	0.865	0.272	0.864
Low Choice, %	36.19	30.95	0.381	20.16	50.18	0.420	0.715	0.267	0.635
USDA Yield Grade[6]									
Yield Grade 2, %	57.55	61.62	0.339	50.95	67.69	0.381	0.761	0.384	0.556
Yield Grade 3, %	40.50	36.50	0.339	46.59	30.96	0.383	0.761	0.399	0.794

[1]Diets formulated based on NRC (2000) requirements for dams fed either a limit-fed concentrate or ad-libitum forage diet during mid- and late-gestation.

[2]Probability of difference among least square means

[3]Standard error of the mean

[4]Marbling score: 200=Traces^0, 300=Slight^0, 400=Small^0, 500=Modest^0

[5]Recorded 3 d postmortem; L*: 0 = Black, 100 = White; a*: Negative values = green; Positive values = red; b*: Negative values = blue; Positive values = yellow

[6]Calculated proportions of USDA Quality and Yield Grade (data did not converge for a quality grade of USDA Select, or USDA Yield Grade less than a 2 or greater than a 3)

Table 4. Least squares means for maternal prepartum dietary energy source on Experiment 2 progeny carcass characteristics, meat quality and carcass value

Item	Treatment[1]			Sex			P-value[2]		
	CONC	FOR	SEM[3]	Heifers	Steers	SEM[3]	Treatment	Sex	Treatment x Sex
Hot carcass weight, lb	728	728	10.2	699	754	10.2	0.972	0.001	0.611
Ribeye area, in^2	12.8	12.7	0.35	12.1	13.4	0.35	0.814	0.013	0.508
12th rib fat thickness, in	0.37	0.40	0.02	0.42	0.35	0.02	0.418	0.016	0.497
USDA Yield grade	2.7	2.8	0.130	3.0	2.5	0.130	0.452	0.013	0.957
Marbling score[4]	484	493	20.43	529	448	20.43	0.770	0.008	0.526
L*[5]	42.27	42.26	0.366	42.30	42.22	0.366	0.989	0.885	0.282
a*[5]	25.51	25.36	0.189	25.36	25.50	0.189	0.573	0.588	0.192
b*[5]	10.56	10.54	0.148	10.55	10.55	0.148	0.911	0.994	0.224
USDA Quality Grade[6]									
Low Choice, %	56.70	34.83	0.525	30.00	62.02	0.510	0.425	0.309	0.425
Select, %	20.00	21.39	0.618	14.29	28.99	0.659	0.935	0.477	0.477
USDA Yield Grade[6]									
Yield Grade 2, %	66.67	44.50	0.506	39.56	71.01	0.510	0.413	0.308	0.939
Yield Grade 3, %	28.99	50.00	0.510	55.50	24.66	0.525	0.425	0.309	0.702

[1]Diets formulated based on NRC (2000) requirements for dams fed either a limit-fed concentrate or ad-libitum forage diet during mid- and late-gestation.

[2]Probability of difference among least square means

[3]Standard error of the mean

[4]Marbling score: 200=Traces^0, 300=Slight^0, 400=Small^0, 500=Modest^0

[5]Recorded 3 d postmortem; L*: 0 = Black, 100 = White; a*: Negative values = green; Positive values = red; b*: Negative values = blue; Positive values = yellow

[6]Calculated proportions of USDA Quality and Yield Grade (data did not converge for a quality grade of USDA Select, or USDA Yield Grade less than a 2 or greater than a 3)

Table 5. Least square means for meat characteristics from Experiment 1 progeny of cattle fed a prepartum dietary energy source consisting of limit-fed concentrate (CONC) or ad-libitum forage (FOR) diet during mid- and late-gestation.

	Treatment[1]			Sex			P-value[2]		
Item	CONC	FOR	SEM[3]	Heifers	Steers	SEM[3]	Treatment	Sex	Treatment x Sex
Crude Fat, %	6.31	6.24	0.339	7.17	5.39	0.384	0.865	<0.001	0.621
Moisture, %	71.48	71.50	0.264	70.69	72.29	0.299	0.945	<0.001	0.728
WBSF[4], kg	3.48	3.60	0.128	3.38	3.71	0.137	0.480	0.068	0.637
Tenderness[5]	12.43	12.85	0.285	12.87	12.41	0.318	0.263	0.284	0.833
Juiciness[5]	10.98	11.49	0.295	11.33	11.14	0.330	0.192	0.665	0.328
Flavor[5]	9.83	9.64	0.228	9.84	9.64	0.255	0.531	0.555	0.232

[1]Diets formulated based on NRC (2000) requirements for dams fed either a limit-fed concentrate or ad-libitum forage diet during mid- and late-gestation.

[2]Probability of difference among least square means

[3]Standard error of the mean

[4]Warner-Bratzler Shear Force

[5]Striploin samples were evaluated for juiciness (1 = extremely dry; 18 = extremely juicy), tenderness (1 = extremely tough; 18 = extremely tender), and beef flavor (1= extremely bland; 18 = extremely intense).

Table 6. Least square means for meat characteristics from Experiment 2 progeny of cattle fed a prepartum dietary energy source consisting of limit-fed concentrate (CONC) or ad-libitum forage (FOR) diet during mid- and late-gestation.

	Treatment[1]			Sex			P-value[2]		
Item	CONC	FOR	SEM[3]	Heifers	Steers	SEM[3]	Treatment	Sex	Treatment x Sex
Crude Fat, %	5.20	5.54	0.360	6.21	4.53	0.360	0.513	0.002	0.767
Moisture, %	72.59	72.45	0.293	71.87	73.18	0.293	0.729	0.003	0.523
WBSF[4], kg	3.50	3.54	0.165	3.40	3.64	0.173	0.836	0.308	0.342
Tenderness[5]	12.59	11.73	0.341	12.56	11.76	0.341	0.082	0.106	0.441
Juiciness[5]	10.70	9.67	0.304	10.16	10.21	0.304	0.022	0.921	0.201
Flavor[5]	9.20	8.82	0.332	9.09	8.93	0.332	0.415	0.729	0.166

[1]Diets formulated based on NRC (2000) requirements for dams fed either a limit-fed concentrate or ad-libitum forage diet during mid- and late-gestation.

[2]Probability of difference among least square means

[3]Standard error of the mean

[4]Warner-Bratzler Shear Force

[5]Striploin samples were evaluated for juiciness (1 = extremely dry; 18 = extremely juicy), tenderness (1 = extremely tough; 18 = extremely tender), and beef flavor (1= extremely bland; 18 = extremely intense).

Table 7. Total concentration of fatty acids in raw tissue (Saturated fatty acids, SFA; monounsaturated, MUFA; and polyunsaturated fatty acids, PUFA) from Experiment 1 progeny of dams fed a concentrate (CONC) or forage (FOR) diet during mid- and late-gestation.

	Treatment[1]			Sex			P-value[2]		
	CONC	FOR	SEM[3]	Heifers	Steers	SEM[3]	Treatment	Sex	Treatment x Sex
Fatty Acid	---- Fatty acid concentrations (mg/g raw wet tissue) ----								
C10:0	0.03	0.03	0.003	0.03	0.02	0.003	0.710	0.013	0.290
C12:0	0.04	0.04	0.003	0.05	0.04	0.003	0.540	0.100	0.466
C14:0	2.15	2.06	0.154	2.34	1.87	0.172	0.663	0.042	0.348
C15:0	0.29	0.30	0.024	0.32	0.27	0.027	0.846	0.105	0.629
C16:0	19.37	19.43	1.410	20.58	18.23	1.572	0.974	0.264	0.477
C17:0	0.86	0.89	0.079	0.94	0.81	0.088	0.742	0.250	0.853
C18:0	10.33	10.73	0.788	10.45	10.61	0.879	0.697	0.896	0.495
C20:0	0.05	0.04	0.006	0.05	0.04	0.007	0.452	0.103	0.660
C14:1n5	0.57	0.50	0.042	0.62	0.46	0.047	0.204	0.017	0.402
C16:1n7	2.15	1.95	0.134	2.35	1.76	0.150	0.264	0.005	0.295
C16:1trans	0.24	0.25	0.014	0.25	0.24	0.016	0.723	0.698	0.566
C18:1n9	27.24	27.33	1.909	29.34	25.23	2.128	0.970	0.152	0.593
C18:1 trans	2.58	2.41	0.203	2.47	2.52	0.226	0.517	0.853	0.467
C18:1n7	0.94	1.10	0.104	1.16	0.89	0.116	0.230	0.088	0.603
C18:2 trans	0.004	0.003	0.0001	0.004	0.003	0.0006	0.628	0.596	0.245
C18:2n6	2.96	2.63	0.170	2.80	2.79	0.190	0.147	0.978	0.657
C18:3n6	0.02	0.02	0.001	0.01	0.02	0.001	0.766	0.201	0.806
C18:3n3	0.27	0.24	0.012	0.25	0.25	0.014	0.051	0.916	0.948
C20:2	0.06	0.05	0.004	0.06	0.05	0.005	0.638	0.240	0.921
C20:3n6	0.01	0.01	0.001	0.01	0.01	0.001	0.210	0.901	0.749
C20:4n6	0.55	0.46	0.025	0.493	0.524	0.028	0.009	0.405	0.547
C22:3	0.01	0.01	0.001	0.01	0.01	0.001	0.056	0.721	0.855
C24:1n9	0.02	0.01	0.002	0.01	0.01	0.002	0.011	0.530	0.224
C22:5n3	0.02	0.01	0.003	0.02	0.02	0.003	0.007	0.329	0.544
C22:6n3	0.03	0.03	0.003	0.03	0.03	0.003	0.514	0.811	0.888
SFA	33.12	33.52	2.410	34.77	31.87	2.688	0.897	0.419	0.477
MUFA	34.45	34.21	2.248	36.97	31.69	2.506	0.937	0.119	0.651
PUFA	3.93	3.47	0.192	3.69	3.71	0.214	0.068	0.958	0.767

[1]Diets formulated based on NRC (2000) requirements for dams fed either a limit-fed concentrate or ad-libitum forage diet during mid- and late-gestation.

[2]Probability of difference among least square means

[3]Standard error of the mean