Can We Modify Future Beef Calf Performance by Changing Cow Nutrition During Gestation?

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Introduction

The beef cattle industry in the southeastern US relies primarily on the use of high-forage diets to develop replacement heifers, maintain the cow herd, and sustain stocker operations. However, forage quantity and quality changes with season and environmental conditions. Depending on the physiological state and animal category, forage-based diets may not always meet 100% of the nutritional requirements, resulting in body weight loss or reduced performance if supplemental nutrients are not provided (Funston et al., 2012). Cattle experience nutrient restriction more often than realized because of overgrazing situations and a lack of forage frequently observed throughout the state.

There are two typical priorities related to feeding beef cows. First, provide the cheapest diet possible to reduce annual feeding costs and secondly, provide enough nutrients to prevent reproductive failure. It is well known that poor cow nutrition can decrease reproductive performance. If cows' nutrient requirements are not met before calving, they will start mobilizing nutrients from their own reserves to survive and to maintain fetal calf growth. Consequently, it is likely that these cows will calve at a low body condition score **(BCS**). The BCS system is an indicator of the percentage of body fat during the cow's production cycle, and it is a crucial determinant of their reproductive performance and productivity. Cows will not conceive at an acceptable rate (generally >85%) without adequate body fat reserves (BCS = 5; 1 to 9 scale). A low BCS at the time of calving (less than 5) extends the *anestrous period*, which is the period when the cow is recovering from calving and is not cycling. An extended anestrous period decreases the percentage of cows that are cycling and able to breed at the start of the breeding season, leading to lower pregnancy rates as shown in **Figure 1**. As BCS at calving decreases, pregnancy rates also decrease (**Figure 1**). In addition, pregnancy will probably occur at the end of the breeding season, delaying the subsequent calving and leaving less time to recover before the next breeding season.

Recently, multiple studies have demonstrated that cow nutrition can impact more than just pregnancy rates. In this publication, we will summarize some of the recent data showing the effects of poor cow nutrition on subsequent calf growth and health (fetal programming concept).

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Fetal programming

Fetal programming is the concept that a maternal stimulus or insult at a critical period in fetal development has long-term effects on the offspring (Funston et al., 2010). Approximately 75% of calf fetus growth occurs during the last two months of gestation (Robinson et al., 1977). Calf nutrient requirements are therefore relatively low during the first two trimesters of gestation. For that reason, many people believed that cow nutrition could only affect calf growth during the last trimester of gestation. Recent data demonstrate that this is not the case.

Maximal placental growth, differentiation, and vascularization occur during the early phase of fetal development. The placenta is the major regulator of calf fetal growth, and it appears that maternal nutrition may affect the development and function of the placenta (Funston et al., 2010). In addition, most of calf organs form simultaneously with placental development during early gestation. For instance, pancreas, liver, adrenals, lungs, thyroid, spleen, brain, thymus, and kidneys start to develop at 25 days of pregnancy (Hubbert et al., 1972). Each organ and tissue has its own "window" of formation. For example, organs such as kidneys and pancreas develop during early gestation, whereas muscle and adipose tissue formation occurs primarily during mid to late gestation (Du et al., 2010). Thus, nutrient restriction during gestation might impact placental formation and calf organ development. Also, depending on when the nutrient restriction happens during gestation, the outcome of this insult might have different consequences on calf performance. We will report how cow nutrient restriction during early, mid, and late gestation might differently affect the subsequent calf performance.

Consequences of Nutrient Restriction

Early Gestation (0 to 3 months of gestation)

Cows must conceive within 80 days postpartum if a yearly calving interval is desired. Cows' milk production and nutrient requirements peak at 60 days postpartum; however, intake lags behind. This results in negative energy balance during early to mid lactation (NRC, 1996), especially if cows are managed to calve during the dry or winter seasons when poor forage quality and quantity is available.

Unfortunately, a limited amount of published results exists regarding the effects of cow nutrient restriction during early gestation on beef calf performance. A University of Wyoming study evaluated the growth performance and organ development of calves born to cows experiencing nutrient restriction during the first trimester of gestation (Long et al., 2010). In that study, cows were separated into two groups that were fed at 55 or 100% of their nutrient requirements for the first 83 days of gestation. Following 83 days, both groups were provided 100% of their nutrient requirements until calving. Understandably, cows provided 55% of their nutrient requirements lost 137 lb of body weight, whereas cows fed 100% of their nutrient requirements gained 95 lb of body weight during the first 83 days of gestation. No differences were observed on calf birth weight, weaning weights, and average daily gain from birth to weaning or during the feedlot finishing phase (**Table 1**). However, lung and trachea weights of steers born to heifers provided 55% of their nutrient requirements were significantly less than steers born to heifers fed 100% of their nutrient requirements (**Figure 2**). Although growth performance was not affected, it would be misleading to interpret these results as if nutrient restriction during early gestation could not impact calf performance. In a commercial feedlot, calves are constantly exposed to several pathogens and commingled with calves of unknown health background. It is therefore possible that smaller lungs could be detrimental to calf performance if those calves experience bovine respiratory disease after entering a commercial feedlot. However, additional studies are needed to confirm this hypothesis.

Mid Gestation (3 to 6 months of gestation)

Production-oriented tissues, such as muscle, appear to be responsive to fetal programming effects in utero (Caton and Hess, 2010). Muscle formation is divided into two waves of muscle fiber synthesis. The first wave begins at mid gestation, whereas the second wave occurs from six to nine months of gestation (Du et al., 2010). Thus, nutrient restriction during mid gestation is expected to decrease muscle fiber formation, leading to lower birth and weaning weights.

At the University of Wyoming, researchers evaluated the growth performance of steers born to cows grazed on low-quality, native pastures (6% crude protein) or high-quality, fertilized and irrigated pastures (11% crude protein) for 60 days from 120 to 150 days through 180 to 210 days of gestation (Underwood et al., 2010). In that study, researchers reported that body weight at weaning and carcass weights were reduced for male offspring born to cows grazed on native pastures compared to male offspring born to cows grazed on improved pastures during mid gestation (**Table 2**). In addition, the Warner-Bratzler shear force, which is an indicator of meat tenderness, was less for *Longissimus* muscle samples of male offspring born to cows grazed on improved pastures (31 vs. 37 N; $P = 0.004$). In other words, cows that grazed on improved pastures during mid gestation produced calves that were heavier at weaning and harvesting, and that had greater meat tenderness at slaughter.

Nutrient restriction during mid gestation also may have consequences on organ development. Angus × Gelbvieh cows were randomly allotted into groups and fed at 70 or 100% of their nutrient requirements from day 45 to 185 of gestation. They were then commingled and fed at 100% of their nutrient requirements from day 185 of gestation until calving (Long et al., 2012). Although body weight at birth and at weaning did not differ ($P \geq 0.19$) between treatments, heifers born to cows fed at 70% of their nutrient requirements had smaller ovaries and luteal tissue (**Figure 3**). Luteal tissue is crucial for progesterone synthesis and pregnancy maintenance. Therefore, smaller ovary and luteal tissue could affect cows' reproductive performance during their first breeding season. Additional studies are required in this area to confirm these results and evaluate long-term effects of nutrient restriction during mid gestation on subsequent reproductive performance of the heifer progeny.

Late Gestation (6 to 9 months of gestation)

Late gestation is probably the most important gestation period in terms of potential impact on production-oriented tissues such as muscle and adipose tissue. As mentioned before, major portions of beef cattle muscle and adipose tissue form during late gestation (Du et al., 2010). Muscle fiber number is set at birth, meaning that after the calf is born, there is no net increase in the number of existing muscle fibers. Thus, if nutrient restriction during late gestation reduces muscle fiber number (Zhu et al., 2004), calf growth performance following birth might be compromised. In addition, maternal nutrient restriction may also compromise adipocyte populations (cells responsible for accumulating fatty acids and generating intramuscular fat, for example), resulting in carcasses with lower quality and marbling scores.

In a series of studies from the University of Nebraska (Stalker et al., 2006, 2007; Larson et al., 2009), researchers evaluated the effects of providing protein supplementation during late gestation on subsequent offspring performance (**Table 3**). Cows were sorted into groups that received or did not receive 1 lb/day of a protein supplement (42% crude protein) during late gestation. All studies reported that male offspring born to cows that received the protein supplement were heavier than male offspring born to non-supplemented cows. In addition, two of those three studies (Stalker et al., 2007; Larson et al., 2009) reported heavier carcasses for males born to cows that were supplemented with protein, whereas one study (Larson et al., 2009) reported greater percentages of carcasses grading Choice and greater marbling scores for steers born from cows that were supplemented with protein during late gestation.

Similar studies from the University of Nebraska also evaluated the effects of supplementing beef cows with 1 lb/day of a protein supplement during late gestation (**Table 4**). In those studies, weaning weights (Martin et al., 2007) and weights adjusted for 205 days of age (Funston et al., 2010) were greater for heifers born to cows that received protein supplementation during late gestation. In addition, heifers born to cows that were supplemented achieved puberty at younger ages (Funston et al., 2010) and had greater pregnancy rates (Martin et al., 2007) than heifers born to cows that did not receive protein supplementation (**Table 4**).

Progeny health

Few reports have focused on the effects of maternal nutrition during gestation on calf health. Corah et al. (1975) reported increased morbidity and mortality rates in beef calves born to primiparous heifers receiving 65% of their dietary energy requirement over the last 90 days of gestation compared with calves from primiparous heifers receiving 100% of their energy requirement. A potential factor contributing to increased morbidity and mortality is decreased calf birth weight. Calves born to nutrient-restricted cows were 5 lb lighter at birth compared to calves born from cows receiving adequate nutrition (Corah et al., 1975).

Larson et al. (2009) observed no differences in the number of calves treated for bovine respiratory disease (**BRD**) from birth to weaning. However, less calves had to be treated for BRD after feedlot entry if they were born from cows provided 1 lb/day of a protein supplement for the last 90 days of gestation compared to calves from non-supplemented cows. Stalker et al. (2006) reported increased proportions of live calves weaned to dams offered supplement during late gestation; however, there was no difference in the number of calves treated for BRD before weaning or in the feedlot.

Our research conducted at North Carolina State University reported no differences on calf birth weight and pre-weaning growth performance of calves born from cows that received either 70% or 100% of their energy requirements during the last 40 days of gestation (Moriel et al., 2016). However, calves born to cows that were fed 70% of energy requirements during the last 40 days of gestation had lower overall plasma concentrations of cortisol (indicator of stress level) and haptoglobin (indicator of inflammatory response) compared to calves born to cows fed at maintenance levels (**Table 5**). Also, calves born to cows that were energy restricted during late gestation produced less antibodies against bovine viral diarrhea virus, which is one of the main pathogens that cause BRD. These results together indicate that calves born to cows that were energy restricted for just 40 days before calving had an immune system that is not responsive and potentially "weaker" than calves born to cows that were fed at maintenance levels during late gestation. Therefore, even though calf growth performance was not affected, calves might be more susceptible to diseases if they are born to cows that were energy restricted. More studies need to be conducted in this research area as it has substantial implications to cow-calf producers, and this need will be addressed by our research group at Ona, FL.

Fetal-programming research in Florida Beef Herds

It is important to highlight that all studies mentioned above were conducted with *Bos taurus* cows grazing cool-season forages, and not with cows having *bos indicus* genetic influence and consuming low-quality, warm-season forages that represent most pastures in FL. It is unknown if cows and calves will experience similar positive (or negative) results mentioned above under our environmental conditions. Thus, starting in May 2017, our research group will focus on evaluating the impact of fetal programming on growth, reproduction, health, and carcass quality of offspring born to cows grazing warm-season grasses and exposed to climatic conditions of FL.

To begin our efforts, we successfully obtained funding from the FL Cattle Enhancement Fund from FL Cattlemen's Association to conduct 2 long-term experiments at the Range Cattle Research & Education Center (Ona, FL) and commercial operations located in the South/Central part of FL.

Experiment 1 will begin in May 2017 and will evaluate if year-round supplementation of energy and protein could improve cow reproductive success and offspring performance following birth compared to a Fall/Winter supplementation program traditionally used in FL beef cattle operations. Pregnant cows will be sorted into 3 groups, and will be provided molasses supplementation from calving until the end of the breeding season (CONTROL), or year round supplementation of molasses or range cubes. Total annual amount of supplement will be similar among all treatments (approximately 600 lb of supplement dry matter/cow annually). Optimal BCS at calving is one of the most important factors needed to obtain successful pregnancy rates. Cows supplemented year-round might achieve a greater BCS at calving without increasing the annual supplement amount. Another advantage is that the trace mineral salt can be mixed into the supplement, reducing annual fluctuations in voluntary intake and wastage of free-choice trace mineral formulations, and simultaneously improve cow trace mineral status. We believe that year-round supplementation of molasses or range cubes will increase BCS at calving and trace mineral status of cows throughout the year, which will enable cows to experience greater BCS loss during early-lactation without reducing their reproductive performance compared to cows supplemented with molasses during the Winter/Fall season only. In addition, year-round supplementation of molasses and range cubes will improve calf development during pregnancy, and then, improve calf health, survivability, and growth following birth.

Experiment 2 will begin in September 2017 and will evaluate: (1) if supplementation of Brangus cows during the entire late-gestation period (1 lb/day of protein supplement for 90 days = 90 lb per cow) will increase reproductive success of cows, calf development during gestation and performance after birth to levels higher than the cost of this supplementation strategy, and (2) if concentrating cow supplementation during their period of lowest nutrient demand (first 30 days after weaning) will be more cost-effective than cows supplemented during the entire late-gestation period. We believe that cows supplemented during late-gestation, regardless of length of supplementation, will have greater profitability than non-supplemented cows due to improvements on cow reproduction and calf performance. We also believe that supplementing 3 lb/day for 30 days after weaning will reduce feeding costs, have the greatest improvement on cow weight gain and reproduction success, but not cause fetal-programming effects (due to the shorter supplementation period). In contrast, supplementation of 1 lb/day for 90 days will have greater labor costs, lower improvement on reproduction, but enhance calf development during gestation and performance after birth.

Conclusions

Nutrient deficiency often occurs in animals provided forage-based diets due to seasonal variation in forage quality and quantity, and because of mismanagement leading to overgrazed pastures. This nutrient deficiency has been shown to impact the reproductive performance of cows, the subsequent growth and reproductive performance of calves, and meat quality. Hence, closer attention and proper nutrition of the herd need to be enforced to avoid or alleviate the negative impacts of nutrient restriction during gestation on cow and calf performance. Furthermore, this publication focused solely on the effects of gestational nutrient restriction. It is important to realize that excessive nutrient consumption (energy, protein, minerals, vitamins, and fatty acids), diet composition (starch concentration), energy and protein sources, and stress also have potential for programming calf development in utero. Thus, cow-calf nutrition termed “fetal programming” has large implications for the beef industry and merits producer attention and further research attention in the future.

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Figure 1. Pregnancy rates of cows calving at different body condition scores (BCS; Selk et al., 1988; n = 300 multiparous cows).

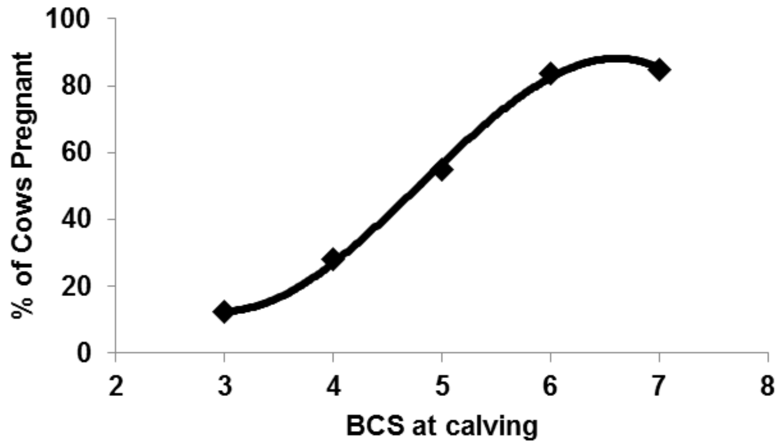

Figure 2. Lung plus trachea weights of steers born to first-calf heifers provided 55 or 100% of their nutrient requirements during the first 83 days of gestation (n = 10 steers per treatment; *$P < 0.05$).

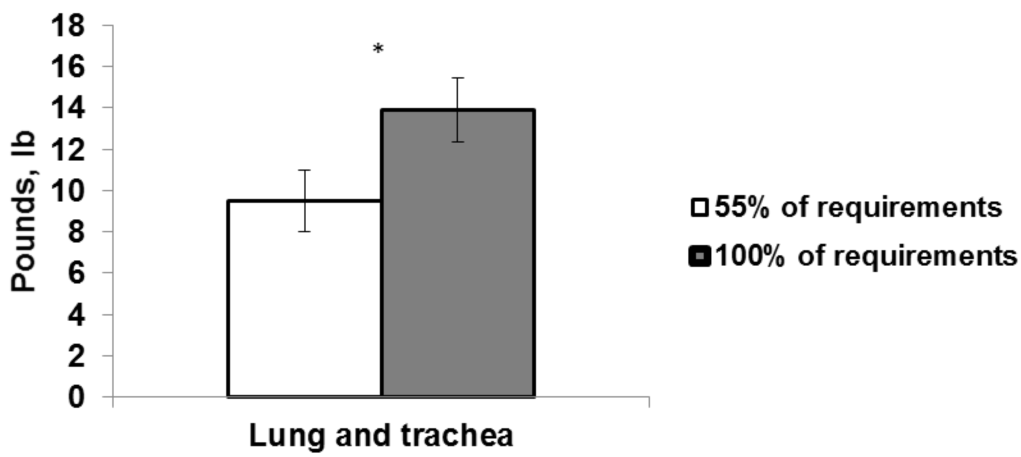

Figure 3. Wet ovary and luteal tissue weights of heifers born to cows provided 70 or 100% of their nutrient requirements from 45 to 185 days of gestation (Long et al., 2012; n = 4 heifers per treatment; 13 months of age; *$P < 0.05$).

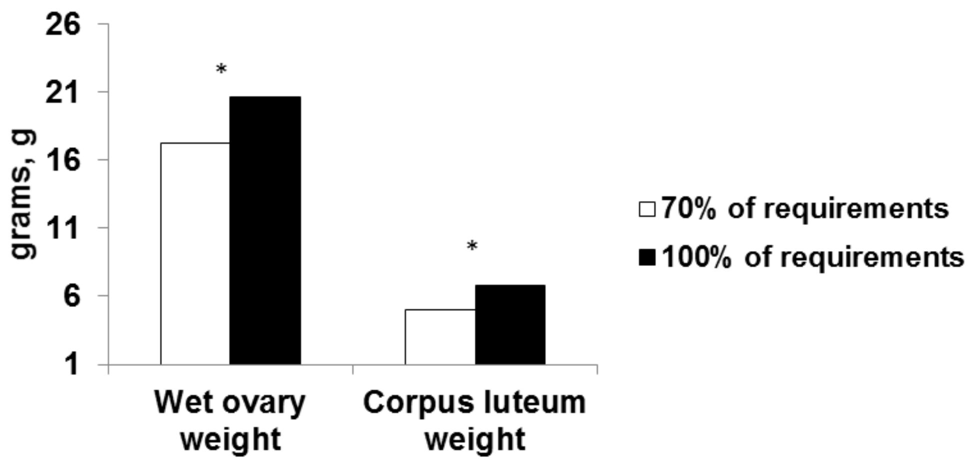

Table 1. Growth performance of male offspring born to first-calf heifers fed 55 or 100% of their nutrient requirements during the first 83 days of gestation (Long et al., 2010).

	Steers born to heifers fed:			
	55% of requirements	100% of requirements	SEM	*P*-value
Body weight, lb				
Birth	69	71	2.8	0.31
Weaning	491	480	26.4	0.32
Average daily gain, lb				
Birth to weaning	1.8	1.9	0.08	0.14
During finishing	4.9	4.6	0.28	0.40

Table 2. Growth performance of male offspring born to cows grazed on native (6% crude protein) or improved pastures (11% crude protein) for 60 days during mid gestation (Underwood et al., 2010).

	Grazing management during mid gestation			
	Native pastures	Improved pastures	SEM	*P*-value
Birth, lb	85	81	4.4	0.46
At weaning, lb	533	564	8.1	0.02
At slaughter, lb	1145	1198	17.0	0.04
Hot carcass weight, lb	726	767	10.6	0.04

Table 3. Growth performance and carcass quality of male offspring born to cows that received (Supp.) or did not receive (No Supp.) protein supplementation (1 lb daily of a 42% crude protein supplement) during late gestation (*$P < 0.05$).

	Stalker et al. (2007)		Stalker et al. (2006)		Larson et al. (2009)	
Item	No Supp.	Supp.	No Supp.	Supp.	No Supp.	Supp.
Weaning weight, lb	441*	463*	465*	480*	518*	531*
Carcass weight, lb	764*	804*	800	813	802*	819*
Choice, %	-	-	85	96	71*	86*
Marbling	449	461	467	479	444*	493*

Table 4. Growth and reproductive performance of heifers born to cows that received (Supp.) or did not receive (No Supp.) protein supplementation (1 lb daily of a 42% crude protein supplement) during late gestation (*$P < 0.05$).

	Martin et al. (2007)		Funston et al. (2010)	
Item	No Supp.	Supp.	No Supp.	Supp.
Weaning weight, lb	456	467	496*	511*
Adj. 205-day weight	480*	498*	469	478
Age at puberty, days	334	339	366*	352*
Pregnancy rate, %	80*	93*	80	90

Table 5. Immune response of calves born to beef cows offered diets formulated to meet 100% of energy requirements (Maintenance) or 70% of energy requirements (Restricted) during late gestation (day 0 until calving; approximately 40 days before calving; Moriel et al., 2016).

	Maternal Diet			
Item	Maintenance	Restricted	SEM	*P*-value
Post-weaning phase (day 266 to 306)				
ADG, lb	1.8	1.9	0.13	0.59
Plasma cortisol, ng/mL	17.5	13.7	1.53	0.05
Plasma haptoglobin, mg/mL	0.53	0.42	0.043	0.10
Serum antibody titers against BVD-1a, log_2	6.36	5.15	0.463	0.05

SESSION NOTES