Management considerations for beef cows with emphasis on offspring performance and cow nutrient requirements

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Introduction

The beef cattle industry in the western United States is dependent on forage production; however, variable environmental conditions pose significant production challenges for the region's cow/calf producers (DelCurto et al., 2000; Reeves et al., 2013). These include concerns around forage quality and availability and how subsequent animal performance is affected. In addition, these challenges often result in significant fluctuations in cow weight and body condition score (BCS) during their annual production cycle if they are not supplemented to address nutrient deficiencies. Thus, producers require knowledge of forage nutritional value and animal nutrient requirements to manage economically for a desired level of productivity.

The productivity and profitability of cow/calf operations depends, in part, on how well their nutritional management plans meet the nutritional needs of the cow herd. Historically, when evaluating cow nutrient requirements, producers were concerned about maintaining/obtaining a desired cow BCS and/or specific intake of nutrients. However, a growing body of data suggests that current beef cow nutritional requirements (NASEM, 2016), especially during gestation, do not adequately account for subsequent offspring performance (Caton et al., 2019). Herein follows a brief discussion of factors for livestock managers to consider when developing nutritional management plans for gestating beef cows.

Forage Quality on Pacific Northwest Rangelands

Forage Species. Most rangeland grasses in the Pacific Northwest are cool-season (C3) due to climatic conditions (Roché et al., 2019). This is important because research has shown that low-quality forage intake and digestibility by non-supplemented ruminants depends, in part, on the cell wall structure and composition, with C3 forages being greater compared to warm-season (C4) forages with similar nutritional indices (Bohnert et al., 2011). Consequently, the response of ruminants to protein supplementation of low-quality forages appears to be dependent on forage type (Table 1).

Precipitation. After plant phenological stage (Angell et al., 1990; Clark et al., 1998; Arzani et al., 2004), the quantity and timing of precipitation has the most influence on quality of forage produced on western rangelands (Ganskopp and Bohnert, 2001; 2003). Ganskopp and Bohnert (2001; 2003) documented reduced forage quality (crude protein, digestibility, and mineral content) with above average, compared to below average, crop year precipitation for 7 common grass species on rangelands in SE Oregon (Figure 1). Thus, with abundant moisture during the growing season, forage quality rapidly deteriorates as plants progress through their reproductive stages of

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phenology. In contrast, fewer reproductive tillers develop with below average precipitation during the growing season, resulting in elevated forage quality and/or an extended period of adequate nutrition.

Cow Nutritional Requirements may not Account for Offspring Performance

Recent research has demonstrated that we do not have a good understanding of the nutrient requirements of gestating ruminants as they relate to the performance of the resulting progeny. A 2019 issue of the *Veterinary Clinics of North America: Food Animal Practice* (volume 35; issue 2) is dedicated to a comprehensive review of this topic, with articles covering multiple aspects of developmental programming in livestock production. In addition, this body of research has demonstrated effects of both nutrient restriction and provision of nutrients in excess of current requirements.

Protein and/or Energy. Many of the early studies designed to evaluate the effects of gestational nutrition on subsequent offspring in beef cattle focused on nutrient restriction of females at various stages of gestation (Corah et al., 1975; Stalker et al., 2006; Larson et al., 2009). Also, most revolved around supplementation of animals consuming low-quality forages with a protein supplement (Martin et al., 2007; Stalker et al., 2007; Bohnert et al., 2013). The supplements used in these studies also provided a source of energy, thereby making it difficult to determine if the observed responses were due to provision of supplemental protein, energy, or some combination. Briefly, these studies demonstrated that late-gestation supplementation of beef cows was an economical management practice due to improved cow pregnancy rate and performance of resulting progeny (greater weight gain; decreased calf morbidity and mortality). Interestingly, data also suggested that late-gestation supplementation of beef cows favorably influenced heifer progeny reproductive performance, by reducing age at puberty (Funston et al., 2010) and improving pregnancy rate (Martin et al., 2007). Recently, Caton et al. (2019) prepared an excellent review on the effects of gestational nutrition and developmental programming on the energy requirements of resultant progeny. Briefly, they concluded that the preponderance of data available with beef cattle suggests that epigenetic incidents occurring during fetal development alter the lifetime energy requirements of the subsequent offspring. Consequently, there is a need for research that directly assesses how maternal manipulation of nutrient supply alters protein and energy requirements of progeny.

Minerals. Mineral supplementation, specifically trace minerals, are essential for fetal development (Hostetler et al., 2003); however, little research is available related to gestational supplementation of beef cows on the performance and productivity of subsequent offspring. A recent study conducted by Marques et al. (2016a), provided above NRC (2000) requirements of Cu (200%), Co (2,160%), Mn (130%), and Zn (200%) from organic or inorganic sources to beef cows during the last third of gestation. They compared progeny performance with a control that received the same basal diet consumed by all cows, which met requirements for protein, energy, and macro minerals, trace minerals, and vitamins (NRC, 2000). They noted no treatment effects on calf birth weight; however, compared with the control, weaning weight was 24 kg greater for calves from cows receiving the organic source of minerals while the weaning weight of calves from cows receiving inorganic source was intermediate (Table 2). Similar tendencies were noted for calf weight at the end of both the growing lot and finishing lot feeding periods (112 and 153 d, respectively). The number of calves treated for bovine respiratory disease (BRD) in the growing lot was 60% less for calves born to cows supplemented with the organic source of minerals when compared to calves born to cows supplemented with the inorganic source of minerals or assigned to control treatment (Table 2). The results of this study suggest that strategic provision of minerals above current recommendations (NASEM, 2016) to gestating beef cows has developmental programming implications and requires additional research to evaluate potential ramifications on our current knowledge of cow mineral requirements – especially during gestation.

Fats/Lipids. In humans and livestock species, ω-3 and ω-6 polyunsaturated fatty acids (PUFA) are not synthesized by the body, yet play critical roles in several body functions (Hess et al., 2008). Consequently, they must be provided and consumed in the diet. In addition, dietary PUFA are transferred to the fetus during gestation from the dams' circulation via the placenta (Noble et al., 1978; Innis, 2005). In human nutrition, mothers are encouraged to consume supplemental PUFA for proper growth, nervous tissue response, immune function, and early-life development of the fetus/child (Greenberg et al., 2008). Consequently, recent research, albeit limited, has evaluated strategic supplementation of essential fatty acids to beef cows during gestation for effects on developmental programming. Marques et al. (2017) provided gestating beef cows in the last third of gestation with Ca salts of PUFA (ω-3 and ω-6) or an isolipidic amount of Ca salts of palmitic and oleic acids (control). They reported no effects on cow performance, calf birth weight, weaning weight, or health parameters; however, they did note that calves from PUFA supplemented cows had greater post-weaning ADG, which resulted in a greater body weight and hot carcass weight at slaughter compared with calves from control cows. Also, calves from PUFA supplemented cows had greater carcass marbling and the proportion of carcasses yielding choice tended to be greater compared with the calves from control cows. Additionally, in previous studies, cold tolerance and ability to respond to cold stress in calves was improved by providing essential fatty acids to gestating beef cows (Lammoglia et al., 1999a; 1999b). These data suggest that PUFA supplementation of gestating beef cows results in developmental programming effects in the subsequent offspring that could benefit their productivity, efficiency, and value. Consequently, further research is needed to elucidate the mechanisms underlying the observed responses. This is especially relevant, given that there is currently no defined requirement for essential fatty acids in ruminants (NASEM, 2016).

Consequences of Annual Variability in Cow Body Weight and BCS

Beef cows grazing rangelands in the Pacific Northwest typically gain and lose weight and BCS throughout the production year depending on their production state, forage quantity and quality, and environmental conditions. Figure 2 provides a typical weight/BCS cycle for an "average" spring calving cow. Given the narrow window of adequate forage quality noted for rangelands in the Pacific Northwest (Figure 1), cows often struggle to maintain BCS until weaning and/or until provided supplemental feed. Consequently, cows grazing rangelands in the Pacific Northwest face an inadequate or compromised nutritional environment during gestation. Our group evaluated the timing and effect of nutritional deficiencies and realimentation, throughout gestation, on the performance of the subsequent offspring (Marques et al., 2016b). Briefly, we classified cows at the beginning of gestation as adequate (BCS = 5.7) or inadequate (BCS = 4.5). Furthermore, within the inadequate group we randomly assigned cows to one of four groups that either maintained their BCS through gestation or gained 1.5 BCS during the first, second, or third trimester of gestation and maintained that BCS until calving. Following parturition, all cows were maintained in a common herd and managed similarly. We noted no differences in live calves at birth, birth weight, or live calves at weaning (Table 3); however, calf daily gain to weaning and weaning weight were affected by gestational nutrition. Calves from cows managed to gain BCS during the second and third trimesters had greater weight gains than the cows that maintained adequate and inadequate BCS throughout gestation. Interestingly, calf performance was similar for both cows that maintained adequate BCS and those that maintained inadequate BCS throughout gestation. In a similar study, Mulliniks et al. (2015) noted ADG of calves from cows that gained or maintained their BCS during the last third of gestation tended to be greater than that for calves from cows that lost BCS during the same period. Together, these data suggest that moderate nutrient restriction followed by realimentation of beef cows during mid- to late-gestation can be an acceptable management practice while maintaining or improving calf performance.

Management Recommendations for Beef Cows in the Pacific Northwest

Cow/calf producers in the Pacific Northwest require a knowledge of the highly variable climate and the probable responses of their livestock to the resulting variability in quantity and quality of forage produced each year. In addition, this necessitates a knowledge of cow nutrient requirements. Historically, beef cattle nutrient requirements have been studied, established, and incorporated by our industry. They have successfully allowed animals to be nutritionally managed for an expected level of performance. In addition, when economically evaluating a nutritional management plan, cattle producers have been primarily concerned with the cost of the nutritional inputs and the subsequent return from the performance of the animals being fed/managed. Developmental programming research has clearly shown that our current understanding of the nutritional requirements of gestating beef cows does not adequately account for the future performance of the resulting progeny. More importantly, cow/calf producers do not have the knowledge to assess accurately the full economic impact of nutritional management of gestating beef cows and the effects on the subsequent progeny. Box 1 provides some considerations related to developmental programming, based on recent research, for cow/calf producers to bear in mind when developing their nutritional plans.

Conclusion

Beef cattle grazing rangelands in the Pacific Northwest face a variety of environmental challenges ranging from annual variation in the amount, type, and timing of precipitation to challenges associated with forage quality and quality that can nutritionally restrict their performance. Consequently, gestating beef cattle face a much less controlled and managed production environment compared with other livestock species. They often go through cycles, within a year, in which they gain and lose weight depending on their production state and quality of the forage resources they are consuming. These challenges often interact to challenge the beef cattle manager who tries to balance animal performance with economic viability. Cattle operations have learned to deal with these nutritional challenges through management practices that have served our industry well (Cook and Harris, 1968; DelCurto et al., 2000; Olson, 2007); however, recent studies have highlighted additional challenges associated with the impact of gestational nutrition on offspring performance through what is commonly called developmental programming or fetal programming.

Gaps in our understanding of the consequences of gestational nutrition highlight the inadequacy of our current knowledge related to the nutrient requirements of gestating beef cows. In addition, the lack of consistency in progeny effects due to alterations in the nutritional management of beef cows demonstrates the need for more research around the timing and type of nutritional manipulation(s) applied to gestating beef cattle. Current and future research in the areas of gestational nutrition of beef cows should be designed to provide beef cattle producers with the knowledge and tools for development of nutritional management plans, and animal selection, that will help improve cattle production efficiency, predictability, and economic viability in an increasingly competitive industry.

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Table 1. Forage intake and nutrient[1] digestibility by steers consuming low-quality cool-season (C3) and warm-season (C4) grass hay with or without crude protein (CP) supplementation. Adapted from Bohnert et al. (2011).

	Treatment					*P*-Value[2]		
Item	C4	C4+CP	C3	C3+CP	SEM	CP vs No CP	C4 vs C3	Supp × Type
DM Intake, g/kg BW								
Forage	15.6	22.9	23.7	25.3	0.6	<0.01	<0.01	<0.01
Soybean meal	0.0	1.7	0.0	1.7				
Total	15.6	24.6	23.7	27.0	0.6	<0.01	<0.01	<0.01
Apparent digestibility, %								
DM	42.8	51.8	49.7	54.2	0.9	<0.01	<0.01	0.05
OM	45.6	54.6	53.6	58.5	0.9	<0.01	<0.01	0.05
N	28.4	54.5	37.5	55.2	3.5	<0.01	0.21	0.27
NDF	43.5	50.0	48.0	52.7	1.7	0.02	0.07	0.61

[1] DM = dry matter; OM – organic matter; N = nitrogen; NDF = neutral detergent fiber, [2] Supp = CP supplementation; Type = forage type.

Table 2. Effects of providing excess[1] Cu, Co, Mn, and Zn, from inorganic or organic sources, to late-gestation beef cows on performance of progeny from birth to slaughter. Adapted from Marques et al. (2016a).

Item	Control[2]	Inorganic	Organic	SEM	P-value
Birth wt., kg	42	42	41	1	0.63
Weaning wt., kg	212[a]	223[ab]	236[c]	6	0.04
Growing lot performance[3]					
Treated for BRD, %[4]	42[a]	59[a]	20[b]	10	0.02
Wt. at end of growing lot, kg	352[a]	359[ab]	374[b]	8	0.09
Finishing lot performance[3]					
Treated for BRD, %[4]	0	5	4	4	0.37
Wt. at end of finishing lot, kg	649[a]	663[ab]	680[b]	11	0.10
Hot carcass wt., kg	409[a]	418[ab]	428[b]	7	0.10

[a,b,c] Within rows, means with different superscripts differ

[1] Trace minerals provided so the diet was above NRC (2000) requirements (200% for Cu & Zn; 2,160% for Co; 130% for Mn). Treatments were provided during the last third of gestation.

[2] No additional Cu, Co, Mn, or Zn provided; concentrations in diet were at or above requirements.

[3] Cattle were in the growing lot for 112 d, and then moved to an adjacent finishing lot where they remained for an average of 153 d until slaughter.

[4] Calves were classified as positive for BRD symptoms according to the DART system (Zoetis, Florham Park, NJ), and received medication according to the feedyard management criteria.

Table 3. Calving and weaning outcomes from cows that maintained inadequate (LBCS) or adequate (HBCS) body condition score throughout gestation, or cows that gained body condition score during the first (BCSG1), second (BCSG2), and third (BCSG3) trimester of gestation and maintained the resultant body condition score until calving. Adapted from Marques et al. (2016b).

Item	LBCS	BCSG1	BCSG2	BCSG3	HBCS	SEM	P-value
Calving							
Live calves, %	92	92	100	100	100	4.5	0.49
Birth wt., kg	44	43	44	42	42	1.4	0.73
Weaning							
Live calves, %	92	92	100	100	100	4.5	0.49
ADG to weaning, kg/d	1.07[a]	1.10[ab]	1.13[b]	1.15[b]	1.07[a]	0.02	<0.01
Weaning wt., kg	249[a]	256[a]	265[b]	262[b]	248[a]	4	<0.01

[ab] Means within a row with different superscripts differ ($P < 0.05$).

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Box 1. Nutritional management considerations for beef cows in the Pacific Northwest with emphasis on developmental programming of subsequent offspring

- Providing mid- to late-gestation cows consuming low-quality forage with a protein/energy supplement
    - Increased weaning weight
    - Increased reproductive efficiency in heifers
    - Decreased morbidity and mortality

- Strategic supplementation of trace minerals, specifically Cu, Co, Mn, and Zn, during late-gestation
    - Increased weaning weight and weight at slaughter
    - Improved calf health

- Strategic supplementation of polyunsaturated fatty acids during late-gestation
    - Increased post-weaning performance
    - Improved carcass quality

- Allowing cows to have moderate nutrient restriction followed by realimentation during mid- to late-gestation
    - Increased weaning weight

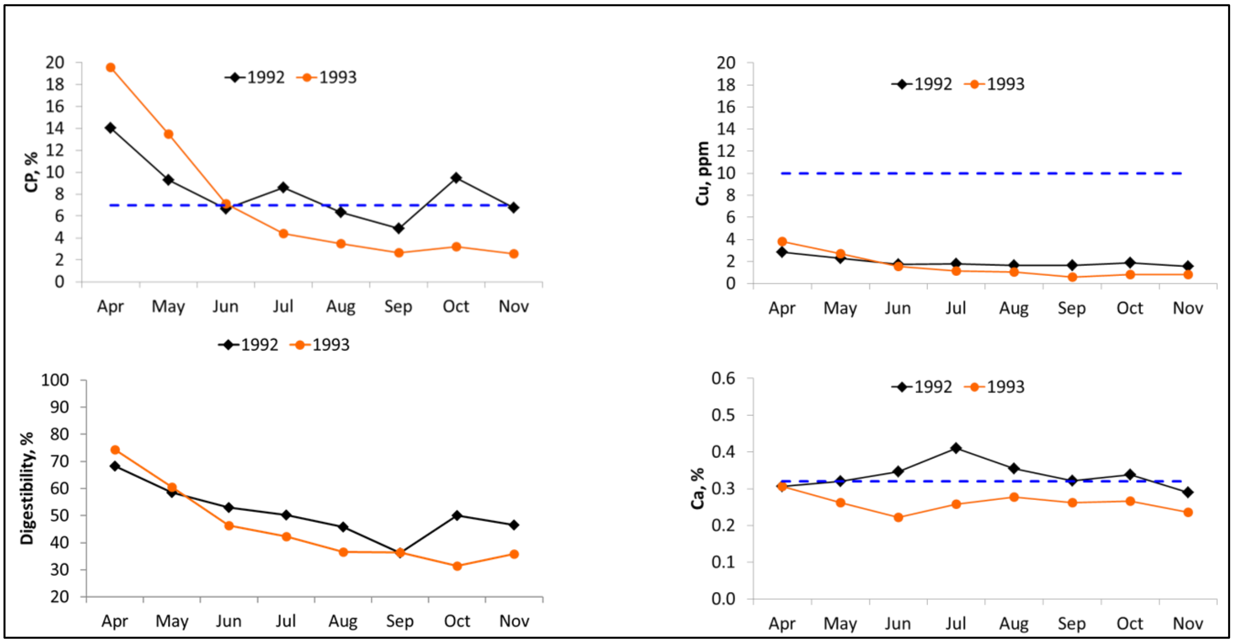

Figure 1. The effects of crop year precipitation on forage quality indices; averaged for 7 common grass species. Crop year precipitation in 1992 (black markers and line) was 86% of long-term average; 1993 (orange markers and line) was 167% of long-term average. The observed response for forage Zn concentration was similar to that reported for Cu while Mg, P, K, and Mn were similar to that observed for Ca. The dotted, blue horizontal lines indicate the estimated nutrient concentration necessary to meet the requirements of a 5 year old, 454 kg Angus x Hereford cow that has a body condition score 5, is 60 days pregnant, 120 days in milk, and consuming 11.4 kg of forage dry matter per day (NRC, 1996). Adapted from Ganskopp and Bohnert (2001; 2003).

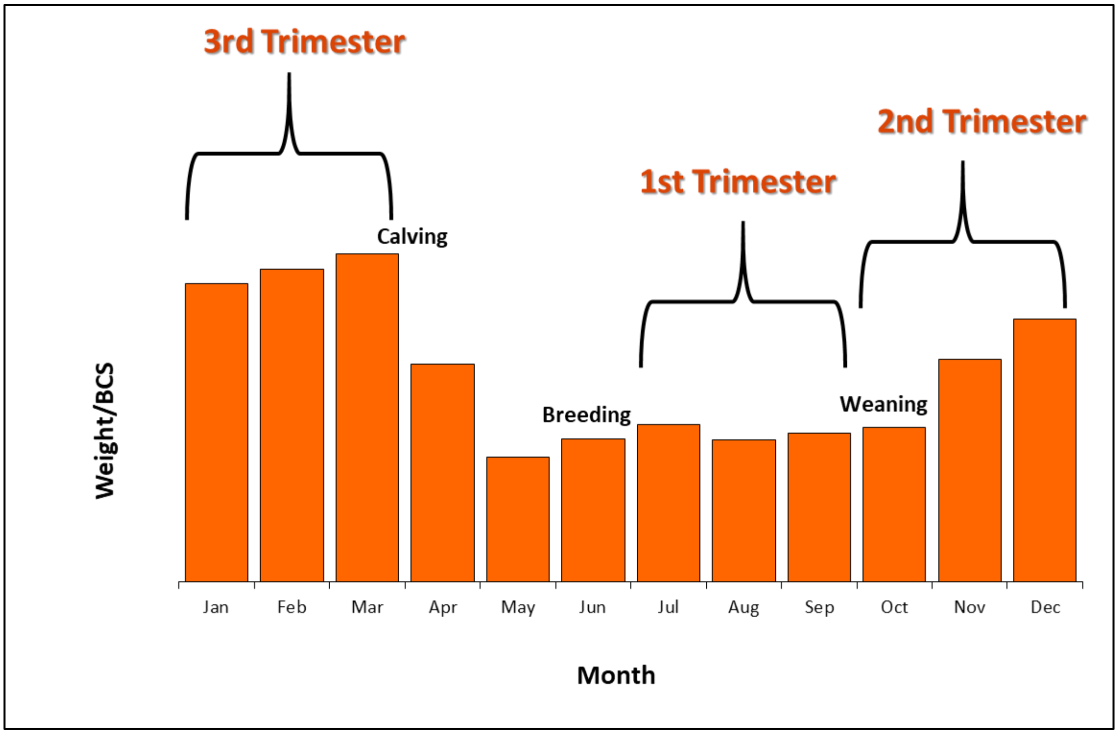

Figure 2. Typical weight/Body Condition Score (BCS) cycle for spring calving beef cows in the Pacific Northwest.