Proceedings, Applied Reproductive Strategies in Beef Cattle
September 4-5, 2024, Athens, GA

COW HERD NUTRITION DURING PREGNANCY: IMPACT ON SUBSEQUENT FERTILITY AND OFFSPRING PERFORMANCE

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Introduction

The beef cattle industry in Southeast 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 and a lack of forage frequently observed throughout the state.

It is well reported in the literature that cows will not conceive at an acceptable rate without having adequate body fat reserves at calving (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. 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 nutrition of *Bos taurus* cows on subsequent calf growth and health (Fetal programming), and the discuss the potential impact of *Bos indicus* genetics on the outcomes of fetal programming, as well as the current research being conducted by our laboratory at the Range Cattle Research & Education Center - University of Florida.

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 fetal 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.

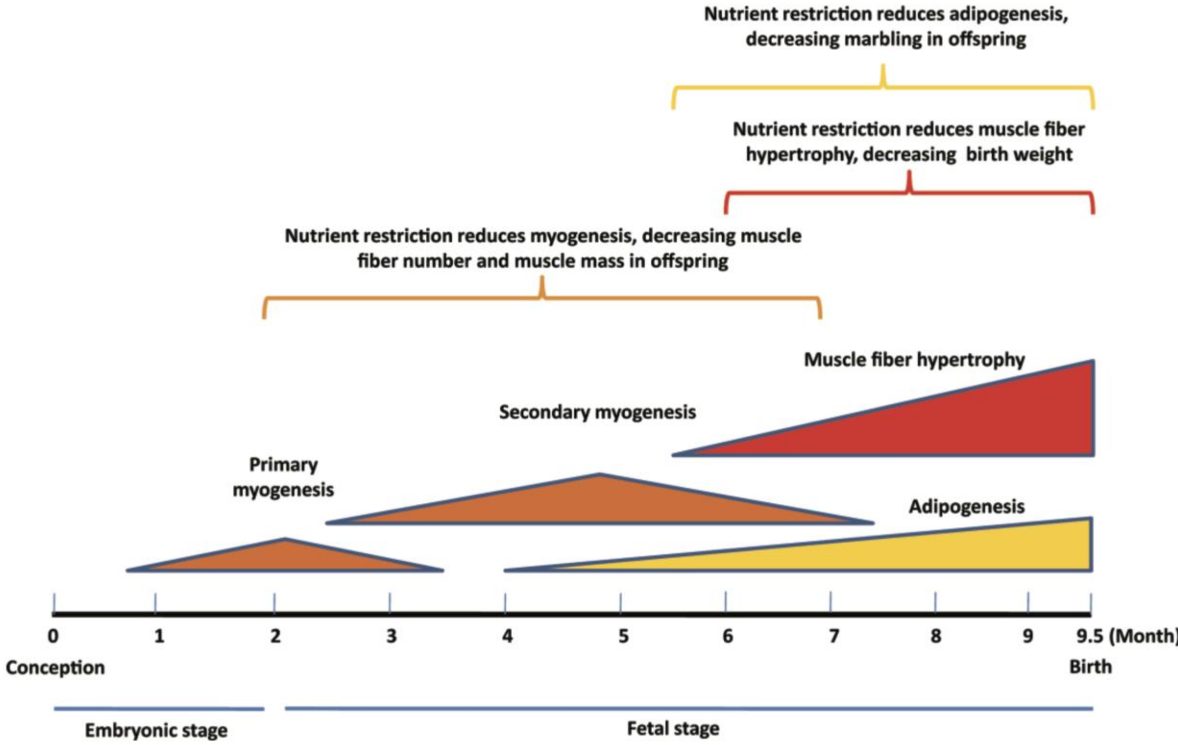
Maximal placental growth, differentiation, and vascularization occur during the early phase of fetal development. The placenta is the major regulator of calf fetal growth, and it appears that maternal nutrition may affect the development and function of the placenta (Funston et al., 2010). In addition, 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 have its own “window” of formation. For example, organs such as kidneys and pancreas occur during early gestation, whereas muscle and adipose tissue formation occurs primarily during mid to late gestation (Du et al., 2010). Thus, nutrient restriction or excess during gestation might impact placental formation and calf organ development. Also, depending on when the nutrient restriction or excess occurs during gestation, the outcome of this insult to calf performance might differ.

Muscle and adipose tissue formation

Muscle fiber development can be separated into prenatal and postnatal stages (Du et al., 2017). During bovine fetal development, the formation of primary muscle fibers occurs within the first 2 months after conception (Russell and Oteruelo, 1981), whereas the formation of secondary muscle fibers (which represents most of muscle fibers) occurs between 2 and 7 months of gestation (Du et al., 2010). Subsequently, the formation of new muscle fibers is limited, and muscle growth occurs primarily by the increase in size and length of each muscle fiber (Figure 2; Du et al., 2017). Therefore, reducing the proliferation of precursors for muscle fibers decreases the number of muscle fibers, which has irreversible negative effects on offspring muscle growth after birth (Zhu et al., 2006). Proper maternal nutrition provides nutrients needed for proliferation and formation of muscle fibers (Du et al., 2017). Because skeletal muscle has a lower priority in nutrient partitioning compared with the brain, heart, and liver, muscle development is highly vulnerable to the variation in nutrient availability (Zhu et al., 2006). Also, insufficient maternal nutrition reduces the concentration of insulin growth factors 1 and 2 (IGF-1 and IGF-2) in fetal circulation, which also decreases the development of muscle fibers (Gonzalez et al., 2013).

Adipose tissue development is also profoundly affected by maternal nutrition. There are 4 fat tissue depots in animals: visceral, subcutaneous, intermuscular, and intramuscular fat (Du et al., 2017). Intramuscular fat (also referred as marbling) contributes to the flavor and juiciness of meat. However, visceral, subcutaneous, and intermuscular fat comprise the majority of body fat tissue reserves and have low commercial value. To accumulate these fat tissue reserves, a large amount of nutrients is required, leading to a reduction on feed efficiency (Du et al., 2017). Therefore, studies are being conducted to enhance marbling deposition while reducing fat accumulation in other depots. The mass of fat tissue is determined by the number and size of adipocytes. The number of adipocytes is mostly determined during the fetal and early postnatal development, reaching maximum total number of adipocytes at adolescence (Spalding et al., 2008). In beef cattle, visceral and subcutaneous fat develop primarily from mid-gestation to neonatal stage, whereas the formation of intramuscular adipocytes occurs primarily from late gestation until approximately 250 days of age (Figure 1). This chronological difference in adipocyte formation provides an opportunity to enhance marbling adipocyte formation without increasing overall adiposity of beef cattle (Corah and McCully, 2007; Du et al., 2013).

Figure 1. Muscle and adipose tissue development (Du et al., 2010).



Consequences of Nutrient Restriction to *Bos taurus* cattle

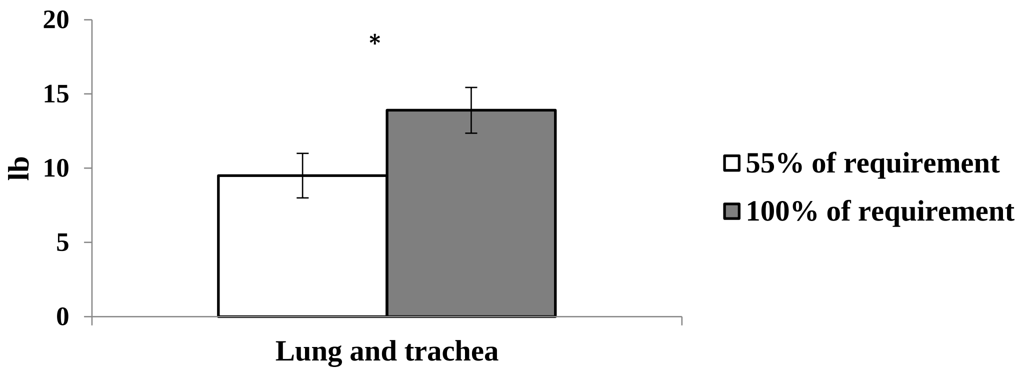
Early Gestation (0 to 3 months of gestation)

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. This results in negative energy balance during early to mid-lactation (NRC, 1996), especially if cows are managed to calf 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 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.

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	68	70	2.9	0.31
Weaning	491	480	26.4	0.32
Average daily gain, lb/day				
Birth to weaning	1.81	1.89	0.09	0.14
During finishing	4.85	4.62	0.29	0.40

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; *$P < 0.05$).



Mid Gestation (3 to 6 months of gestation)

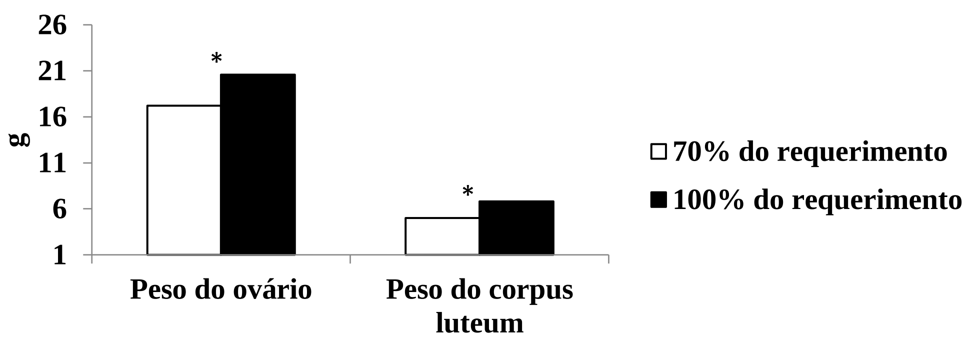
As described above, nutrient restriction during mid gestation is expected to decrease muscle fiber formation, leading to lower birth and weaning weights. At the University of Wyoming, researchers evaluated the growth performance of steers born to cows grazed on low-quality, native pastures (6% crude 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 (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 may also have consequences on organ development. Angus × Gelbvieh cows were fed either 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.

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	86	79	4.4	0.46
At weaning, lb	533	564	8.1	0.02
At slaughter, lb	1145	1198	16.9	0.04
Hot carcass weight, lb	726	767	10.6	0.04

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; 13 months of age; *$P < 0.05$).



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. 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 intramuscular fat, for example), resulting in carcasses with lower quality and marbling scores.

In a series of studies (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 the male offspring born to cows that received protein supplementation were heavier than male offspring born to non-supplemented cows. Also, two of those 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 derived from cows that were supplemented with protein during late gestation.

Similar studies evaluated the effects of supplementing beef cows with 1 lb/day of a protein supplement during late gestation (Table 3). 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. Also, heifers born to cows that were supplemented achieved puberty sooner (Funston et al., 2010) and had greater pregnancy rates (Martin et al., 2007) than heifers born to cows that did not receive supplementation (Table 4).

Table 3. Performance 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*	808*
Choice, %	-	-	85	96	71*	86*
Marbling scores	449	461	467	479	444*	493*

Table 4. 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, lb	480*	498*	469	478
Age at puberty, days	334	339	366*	352*
Pregnancy rate, %	80*	93*	80	90

Offspring 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 2.3 kg 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 (BVDV), 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.

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				
ADG (42 days after weaning), lb/day	1.81	1.89	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 BVDV-1a, *log_2*	6.36	5.15	0.463	0.05

Fetal-programming research in Southeast USA

STUDY 1: Timing of protein and energy supplementation during late gestation (Palmer et al., 2022).

Figure 4. Total daily energy requirements (NEm), Mcal/day

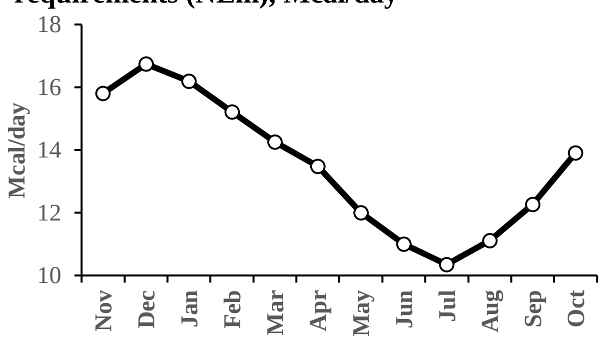


Figure 4 represents the daily energy requirement of a mature Brangus cows calving in November and weaning its calf in July. Within a production cycle, nutrient demand of cows achieves the lowest levels during the first 30 days after calf weaning, then exponentially grows during late gestation. This occurs because approximately 2 thirds of calf fetus growth occur during the last 90 days of gestation. However, late gestation also corresponds with the beginning of Fall/Winter seasons when forage nutritional value and availability are low. Several cow-calf operations do not provide any kind of supplementation before calving, and inadequate dietary energy/protein during late pregnancy lowers reproduction even if the amount of energy and protein consumed after calving are sufficient (Perry et al., 1991).

Recent studies have shown that the supplementation of energy and protein during the entire-late gestation can improve postnatal offspring growth and health. It is important to highlight that most of the 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 results under our environment conditions. Hence, study #2 will: **(1)** evaluate if supplementation of Brangus cows during the entire late-gestation (August to November) 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)** investigate if concentrating cow supplementation during their period of lowest nutrient demand (first 6 weeks after weaning) will be more cost-effective than cows supplemented during the entire late-gestation (Palmer et al., 2022).

Our group believes 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. Second, we believe that supplementing **4.4 lb per day for 6 weeks after weaning (day 0 to 45, relative to weaning; 185 lb per cow)** will reduce labor costs by half, have the greatest improvement on cow weight gain and reproduction success, but not cause fetal-programming effects (due to the shorter supplementation period), whereas the supplementation of **2.2 lb per day for 12 weeks after weaning (day 0 to 84, relative to weaning; 185 lb per cow)** will have greater labor costs, have a lower improvement on reproduction, but enhance calf development during gestation and performance after birth.

Partial results: Cows receiving 2.2 lb per day of DDG from day 0 to 84 had greater body condition score on days 45 and 84 compared to cows receiving no supplementation (Table 6). This improved nutritional status during late gestation and at calving is expected to improve subsequent reproductive performance of cows and postnatal calf performance due to fetal programming effects. In agreement with our hypothesis, cows supplemented with 4.4 lb per day of DDG from day 0 to 45 had the greatest body condition score on days 45 and 84 (Table 6). These results indicate that by concentrating the total amount of supplementation during the period of lowest nutritional requirements of cows (first 45 days after weaning), producers will harvest a greater improvement on cow body condition score and reduce labor by half compared to providing smaller amounts of supplement for a longer period. Like study #1, cows receiving no supplementation (NOSUP cows) lost body condition score during the last half period of late gestation (day 45 to 84), whereas cows supplemented with 2.2 lb per day of DDG from day 0 to 84 increased their body condition score, which might have different outcomes to postnatal calf immunity as reported by Moriel et al. (2016). Surprisingly, cows that received 4.4 lb per day of DDG supplementation from day 0 to 45, but no supplementation from day 45 to 84, also increased their body condition score from day 45 to 84. Reasons for this response are not known yet. By the time this article was prepared, reproductive performance of cows and calf postnatal performance were not available. Like study 1, we will evaluate the immunity and growth performance of all calves after birth. Steers will be sent to a feedlot for finishing and carcass data collection, and heifers will be developed until the end of their first breeding season.

Table 6. Growth performance of cows that received no supplementation (NOSUP), and cows that were supplemented with 4.4 lb per day of DDG for 6 weeks after weaning (day 0 to 45; SUP6) or with 2.2 lb per day of DDG for 12 weeks after weaning (day 0 to 84; SUP12).

	Treatment				P-value	
Item	**NOSUP**	**SUP6**	**SUP12**	**SEM**	**Treatment x day**	**Treatment**

Cow body condition score (BCS)						
day 45	5.61^{a}	6.15^{c}	5.81^{b}	0.087	<0.0001	<0.0001
day 84	5.29^{a}	6.36^{c}	6.16^{b}	0.090		
Cow BCS change						
day 0 to 45	0.53^{a}	1.04^{c}	0.74^{b}	0.096		0.0001
day 45 to 84	-0.31^{a}	0.22^{b}	0.37^{b}	0.129		0.0001

[a-b] Within a row, means without a common superscript differ ($P \leq 0.05$).
[1]Covariate-adjusted to cow body weight and BCS obtained on d 0 ($P \leq 0.05$).

STUDY 2: Does frequency of supplementation before calving impact cow and calf performance? (Izquierdo et al., 2022)

Decreasing the supplementation frequency (1 or 3 times weekly vs. daily) is a common strategy that reduces labor and feeding costs when longer periods of supplementation are needed, but it may also impact blood concentrations of hormones and metabolites that are important for cow reproductive performance and fetal development. The following study was designed to identify the lowest frequency of precalving supplementation that could be implemented without reducing the performance of cows and calves. Treatments started in September (80 days before calving) and consisted of cows receiving no precalving supplementation, and cows fed 2.2 lb of dried distillers grains (DDG) every day until calving (**7X cows**; total of 176 lb per cow), 5.13 lb of DDG every Monday, Wednesday, and Friday until calving (**3X cows**; total of 176 lb per cow), or 15.4 lb of DDG every Monday until calving (**1X cows**; total of 176 lb per cow). All cows and calves were managed similarly from calving until weaning.

All cows started the study with a BCS of 5.5. As expected, cows not offered precalving supplementation lost BCS and calved at a BCS of 4.75, whereas all cows that received precalving supplementation gained BCS. More importantly, frequency of precalving supplementation did not impact cow BCS at calving (*5.34 for 1X cows, 5.36 for 3X cows, and 5.45 for 7X cows*), indicating that frequency of supplementation could be reduced to 1 or 3 times weekly without sacrificing cow BCS at calving.

Calf body weight at weaning was less for calves born from cows that did not receive precalving supplementation (557 lb). However, **calf body weight at weaning decreased as we reduced the frequency of precalving supplementation (575 lb for calves born from 1X and 3X cows, and 593 lb for calves born from 7X cows).** Although cow performance was not impacted, decreasing the frequency of precalving supplementation was harmful to calf weaning weight. This study provided additional information on how to properly supplement pregnant beef cows in Florida. So far, we learned that cows need to be supplemented for the entire third trimester of gestation and more consistently (daily is better than 1 or 3 times weekly, which is better than offering no precalving supplementation) if the primary goal is to maximize calf body weight at weaning.

STUDY 3: Bakery waste: an alternative feed ingredient for pregnant beef females in Florida (Izquierdo et al., 2023).

Our recent study evaluated if bakery waste could be an alternative feed ingredient for pregnant beef females in Florida. Bakery waste consist of unused products, such as bread, bread rolls, biscuits, cakes, cookies, and dough, that did not meet consumer preferences of freshness or are due to expire. Nutritionally, bakery waste contains less starch and fiber but more sugars and fat from oilseeds rich in omega-6 fatty acids, which have been shown to benefit cow reproductive performance and fetal development. Our hypothesis was that precalving supplementation of bakery waste containing low or high concentrations of fat would enhance maternal circulating concentrations of omega-6 fatty acids during gestation and body condition score (**BCS**) at calving leading to increased offspring growth and immune function following birth compared to no supplementation. We also believed that bakery waste containing higher concentrations of omega-6 fatty acids would lead to the best results on calf performance.

The study began in August 2021 (70 days before calving) and finished in December 2022. Cows grazed bahiagrass pastures and received: no precalving supplementation (**NOSUP**); 2 lb/day of <u>low-fat bakery waste</u> from August until calving (**LFAT**); or 2 lb/day of a <u>high-fat bakery waste</u> from August until calving (**HFAT**). Low- and high-fat bakery supplements provided same amount of energy and protein. In June 2022, 40 heifers were weaned and assigned to a 45-day evaluation period of growth and immune response. Low-fat and high-fat bakery waste increased cow body condition score at calving by 0.73 and 0.54-unit, respectively, compared to no maternal supplementation. Although cow pregnancy rate did not differ, a greater percentage of cows conceived earlier and calved within the first 21 days of the calving season when they were offered high-fat bakery waste (86% vs. 68% and 71% for cows fed high-fat bakery waste, low-fat bakery waste, and no supplement). Calf birth body weight was not impacted by maternal treatment. However, calf weaning weight were highest for calves born from cows offered low-fat bakery waste (537 lb), intermediate for calves born from cows fed high-fat bakery waste (515 lb), and lowest for calves born from cows that were not supplemented (500 lb). In terms of immune function, serum antibody titers produced against 2 viruses that cause bovine respiratory disease (infectious bovine rhinotracheitis and bovine respiratory syncytial virus) were greatest at the end of the vaccination protocol for calves born from cows fed high-fat bakery waste. In summary, low-fat bakery waste led to greatest calf weaning weight whereas high-fat bakery waste enhanced maternal reproduction and had minor benefits to calf post-vaccination immune response. **Precalving supplementation of bakery waste is an additional economic feasible strategy for Florida beef producers**.

Final comments

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 cattle breed, 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.

Literature Cited

Corah, L. R., T. G. Dunn, and C. C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819–824.

Corah, L., and M. McCully. 2007. Declining quality grades: A review of factors reducing marbling deposition in beef cattle. Certified Angus Beef LLC. http://www.cabpartners.com/news/research/declining_quality_grades.pdf.

Du, M., Y. Huang, A.K. Das, Q. Yang, M.S. Duarte, M.V. Dodson, and M.J. Zhu. 2013. Meat science and muscle biology symposium: Manipulating mesenchymal progenitor cell differentiation to optimize performance and carcass value of beef cattle. J. Anim. Sci. 91:1419–1427. doi:10.2527/jas.2012-5670

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. J. Anim. Sci. 88:E51–E60.

Du, M., S. P. Ford, and M. Zhu. 2017. Optimizing livestock production efficiency through maternal nutritional management and fetal developmental programming. Animal Frontiers 7:5-11.

Funston, R. N., D. M. Larson, and K. A. Vonnahme. 2010. Effects of Maternal Nutrition on Conceptus Growth and Offspring Performance: Implication for Beef Cattle Production. J. Anim. Sci. 88:E205-E215.

Funston, R. N., A. F. Summers, and A. J. Roberts. 2012. Implications of Nutritional Management for Beef Cow-Calf Systems. J. Anim. Sci. 90:2301-2307.

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. J. Anim. Sci. 87:1147–1155.

Gonzalez, J.M., L.E. Camacho, S.M. Ebarb, K.C. Swanson, K.A. Vonnahme, A.M. Stelzleni, and S.E. Johnson. 2013. Realimentation of nutrient restricted pregnant beef cows supports compensatory fetal muscle growth. J. Anim. Sci. 91:4797–4806.

Hubbert, W. T., O. H. V. Stalheim, and G. D. Booth. 1972. Changes in Organ Weights and Fluid Volumes during Growth of the Bovine Fetus. Growth 36:217-233.

Izquierdo, V., M. Vedovatto, E. A. Palmer, R. A. Oliveira, H. M. Silva, J. M. B. Vendramini, and P. Moriel. 2022. Frequency of maternal supplementation of energy and protein during late gestation modulates preweaning growth of their beef offspring. Trans. Anim. Sci. 6(3):txac110. doi:10.1093/tas/txac110

Izquierdo, V. S., J. V. L. Silva, E. Palmer, J. Ranches, J. H. J. Bittar, G. C. M. Santos, A. Pickett, R. F. Cooke, J. M. B. Vendramini, and P. Moriel. 2023. Bakery waste supplementation to late gestating Bos indicus-influenced beef cows successfully impacted offspring postnatal performance. J. Anim. Sci. 101:skad244. doi:10.1093/jas/skad244

Long, N. M., M. J. Prado-Cooper, C. R. Krehbiel, U. DeSilva, and R. P. Wettemann. 2010. Effects of Nutrient Restriction of Bovine Dams during Early Gestation on Postnatal Growth, Carcass and Organ Compositions, and Gene Expression in Adipose Tissue and Muscle. J. Anim. Sci. 88:3251–3261.

Long, N. M., C. B. Tousley, K. R. Underwood, S. I. Paisley, W. J. Means, B. W. Hess, M. Du and S. P. Ford. 2012. Effects of Early- to Mid-Gestational Undernutrition with or without Protein Supplementation on Offspring Growth, Carcass Characteristics, and Adipocyte Size in Beef Cattle. J. Anim. Sci. 90:197-206.

Martin, J. L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of Dam Nutrition on Growth and Reproductive Performance of Heifer Calves. J. Anim. Sci. 85:841–847.

Moriel, P., L. F. A. Artioli, M. B. Piccolo, M. H. Poore, R. S. Marques, and R. F. Cooke. 2016. Short-term energy restriction during late gestation and subsequent effects on postnatal growth performance, and innate and humoral immune responses of beef calves. J. Anim. Sci. 94:2542-2552.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th rev. ed. Washington, DC: Natl. Acad. Press.

Palmer, E. A., M. Vedovatto, R. A. Oliveira, J. Ranches, J. M. B. Vendramini, M. H. Poore, T. Martins, M. Binelli, J. D. Arthington, and P. Moriel. 2022. Timing of maternal supplementation of dried distillers' grains during late gestation influences postnatal growth, immunocompetence, and carcass characteristics of Bos indicus-influenced beef calves. J. Anim. Sci. 100(2):skac022. doi:10.1093/jas/skac022

Perry, R. C., L. R. Corah, R. C. Cochran, W. E. Beal, J. S. Stevenson, J. E. Minton, D. D. Simms, and J. R. Brethour. 1991. Influence of dietary energy on follicular development, serum gonadotropins, and first postpartum ovulation in suckled beef cows. J. Anim. Sci. 69:3762–3773.

Robinson, J. J., I. McDonald, C. Fraser, and I. McHattie. 1977. Studies on Reproduction in Prolific Ewes. I. Growth of the Products of Conception. J. Agric. Camb. 88:539-552.

Russell, R.G., and F.T. Oteruelo. 1981. An ultrastructural study of the differentiation of skeletal muscle in the bovine fetus. Anat. Embryol. (Berl.) 162:403–417.

Spalding, K.L., E. Arner, P.O. Westermark, S. Bernard, B.A. Buchholz, O. Bergmann, L. Blomqvist, J. Hoffstedt, E. Naslund, T. Britton, H. Concha, M. Hassan, M. Ryden, J. Frisen, and P. Arner. 2008. Dynamics of fat cell turnover in humans. Nature 453:783–787.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. M. Feuz, and R. N. Funston. 2006. Effects of Pre- and Postpartum Nutrition on Reproduction in Spring Calving Cows and Calf Feedlot Performance. J. Anim. Sci. 84:2582–2589.

Stalker, L. A., L. A. Ciminski, D. C. Adams, T. J. Klopfenstein, and R. T. Clark. 2007. Effects of Weaning Date and Prepartum Protein Supplementation on Cow Performance and Calf Growth. Rangeland Ecol. Manage. 60:578–587.

Underwood, K. R., J. F. Tong, P. L. Price, A. J. Roberts, E. E. Grings, B. W. Hess, W. J. Means, and M. Du. 2010. Nutrition during Mid to Late Gestation affects Growth, Adipose Tissue Deposition, and Tenderness in Cross-bred Beef Steers. Meat Sci. 86:588–593.

Zhu, M. J., S. P. Ford, P. W. Nathanielsz, and M. Du. 2004. Effect of Maternal Nutrient Restriction in Sheep on the Development of Fetal Skeletal Muscle. Biol. Reprod. 71:1968–1973.

Zhu, M.J., S.P. Ford, W.J. Means, B.W. Hess, P.W. Nathanielsz, and M. Du. 2006. Maternal nutrient restriction affects properties of skeletal muscle in offspring. J. Physiol. 575:241–250.