Impact of Maternal Nutrition on Calf Performance

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Introduction

Beef cattle production in the United States is currently facing many challenges. The nation's cow herd has continued to decline since its peak in 1975 (NASS USDA, 2010). A major reason for this decline in cow numbers is increased input costs, of which feed represents the greatest portion. Therefore, investigations on how to more efficiently produce beef from conception and how the environment may influence the final phenotype of the animal are critical. The phenotype of the animal is a combination of genetics and environment. While the genes the animal inherits from his/her parents cannot be changed, how the genes are expressed can be influenced by environmental factors, such as nutrition, from the time of conception. Most of the research in beef cattle feedlot nutrition has focused on post-weaning environmental influences on the final phenotype of the calf in regards to growth and carcass traits; however, recent research in the area of developmental programming has started to provide more insight into the impacts of early postnatal period and even gestational environment on lifetime productivity of humans and livestock species. Research has begun to demonstrate that maternal nutrition during gestation may impact progeny postnatal growth, health, feed efficiency, and carcass composition as outlined here.

Developmental Programming

The fetal origins hypothesis was first proposed by Dr. Barker based on epidemiological studies investigating low nutrient intake by pregnant mothers experience during the 1944 Dutch Famine of World War II and the resulting long-term health implication of their children. Dr. Barker reported low caloric intake during gestation induced drastic changes in developmental programming, thereby impacting the future health of offspring observed by an increased incidence of clinical conditions as obesity, insulin resistance, and type 2 diabetes (Barker et al., 2002).

Similarly, in domestic animal studies, maternal nutrition during gestation has been reported to impact postnatal body composition, insulin sensitivity, and growth rate, which all have implications for production efficiency and meat quality (Ford et al., 2007; Radunz et al., 2010 and 2012). Factors such as maternal nutrition, environment, or stressors during gestation can change nutrient supply to the fetus, which can then affect growth and development of organs, skeletal muscle tissue, and adipose tissue. These changes to the development of the fetus can alter postnatal skeletal muscle growth, fat

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deposition, insulin resistance, or hypertension of offspring, which can impact economically important traits such as growth rate, health, and carcass composition. To date, most of the research using animals have been focused on human health implications, but recent studies have investigated beef cow gestation nutrition and management to provide evidence of its implications to offspring productivity.

One of the mechanisms by which developmental programing may be explained is epigenetics. Epigenetics encompasses changes to marks on the genome early in development that are copied from one cell generation to the next, which may alter gene expression, but do not involve changes in primary DNA sequence. Epigenetic mechanisms such as DNA methylation and histone modifications (e.g., acetylation, methylation, and phosphorylation) can change genome activity under some environmental (nutrition or toxicants) conditions (Bollati and Baccarelli, 2010). A greater understanding of how maternal nutrition induces epigenetic modifications to adipose tissue would provide critical information in understanding pathways influencing postnatal adipose deposition.

Developmental windows of muscle and adipose tissues, economically important tissues in meat animal production, occur during gestation, which could influence production efficiency and carcass composition of the individual. Muscle hyperplasia (increasing cell number) starts in early gestation and terminates during mid-gestation. Any impact on muscle growth after this point time is achieved by hypertrophy (increasing cell size). Adipose tissue growth primarily begins during late gestation and adipose tissue hyperplasia can continue until maturity, however at a diminishing rate as the animal becomes older. Previous research in early weaning and high starch diets in beef cattle has already provided evidence of postnatal environmental influences on adiposity. In addition to these tissues, other developmental windows occur throughout gestation for the placenta, specific tissues, and organs. Therefore, not only does the type of environmental stress influence the final phenotype but also at what time in development the stress occurs. For example, nutrient restriction followed by adequate nutrition in early gestation results in larger birth weights in sheep compared to adequate nutrition, whereas nutrient restriction in late gestation results in lower birth weights (Munoz et al., 2008). Collectively, these studies and other research has provided evidence that the developmental windows occur from periconception to early postnatal life of the animal (Fowden et al., 2006).

Post-Weaning Growth Traits

Milk production postpartum can be influenced by prepartum nutrition of the dam, which could have development programming implications. Cows receiving an energy-deficient gestation diet verses a high-energy diet, had lower milk production (Corah et al., 1975). Additionally, cows allowed limited vs. ad libitum grazing access prepartum had a 9% decrease in early lactation milk production (Kearnan and Beal, 1992). Over and under nutrition of ewes resulted in decreased IgG concentration, nutrient content, and volume of colostrum in milk (Swanson et al., 2007). Studies have reported prepartum restriction of nutrients resulted in a decrease in colostral IgG (Shell et al.,

1995) and absorption of IgG by calves. Effective passive transfer of IgG in colostrum is vital to calf health and immunity (Perino et al., 1995). These studies indicate that late gestation nutrition impacts mammary gland development, which could impact postpartum milk production and passive immune transfer thus impacting postnatal growth and health.

Most studies investigating gestational nutrition on progeny performance have used gestating sheep as a biomedical model and have focused on the effects of global under-nutrition (McMillen et al., 2001; Ford et al., 2007) and global over-nutrition (Wallace et al., 2002; Long et al., 2010). These studies have reported an association between maternal nutrient intake and progeny's postnatal body composition and glucose metabolism as well as indicated that timing and duration of nutrient modification during gestation differentially impacts outcomes. In cattle, providing a high vs. low energy diet during late gestation in beef cattle was reported to increase calf birth weight and subsequent weaning weight (Corah et al., 1975). The impact of global nutrient restriction during early gestation (d 32 to 115) has varied. Long et al. (2008) observed that nutrient restriction of cows did not influence birth weights or postnatal growth calves. In contrast, Underwood et al. (2008) reported greater postnatal growth and feed efficiency in steers born from cows that were nutrient restricted during a similar period of gestation (d 31 to 120). Nutrient restriction (55% global restriction) during early to mid- gestation in sheep (d 28-78) resulted in male offspring having similar birth weights, but lighter weights at slaughter, greater amounts of internal fat, and less muscle mass (Ford et al., 2007). In these studies, nutrient restriction appears to have provided adequate energy for fetal growth, possibly at the expense of the dam's tissue because nutrient partitioning during pregnancy favors the fetus at the expense of the dam and the placenta efficiency may be different (Barcroft, 1946).

While studies investigating maternal over- or under-nutrition are valuable, the investigation of specific diet components could provide greater insight into mechanisms of developmental programing. A few studies in beef cattle have investigated specific diet components during gestation on postnatal progeny production traits. A series of reports from the University of Nebraska has demonstrated that cows supplemented protein on dormant winter range in late gestation had steer progeny with greater postnatal growth rate and intramuscular fat deposition than progeny from cows not supplemented protein (Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009). Previous research has focused on developmental programming affects elicited by comparing energy sources fed at isoenergetic which differ in energy substrate supply (corn, hay, and corn dried distillers grains [DDGS]) during late gestation in sheep and cattle (Radunz et al., 2012). When corn (high starch) and DDGS (high fiber and fat and excess protein) energy sources verses hay (high fiber) were fed to dams during late gestation this resulted in progeny with greater birth weights. In addition research at Purdue University demonstrated that feeding diets containing excess protein during the third trimester resulted also in greater birth weights (Gunn et al., 2012). Collectively, these studies indicate that maternal nutrition in late gestation influence fetal growth.

Carcass Traits

Comparable to human health research, the desired impact is to deposit less external and internal fat during growth, not only because of the consequences to the efficiency of growth but also impacts on such economically important traits as carcass value and reproduction. One distinct difference in humans compared to beef cattle is concerning the intramuscular (*i.e*. marbling) adipose depot. In beef cattle, marbling has greater economic value than in other livestock species (*i.e.* pigs, sheep), because this fat depot is a major determinant in USDA Quality Grade and is used to determine carcass value. Approximately 80% of fetal adipose tissue is deposited in the final few weeks of gestation, but the development of these adipocytes starts earlier in gestation (Symonds et al., 2007). Adipose tissue growth occurs through two mechanisms: 1) preadipocyte proliferation; impacting capacity to form new mature adipocytes (hyperplasia) and 2) increased size and lipid storage capacity of mature adipocytes (hypertrophy). Adipocyte hyperplasia occurs primarily during late fetal development and early postnatal life in humans (Martin et al., 1998) and bovines (Zhu et al., 2008). This process is highly sensitive to the nutritional environment and to the prevailing concentrations of insulin-like growth factors, glucose, insulin, and glucocorticoids (Martin et al., 1998). Although preadipocytes can proliferate and differentiate in adults, their capacity appears to be limited with most of the developmental work completed early in life (Martin et al., 1998). Therefore, evidence supports that the fetal and early postnatal periods are critical stages of adipose tissue programming which impact later fat deposition.

Research from the University of Nebraska (Stalker et al., 2006; Stalker et al., 2007; Larson et al., 2009) provides supporting evidence that late gestation is a critical period for marbling development (Table 1). Over a 3-year period, steer calves from cows grazing native range with or without protein supplementation were followed from birth to slaughter. Native range was determined not to meet the protein requirements of the cow during late gestation and protein supplementation was provided to one group to meet those requirements. The calves born to cows supplemented with protein had carcasses with higher marbling scores, with a greater percentage of carcasses graded USDA Choice, and 60 lbs heavier hot carcass weights.

Additionally, Radunz et al. (2012) reported similar results indicating an important role of late gestation nutrition on marbling development and fetal growth. Calves born to cows fed corn had the least marbling and lower percentage of carcasses grading in the upper 2/3 of USDA Choice compared to calves born to cows fed distiller's dried grains with solubles or hay at the same fat endpoint. These results suggest that the amount of marbling in the carcass may not only be determined by genetics, postnatal nutrition, and postnatal management but also could be determined by what the cow is fed during gestation. In the following research using the same model in sheep by Radunz, fetal adipose and *longissimus* muscle tissues collected at birth provide the first evidence that maternal diet can influence the expression of imprinted genes associated with adipose tissue development and growth, which could explain difference in postnatal fat deposition.

Conclusions

One of the major challenges in gaining more knowledge in the area of developmental programming in beef cattle production is the time and resources needed to collect the data. Therefore, at this time, more questions may be raised than answered. The research presented here indicates maternal nutrition can impact postnatal growth and fat deposition in ruminants. More specifically, late gestation maternal nutrition may have a significant impact on intramuscular fat deposition in beef cattle. The question remains to be answered whether this is the result of changes in maternal body condition score, substrate supply to the fetus, quantity and/or quality of protein supply or other dietary factors. In order to improve efficiency of beef cattle production, more research is warranted to investigate the impacts of the environment, such as nutrition, during gestation and early postnatal life of cattle on lifetime productivity.

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Table 1. Effects of cow protein supplementation during late-gestation on progeny feedlot performance and carcass traits

	Stalker et al. 2006		Stalker et al. 2007		Larson et al. 2009	
	NS[1]	S[1]	NS	S	NS	S
Weaning weight, lbs	463[a]	476[b]	463[a]	476[b]	514[a]	529[b]
Dry matter intake, lb/d	18.7	18.8	24.6[a]	26.6[b]	19.8[x]	20.3[y]
Feed:Gain	5.41	5.46	6.97	7.19	5.37	5.38
HCW, lbs	800	814	765[a]	805[b]	805[a]	822
USDA Choice, %	85	96	---	---	71[a]	85[b]
Marbling Score[2]	467	479	449	461	445 [a]	492

[ab] Means differ, $P \leq 0.05$.
[xy] Means differ, $P \leq 0.10$.
[1] NS = non supplemented and S = supplemented (contained = 62% dried distillers grain plus solubles, 11% wheat middlings, 9% cottonseed meal, 5% dry corn gluten feed, 5% molasses, 2% urea, 6% vitamin and trace mineral premix, and monensin).
[2] 400 - 499 = Low Choice; 500-599 = Average Choice.

Table 2. Effects of cow late gestation dietary energy source on progeny feedlot performance and carcass traits

	Grass Hay[1]	Corn	DDGS	*P*-value
Birth weight, lbs	85.5[a]	95.0[b]	91.0[b]	0.01
Weaning weight, lbs	548	569	564	0.09
ADG, lbs/d	3.37	3.46	3.41	0.48
Dry matter intake, lbs/d	19.3	19.6	19.6	0.78
Gain:Feed	0.174	0.178	0.176	0.43
Days on Feed, d	178	168	170	0.10
Hot carcass weight, lbs	688	688	675	0.59
12th rib fat, inhes	0.48	0.50	0.51	0.71
Ribeye area, inches[2]	12.0	12.0	11.9	0.79
Yield grade	2.82	2.82	2.85	0.93
Marbling score[2]	549[a]	506[b]	536[ab]	0.03

[1] Diets fed to cows during late gestation. HAY = ad libitum grass hay; CORN = limit-fed corn diet; and DDGS = limit-fed dried distiller's dried grains with solubles.
[2] Slight = 300 to 399, Small = 400 to 499, Modest = 500 to 599.

SESSION NOTES