Nutrient Profiling - Metabolic Imprinting of Beef Calves

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Introduction

Calf nutrition has detrimental effects on future health and performance of these animals. The process by which nutrition during early-stages of a calf life may permanently change calf development and performance was called "metabolic imprinting" (Lucas, 1991). The metabolic imprinting concept has substantial economic implications for agriculture, and should be explored if we want to improve the performance of animals destined for food production. In this article**,** we will summarize some of the research conducted in beef calf nutrition and its impact on growth and reproductive performance of beef calves.

Suckling beef calves weaned between 7 to 8 months of age

The major nutritional factors affecting preweaning calf growth are the milk production of the dam, and the quantity and quality of nutrients from pasture and supplements provided before and after birth (Greenwood and Cafe, 2007). However, limited information is available regarding the effects of nutrition at an early stage of life of suckling beef calves, and their subsequent growth performance.

In general, calf average daily gain, weaning weight, ribeye area, backfat thickness, and marbling scores at weaning increased as milk production of the dam increased. Also, days on feed in the feedlot linearly decreased as dam milk production increased, likely because of the greater body weight of calves at feedlot entry (Stuedemann et al., 1968). Further, grazing pressure (number of calves/acre) on rangeland by Brahman cow-calf pairs also affected calf body weight at weaning, with the increasing grazing pressure linearly decreasing weaning weights (Philips et al., 1991). However, milk production of cows and grazing pressure did not affect calf weight at slaughter, carcass weight, dressing percentage, and marbling scores in numerous studies (Stuedemann et al.,1968; Philips et al., 1991; Abdelsamei et al., 2005). Likewise, forage type provided during preweaning grazing period had little effect on finishing performance of calves. At calving, cow-calf pairs were assigned to either tall fescue or tall fescue-legume grazing (70% tall fescue, and 30 to 40% legume mixture of red clove, Korean and Kobe lespedeza and ladino clover) until the time of weaning (240 days of age). Calves grazing fescue-legume pastures were 48 lb heavier at weaning, 5 days younger at slaughter, and had 24 lb heavier carcass weight at slaughter compared to calves grazing tall fescue pastures. However, ribeye area, yield grade, marbling scores, and percentage of fat in kidney, pelvic and heart (KPH) were not affected by forage type provided during the preweaning grazing period (Holloway and Butts, 1983).

Creep-fed calves

It is well reported that weaning weights may be increased if limited or unlimited access to creep-feeding supplements is provided to beef calves (Faulkner et al., 1994; Sexten et al., 2004; Moriel and Arthington, 2013a,b). Also, creep-fed calves may experience enhanced dry matter intake (Moriel and Arthington, 2013a,b) and weight gain during the feedlot receiving period (Arthington et al., 2008), which represents the period with greatest frequency of health problems in newly received feedlot calves. Indeed, beef calves provided access to creep-feeding have decreased incidence of morbidity and mortality than calves receiving no creep-feeding supplementation (Fluharty and Loerch, 1996). However, most studies did not observe long-term effects of creep-feed supplementation on finishing growth performance and carcass traits of beef steers (Tarr et al., 1994; Myers et al., 1999; Shike et al., 2007).

In addition, creep-feed supplementation has been shown to affect future milk production of beef heifers (Hixon et al., 1982; Sexten et al., 2004). Beef heifers given free choice access to creep-feeding supplements for 90 days before weaning had greater weaning weights, similar milk production at 60 days of first lactation, but decreased milk production at 120 days of lactation compared to heifers that did not receive creep-feeding supplementation (Hixon et al., 1982; Table 1). Likewise, beef heifers provided free-choice access to soybean hull-based supplements (14% or 18% crude protein, CP) for 84 days before weaning were on average 55 lb heavier at weaning, but produced 12 to 21% less milk from day 52 to 164 of their first lactation compared with heifers receiving no creep-feeding (Sexten et al., 2004). However, both studies reported that weaning weights of calves was similar between calves born from heifers that received or did not receive creep-feeding supplementation. This response suggests that beef calves may compensate for the decreased dam milk production by increasing their forage intake. In addition, beef heifers provided creep-feeding supplements containing 18% CP had greater milk production than heifers fed supplements with 14% CP (Sexten et al., 2004). Thus, increasing the dietary concentrations of CP may alleviate the negative effects of enhanced weight gain on mammary gland development and subsequent milk production of beef heifers (Sexten et al., 2004).

Table 1. Growth performance and milk production of heifers that received (Creep) and did not receive (NoCreep) unlimited access to creep-feeding supplementation for 90 days before weaning (Hixon et al., 2005).

	Treatments		
	No Creep	Creep	SEM
Weaning weight, lb	445^{a}	482^{b}	30.8
Milk production, lb/day			
day 60 of lactation	11.0	9.0	0.15
day 120 of lactation	9.9^{b}	7.7^{a}	0.07

^{a,b} within a row, means without common superscripts differ ($P < 0.05$).

Early-weaned beef steers

Early-weaning is a management practice consisting of permanent calf removal at ages often less than 5 months. Conversely, normal weaning traditionally occurs when calves are between 7 to 8 months of age. Early-weaning is usually applied during periods of forage shortage. However, early-weaning may also improve weaning weights of calves (Thrift and Thrift, 2004; Moriel et al., 2014a,b), feed efficiency of cows and calves (Arthington and Minton, 2004), and reproductive performance of cows (Arthington and Kalmbacher, 2003).

Long-term effects of calf management following early-weaning on growth and carcass quality of beef steers have been reported by numerous studies. Although 12 of 18 studies reported that average daily gain of early-weaned calves was equal or less than normally weaned calves during the feedlot phase, 10 of 14 studies reported equal or greater feed efficiency for early-weaned calves (Thrift and Thrift, 2004). Calves provided a high-concentrate diet starting at 177 days of age had 11% greater overall feed efficiency during the feedlot phase compared to calves provided the same diet starting at 231 days of age (Myers et al., 1999). Further, calves weaned at 89 days of age and supplemented with concentrate at 1.0% of body weight on ryegrass pastures for 211 days had greater average daily gain (1.92 lb/day versus 0.88 lb/day) and feed efficiency (0.15 versus 0.08), during the receiving period in the feedlot compared to calves weaned and entering the feedlot at 300 days of age (Arthington et al., 2005).

Intramuscular fat deposition (marbling) can be enhanced if cattle are placed on high-energy diets starting at young ages. In a 2-year study, Myers et al. (1999) reported that providing high-concentrate diets to beef calves starting at 177 days versus 213 days of age enhanced the percentage of carcasses grading average Choice or better (87% versus 63% for early-weaned and normally weaned calves, respectively) and increased marbling scores (1,183 versus 1,128 for early-weaned and normally weaned calves, respectively). Thereafter, numerous studies proposed that feeding high-concentrate diets to calves starting at 3 to 6 months of age compared with starting at 7 months of age or older could be an alternative tool to enhance carcass quality and marbling scores. However, this approach did not result in consistent results. Of 13 studies comparing carcass characteristics of calves early-weaned or normally weaned (Thrift and Thrift, 2004), only 4 studies reported greater percentages of carcasses grading Choice or better, whereas only 6 studies reported greater marbling scores for early- vs. normally weaned calves. Reasons for the inconsistent results among those studies may be attributed to differences on common end point at slaughter (weight, age, or backfat thickness), calf age at the start of the study, diet composition (e.g. starch concentration), timing and number of steroid implants, and interaction among those factors.

Early-weaned beef heifers

Nutrition at early stage of life also has significant effects on reproductive performance of beef heifers. Growth rate between traditional weaning age (6-8 months of age) and puberty, and from early-weaning (3-4 months of age) to the time of normal weaning were negatively associated with age at puberty (Gasser et al., 2006a,b). Gasser et al. (2006a) demonstrated that enhancing the average daily gain of early-weaned heifers (2.80 versus 1.87 lb/day) decreased age at attainment of puberty by approximately 100 days (262 versus 368 days of age), and increased the percentage of heifers achieving precocious puberty at less than 300 days of age (100 versus 0%).

Body weight gain after weaning is a major variable that influences age and weight at puberty. Across multiple breeds, heifers that were fed to achieve the greater average daily gain (1.76 versus 0.88 lb/day) starting at 7 months of age tended to be younger (372 versus 387 days of age) and heavier at puberty (709 lb versus 663 lb) compared with heifers achieving lower growth rates (Ferrell, 1982). In contrast, early-weaned heifers with faster growth rates beginning at 70 days of age achieved puberty earlier, but at similar (Gasser et al., 2006b) or lighter body weight (Gasser et al., 2006a) compared to heifers on a lower plane of nutrition. This differences on body weight at puberty between heifers that were normally or early-weaned is likely an indication of metabolic imprinting effects of nutrition during early-stages of life.

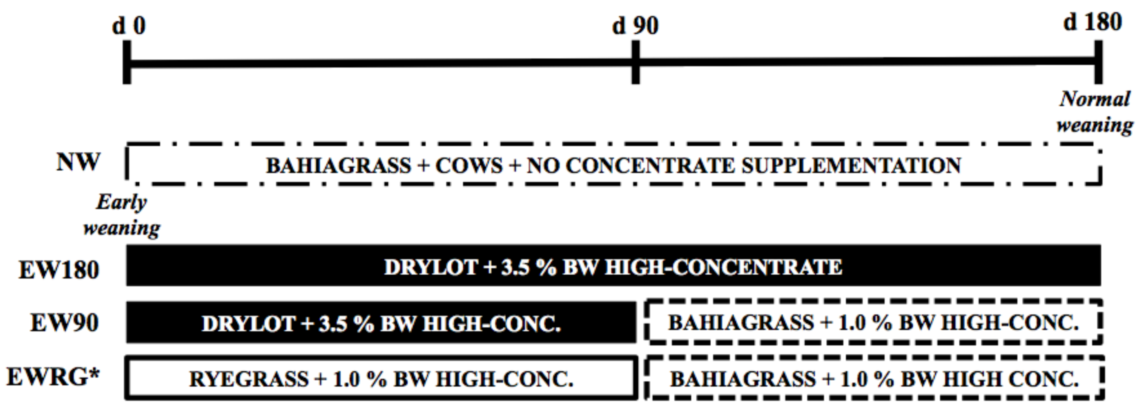
In summary, those results indicate the existence of a critical time in which nutritional management may induce early-activation of the reproductive axis, and have long-term consequences on age at puberty achievement.

Early weaning studies at the University of Florida

Despite the positive effects of early-weaning on growth and reproductive performance of beef calves that were described previously, few beef producers are willing to adopt early-weaning practice because of the limited amount of information on how to manage early-weaned calves, and increased labor associated with feeding calves daily. Therefore, 2 studies were conducted at the UF/IFAS Range Cattle Research and Education Center to evaluate different calf management systems for early-weaned beef calves and their long-term consequences on calf performance (Moriel et al., 2014a,b).

Experiment 1 evaluated the growth performance and carcass characteristics of Brangus crossbred steers, while experiment 2 evaluated the growth and reproductive performance of Brangus crossbred heifers. In both experiments, calves were either normally weaned at 250 days of age (day 180 of the study), or early-weaned at 70 days of age (day 0 of the study) and randomly assigned to 1 of 3 early-weaning calf management systems: 1) calves were early-weaned at 70 days of age and grazed on ryegrass and bahiagrass pastures for 180 days (EWPAST); 2) calves were early-weaned at 70 days of age and limit-fed a high-concentrate diet in drylot for 180 days (EW180); and 3) calves were early weaned at 70 days of age and limit-fed a high-concentrate diet in drylot for 90 days, then grazed on bahiagrass pastures for additional 90 days (EW90; Figure 1). When the early-weaned calves were in drylot, they were limit-fed the high-concentrate diet at 3.5% of body weight (as-fed). When the early-weaned calves were on pasture, they were supplemented with the same high-concentrate diet at 1.0% of body weight (as-fed). Calves that were kept with the mothers until weaning (250 days of age) did not receive supplementation from birth to 250 days of age.

Figure 1. Timeline diagram of each treatment from early-weaning (EW; day 0 of the study) to the time of normal weaning (NW; day 180 of the study). NW = steers remained with cows without concentrate supplementation until day 180 of the study; EW180 = steers early-weaned and limit-fed a high-concentrate diet at 3.5 % of body weight (as-fed) in drylot until day 180 of the study; EW90 = steers early-weaned and limit-fed a high-concentrate diet at 3.5 % of body weight (as-fed) in drylot until day 90 of the study, then grazed on bahiagrass pastures and fed the high-concentrate diet at 1.0 % of body weight (as-fed) until day 180 of the study; **EWRG** = steers early-weaned, grazed on ryegrass pastures and fed the high-concentrate diet at 1.0 % of body weight (as-fed) until day 90 of the study, then on bahiagrass pastures and fed the high-concentrate diet at 1.0 % of body weight (as-fed) until day 180 of the study.



Experiment 1 demonstrated that overall growth performance of early-weaned steers was similar or greater than steers normally weaned at 250 days of age (Table 2). Early-weaned calves provided a high-concentrate diet in drylot for at least 90 days (groups of EW90 and EW180 steers) were heavier at the time of normal weaning and at shipping (day 260 of the study) compared to normally weaned steers and early-weaned steers that grazed ryegrass and bahiagrass pastures. However, calf nutrition provided after birth in this experiment did not affect the overall carcass characteristics and marbling score at slaughter (Table 2). Only 6 of 13 studies reported greater marbling scores for early-weaned vs. normally weaned steers. Reasons for the inconsistent results among those studies and our experiment 1 may be attributed to the differences related to the criteria selected for slaughter (target body weight or backfat thickness), breed, calf age at the start of the study, diet composition (for instance, diets with high or low starch concentrations), and interaction among those factors.

Table 2. Growth performance and carcass characteristics of beef steers developed in different calf management systems from the time of early-weaning (EW; day 0 of the study) until shipping *(Experiment 1)*.

	Treatments[1]					
Item	NW	EWPAST	EW180	EW90	SEM	*P*-value
Body weight, lb						
day 0 (Early-weaning)	189	198	203	203	9.2	0.64
day 180 (Normal weaning)	475[a]	432[a]	652[b]	535[c]	19.7	<0.01
day 260 (Shipping)	504[a]	507[a]	793[b]	610[c]	25.6	<0.01
Slaughter	1042	1066	1132	1119	35.7	0.22
Days on finishing diet	202[bc]	227[c]	141[a]	187[b]	14.9	0.002
Hot carcass weight, lb	650	663	707	705	22.5	0.22
Yield grade	3.12	3.14	3.15	2.98	0.196	0.91
Marbling	404	418	401	456	41.4	0.75

[a,b] Within a row, means without common superscript differ ($P \leq 0.05$).

[1]NW = steers remained with cows from birth until the time of normal-weaning (day 180 of the study); EWPAST = steers early-weaned on day 0 of the study, grazed on ryegrass and bahiagrass pastures + concentrate supplementation at 1% of body weight until the time of shipping (day 260 of the study); EW180 = steers early-weaned on day 0 of the study and limit-fed a high-concentrate diet (3.5% of body weight) in drylot until day 260; and EW90 = steers early-weaned on day 0 of the study, limit-fed a high-concentrate diet (3.5% of body weight) in drylot for 90 days, then grazed on bahiagrass pastures with concentrate supplementation at 1% of body weight until day 260 of the study.

Experiment 2 demonstrated that early-weaned heifers limit-fed a high-concentrate diet for at least 90 days in drylot, and early-weaned heifers grazed on pastures and supplemented with concentrate at 1% of body weight for the entire study, had similar or greater growth performance than heifers that were normally weaned (Table 3). From day 180 of the study until the end of the breeding season (day 395 of the study), heifers were supplemented with concentrate at 1.5% of body weight (as-fed). During this period, no differences were detected for average daily gain among treatments (average daily gain = 1.50 lb per day). Interestingly, limit-feeding a high-concentrate diet in drylot, for at least 90 days, increased the percentage of heifers cycling at the start of the breeding season compared to normally weaned heifers (Table 3). Particularly, a greater percentage of early-weaned heifers fed high-concentrate diet in drylot for 90 days achieved puberty at the start of the breeding season, despite having similar body weight and average daily weight gain compared with heifers normally weaned at 250 days of age. This response indicates that we can anticipate puberty achievement if heifers are exposed to high-concentrate diets and high-growth rates at young ages (approximately 70 days of age).

Table 3. Growth and reproductive performance of beef heifers developed on different calf management systems from the time of early weaning (EW; day 0 of the study) until the time of normal weaning (day 180 of the study; Experiment 2).

	Treatments[1]					
Item	NW	EWPAST	EW180	EW90	SEM	*P*-value
Body weight[2], lb						
day 90 (Early-weaning)	306[a]	297[a]	361[b]	376[b]	8.1	<0.001
day 180 (Normal weaning)	467[a]	392[b]	577[c]	476[a]	14.1	<0.001
day 335 (Breeding season)	712[a]	643[b]	800[c]	720[a]	17.5	<0.001
Age at puberty, days	429[a]	418[a]	298[b]	358[c]	14.9	<0.001
Body weight at puberty, lb	753[a]	674[b]	629[b]	643[b]	26.2	0.09
Pubertal heifers at start of breeding season, % of total heifers	30[a]	40[a]	100[b]	80[b]	13.2	0.002
Pregnant heifers, % of total heifers	60	50	78	70	15.6	0.64

[a,b] Within a row, means without common superscript differ ($P \leq 0.05$).
[1]NW = heifers remained with cows from birth until the time of normal weaning (day 180 of the study); EWPAST = heifers early-weaned on day 0 of the study, grazed on ryegrass and bahiagrass pastures + concentrate supplementation at 1% of body weight until day 180 of the study; EW180 = heifers early-weaned and limit-fed a high-concentrate diet (3.5% of body weight) in drylot until day 180 of the study; and EW90 = heifers early-weaned and limit-fed a high-concentrate diet (3.5% of body weight) in drylot for 90 days, then grazed on bahiagrass pastures with concentrate supplementation at 1% of body weight until day 180 of the study.
[2]From the time of normal weaning (day 180 of the study) to the end of the breeding season (day 395 of the study), heifers were grouped by treatment and rotated among bahiagrass pastures every 10 days, and were provided concentrate supplementation at 1.5% of body weight.

In summary, metabolic imprinting is the process by which calf nutrition, during first few months of life, may permanently affect the metabolism and performance of beef steers and heifers. Early-exposure to high-concentrate diets may enhance growth performance of beef steers, as well as, enhance the growth performance and accelerate puberty achievement of beef heifers. Identifying strategies that can enhance calf performance during early postnatal life may provide unique opportunities to optimize feed resources and increase the profitability of beef cattle operations.

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