Opportunities to Improve Feed Efficiency of Beef Production

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Introduction

Beef cow-calf efficiency has been a topic of several review and symposium papers. A primary focus of many discussions on beef cowherd efficiency has centered on reproductive success and calf yield per cow, or more simplistically calf weight divided by cow weight. Reproduction and weaning weight are important but research has also demonstrated potential benefit from selecting for metabolic efficiency and strategic supplementation to enhance production efficiency. Efficiency is improved when reduction of inputs is achieved without detriment to product value and/or when product value is enhanced without increased input costs. In cow-calf production maintenance cost of the cow is the primary expense and most probable means of reducing input costs. Since reproduction and calf weight determines value methods, to enhance either can benefit cowherd productivity. Potential of selection for residual feed intake to reduce cow maintenance costs and nutritional strategies to enhance reproductive development and conception to improve production efficiency as well as calf growth efficiency will be discussed.

Nutritional Strategies to Improve Efficiency

Effective Energy

Energy requirement of beef cattle is typically based upon net energy (**NE**) requirements for maintenance and growth functions. Even when total digestible nutrients (**TDN**) or metabolizable energy values are used instead of NE, the same base assumptions are made regarding energy requirement for maintenance and growth. Emmans (1994) developed an alternative method of assessing energy requirement (Effective Energy, **EE**) in cattle that has been found to more accurately predict energy requirement. Primary difference between NE and EE was the argument that NE assigned a single energy requirement value to protein and lipid accretion when energetic expenditure for accretion of these tissues was not the same. Emmans (1994) separated energy requirements into separate functions of protein and lipid retention. Effective energy requirement is a function of maintenance energy requirement (**MH**), energy required for protein retention (**PR**) and lipid retention (**LR**) and energy lost as methane (EE = MH + PR + LR + MTHE). Research conducted at University of Missouri has shown that EE estimates of energy requirement were more accurate in predicting intake than NE estimates, with NE typically over predicting energy requirement by 20% or greater. Accurate prediction of energy requirement is important if diets are to be

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balanced that allow an animal to maximize feed efficiency. Research with other species has shown that intake of diets inadequate in supply of amino acids will result in satiety signals being controlled by amino acid intake rather than energy intake. In other words, the animal will consume a diet above its energy requirement to meet its most limiting amino acid requirement. I propose this routinely occurs in most ruminant diets, whether based on forage or grain, and that feed efficiency cannot be maximized until all required nutrients are balanced relative to energy density of the diet.

Cattle Do Not Have a Protein Requirement

Beef cattle may well be the only significant food production species left that balances diets for crude protein requirement, or more recently metabolizable protein requirement. The error with this approach is that cattle do not have a protein or metabolizable protein requirement but rather have a requirement for amino acids. Rumen bacteria have a requirement for ammonia (**RDN**) and amylolytic rumen bacteria have a requirement for peptide/amino acid nitrogen (**RDP**). Non-protein nitrogen, such as urea, can supply RDN and protein fermented in the rumen can supply RDP and RDN. Because research has yet to show microbial requirement of essential amino acids to meet RDP requirements, an argument could be made for a general protein requirement by the rumen, but cattle are similar to swine and poultry in having a requirement for essential amino acids to meet maintenance and growth functions. Balancing diets to meet amino acid requirements is more difficult for cattle than other species due to microbial fermentation of protein in the rumen. Meng et al. (1999) developed equations to predict microbial amino acid flow postruminally based upon mass of substrate fermented and rate of passage from the rumen. These same equations can be used to estimate RDN and RDP requirements of rumen microbes. From these estimates diets can be balanced to meet ammonia and peptide/amino acid requirements of rumen microbes and predict amino acid flow postruminally.

Amino Acid to Effective Energy Ratio

Maximum feed efficiency in cattle will occur when amino acids are supplied to meet amino acid requirement for maintenance and growth. Amino acid requirement will be dependent upon energy intake. As energy intake increases potential for growth or milk production increases and demand for amino acids subsequently increases as well. Our research has shown that balancing absorbable amino acid supply to energy intake can enhance reproductive development of heifers and two-year olds. Outcomes of balancing amino acid to EE (AA:EE) is improved reproduction, increased feed efficiency of replacement heifers and potential for reduced age at first calving.

Forage protein is extensively fermented in the rumen with little rumen undegradable protein. Therefore, the majority of protein flowing post ruminal is microbial origin. Methionine is the first-limiting amino acid in microbial protein for growing cattle. Our research has led us to conclude that most forages are limiting in methionine rather than energy. Because methionine is limiting, protein growth (lean) potential is limited.

This led us to hypothesize that rumen escape methionine supplementation could enhance growth and development of heifers and two-year old cows.

Post ruminal supply of methionine to developing heifers was shown to improve reproductive development. Hersom et al. (2009) compared corn gluten meal and Alimet [methionine hydroxy analogue; DL-2-hydroxy-(4-methylthio) butanoic acid] or Alimet alone on developing heifer growth, efficiency and reproductive development. Table 1 presents results from feeding Alimet to heifers. Heifers were given 0, 7 or 15 grams of methionine per day via supplement (2.5 Kg soy hull based) to an *ad libitum* hay diet. Experiment was conducted over 85 days. Supplementing methionine increased daily gain linearly over the first 30 days and increased reproductive tract score on day 85. Supplementation increased feed efficiency the first 30 days of study and increased feed efficiency numerically at day 85. The most important aspect of developing heifers is to have a reproductively mature tract at breeding season. This research was designed to test if heifers would respond to amino acid supplementation when receiving a diet promoting acceptable weight gain. Data were interpreted to demonstrate that methionine supplementation did improve reproductive development. Data were also used to support hypothesis that early stage development is important in achieving reproductive maturity. Primary difference due to methionine supplementation was measured first 30 days of study, yet significant difference was measured in reproductive tract score at day 85 with heifers fed 15 grams of Alimet having a more mature reproductive tract score. Supplying 15 grams of Alimet would yield approximately 7 grams of methionine post ruminal. When estimating amino acid to energy requirement for these heifers the control diet was deficient approximately 7 grams of methionine, the first limiting amino acid.

A similar strategy was evaluated using two-year old lactating cows. It was hypothesized that requirements of these cows due to milk production and growth could create a deficiency for amino acids. To test this hypothesis, two-year old lactating cows were given pasture only or fed corn-based supplement (approximately 1 Kg per head per day) with 100 or 200 grams per head per day of blood meal. Similar to the heifer study, methionine was predicted to be first limiting amino acid. When cows were fed a supplement with 100 grams of blood meal, hay intake increased numerically and daily gain of cows decreased, whereas milk intake and daily gain of calves increase (Table 2). When 200 grams of blood meal was provided, then daily gain of cows increased, milk intake and daily gain by calves were similar to those of calves nursing cows with no supplement. Cows used in this study averaged 74 days postpartum. Data were interpreted that supplementing young cows with energy alone (deficient in limiting amino acid) resulted in increased milk production at the expense of cow weight gain. Since this animal is still growing to reach mature size, weight loss as measured in this study could hypothetically influence reproduction. The difference between inadequate and adequate amino acid supply at similar energy supplementation was 0.1 Kg weight loss per day and 0.3 Kg weight gain per day. Over a 90 day period this would equate to a body condition score change of 1 to 1.5. Similar to results measured in developing heifers, diets that balance amino acid to energy ratio can potentially have benefits in two-year old cows. This is important since it typically is not the worst heifers that fail to rebreed.

Nutrition management is important for this stage of production not only to enhance probability of conception for the next year but also because successful rebreeding of two-year olds generally result in cows being reproductively sound beyond seven years.

Maximizing Calf Feed Efficiency

Formulating diets and supplements to balance amino acid to energy ratio for calves has been shown to improve growth performance and positively impact feedlot performance and carcass value. Studies were conducted with weaned steers where moderate quality hay was fed *ad libitum* and supplement fed at 0.75 or 1.5% of body weight. Supplement consisted of either dried distillers grains (**DDG**) or DDG, soyhulls, rumen-protected soybean meal, blood meal and corn oil (**BAL**). The BAL supplement was formulated to balance amino acid to energy ratio. Hay offered to steers was tall fescue and moderate in quality (10% crude protein, 62.8% neutral detergent fiber). When steers were fed supplement at 0.75% of body weight it was predicted that post ruminal amino acid supply was adequate with DDG supplementation to meet requirement, and data supported this prediction with daily gain and feed efficiency being 2.6 and 7.1 for both treatments (Table 3). However, when supplementation was increased to 1.5 % of body weight it was predicted that amino acid supply would not meet requirement for growth potential which data supported. When steers were fed a supplement formulated to balance amino acid to energy ratio, daily gain was increased 0.2 Kg per day compared to DDG supplement and feed efficiency was improved by 0.4 Kg less feed per Lb of gain. Using a live weight gain value of $1.60 per Lb, feeding a balanced supplement at 1.5% of body weight allowed supplement cost to be increased $275 per ton compared to supplement fed at 0.75% and $151 per ton more than DDG. In these calves supplemental feed to gain was 5.6:1.

A similar study approach was conducted with calves (Table 4). Calves were weaned in early April and continuously grazed, rotationally grazed or fed 1.2 Kg of supplement balanced for predicted amino acid requirement, and compared to growth performance of calves maintained with cows through July. Supplement consisted of corn, DDG, blood meal, feather meal and **MFP** (flavored methionine hydroxy analogue; DL-2-hydroxy-(4-methylthio) butanoic acid). Calves provided with supplement had similar weights and gains as calves nursing their dams, with calves not supplemented having lower body weights and daily gains as would be expected. The primary goal of this research was to demonstrate potential of supplement to mimic performance of nursing calves. A second goal and more to the point of this paper is performance potential for balanced supplements. Compared to gains by rotationally grazed calves and continuously grazed calves, supplement feed efficiency was 3.4 and 2.7 Lbs of feed per Lb of gain. Formulating supplements to balance amino acid supply to energy potential for growth can improve calf feed efficiency.

Effect of Starch on Forage Digestion

Fiber fermentation is impeded by starch fermentation, an effect regarded as negative associative effects. It is believed that starch fermentation reduces pH below a critical point conducive to fiber-fermenting bacteria, resulting in reduced fiber (forage) digestion. Grigsby et al. (1993) demonstrated that negative associative effects occurred when corn exceeded 0.6% of body weight in growing steers fed hay however positive associative effects occurred when corn was fed at 0.2 to 0.4% of body weight (Table 5). Calves fed corn at 0.2% of body weight had increased fiber digestion and calves fed corn at 0.2 and 0.4% of body weight had increased microbial protein flow post ruminal compared to calves receiving no corn and soyhulls only. When calves were fed corn at 0.6% of body weight fiber digestion was reduced compared to no corn supplement and microbial protein flow post-ruminally was lower than for calves fed 0.4% of body weight corn. This research has been used to base corn inclusion level in supplements for forage-fed cattle.

Supplementing Lipid to Increase First-Service Conception Rates in Mature Cows

Lipid supplementation (linoleic and linolenic acids) was shown to improve reproductive measurements in cattle (sperm quality, egg quality and embryo transfer success). Response was hypothesized to occur from provision of essential fatty acids influencing prostaglandin metabolism. Mature cows were fed whole soybeans (1.6 Kg per head per day) 30 days prior to calving until approximately 15 days post-calving or at calving for 45 days post-calving (Table 6). These time points were used to coincide with estimated timing of egg development for breeding season initiation 60 days post-calving. A control treatment of soyhulls and soybean meal similar in energy and amino acid content was also fed. Cows supplemented soybeans 30 days prior to calving had a 76% first-service conception rate compared to control treatment (62%) or to cows supplemented soybeans at calving (60%). Overall conception rate was not different among treatments, with 93% of cows supplemented 30 days prior to calving conceiving and 86 to 87% of cows fed other treatments conceiving in a 60 day breeding season. Interpreted from these data was that essential fatty acid supplementation could increase first-service conception rate, with an increase of 22% in this study. Subsequent on-farm studies showed similar results with other vegetable oil sources. While overall conception rate was not statistically increased, a 22% increase in first-service conception rate could increase weaning weight approximately 10 Lbs averaged across a herd. Lipid supplementation provides an additional means of potentially improving reproductive performance.

Summary of Nutritional Strategies to Improve Reproductive Efficiency

Nutritional management of developing and first-calf heifers should be to support their growth and development and, for first-calf heifers, to support demands for milk production. The argument made in this presentation is to ensure that supplements are formulated to adequately supply amino acid requirements based on energy intake by the animal. Likewise, the argument for diets/supplements to be formulated for nursing and weaned (preconditioning or stocker programs) calves to balance amino acid supply with requirement based on energy intake is made. If amino acids are not supplied at levels required then efficiency will be compromised. The best check for producers to use would be an assessment of feed to gain ratio. If creep feed or supplements do not yield feed to gains less than 5:1 it would be potentially beneficial to challenge diet/supplement formulation. Research to date has demonstrated that energy requirement is best described by EE and that maximum feed efficiency cannot be attained if amino acid supply is not balanced with EE intake.

Potential to Select for Metabolic Efficiency

Residual feed intake (**RFI**) is a measure of efficiency referenced by Koch et al. (1963) who attributed this measure as a means of selecting for metabolic efficiency. An attribute assigned to RFI is that it identifies efficiency independent of growth. Consequently selection for this trait should allow greater feed efficiency to be achieved in cattle without concomitant selection for increased frame size. Research conducted to date has proven this to be true. A majority of research conducted in the US has focused on impact RFI selection has on feedlot performance, which has proven to be potentially substantial by improving feed efficiency up to 20%. Because RFI is a measure of cellular energy metabolism efficiency its impact on the cow herd should be equally substantial.

Research was conducted comparing correlation between RFI phenotype of cows measured as a heifer and as a mature cow (Minton, 2010). In this study correlation of heifer RFI to cow RFI was only 0.17, however correlation of RFI category (low, average or high) between heifer and cow was significant at 0.31. Dry matter intake measured as a heifer and as a cow was significantly correlated (0.42). Since RFI is a function of dry matter intake correlation of intake between heifer and cow time periods would be expected and is interpreted that heifer RFI has relevance to cow efficiency. When cow RFI and performance was averaged within heifer RFI category (Table 7) cow RFI and dry matter intake followed heifer phenotype trends with no difference in average daily gain. Heifers that were phenotyped as low, average and high RFI had an average RFI value as a cow of -1.1, -0.2 and 1.5, respectively. Dry matter intake by cows increased as heifer RFI category increased, with cows consuming 2.4, 2.5 and 2.7% of body weight in dry matter, respectively. Meyer et al. (2007) phenotyped cows for RFI and then measured forage intake on pasture by low and high RFI phenotypes (Table 8). Low RFI cows consumed 20% less forage than high RFI cows. In this study, reduced intake by low RFI cows did not affect weight change or calf daily gain. Using 20% reduced forage intake could lead one to interpret that selection for RFI would allow every sixth animal to graze for free. While a conclusion that carrying capacity could be increased would be logical, practical outcome from selection for feed efficiency is more likely to be better body condition score and reproductive performance when forage/feed resources are limiting.

Preliminary research has shown milk production differs among RFI phenotypes. Two experiments were conducted measuring milk production of cows categorized by heifer RFI phenotype. When lactating cows were grouped by heifer RFI category there was no difference in dry matter intake among RFI category but body weight change was less for low RFI than other groups, milk production decreased numerically as RFI increased and milk production efficiency improved as heifer RFI improved (Table 9).

The second experiment was conducted with grazing dairy cattle and showed a similar trend (Table 10).

Summary of RFI Selection Potential to Increase Cow Herd Efficiency

Cow maintenance energy requirement is the greatest expense in a beef herd. Intake will vary by 40% between the most and least efficient animal in a herd, suggesting that potential for improvement is substantial. Selection for RFI can improve cow efficiency resulting in reduced forage needs by as much as 20%. Selection for efficiency in the cow herd also results in progeny that are more efficient. Using RFI as a selection trait is still relatively new in the beef industry; however, impact has promise of being substantial. A commercial seedstock producer has reduced average intake 15% compared to population average intake and low RFI animals consume 32% less feed than population average. Research to date leads to the conclusion that potential to improve cow herd efficiency via RFI selection is great.

Conclusion

This paper was written with the intent to provide a brief overview of concepts that will be discussed in the presentation. Goal of presentation will be to identify specific steps that can be taken through nutritional management and selection to improve production efficiency and animal efficiency. Nutritional management discussion will include approaches to balance amino acid supply with energy supply, potential to enhance reproductive development and mature cow conception and diet/supplement formulation that maximizes calf growth efficiency. Selection discussion will include potential of RFI phenotyping to improve cow efficiency.

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Table 1. Effect of Alimet[1] supplementation on growth and reproductive tract development of beef heifers

	Supplement (g Alimet/head/d)		
	0	7.5	15
ADG d 0 to 30, Kg/d	0.8[c]	1.0[a,b]	1.2[a]
Total ADG d 0 to 85, Kg/d	0.8	0.8	0.9
Total gain in 85 d, Kg/d	47	49	53
Begin weight, Kg	374	369	374
End weight, Kg	421	418	426
Pelvic area	184	186	183
Reproductive tract score	4.2	4.2	4.5
Hay disappearance d 0 to 30, Kg/d	12.1	11.6	11.3
Hay disappearance d 0 to 85, Kg/d	12.5	12.7	12.8
Feed to gain, d 0 to 30	16.6	12.3	9.5
Feed to gain, d 0 to 85	16.7	16.5	15.1

[a,b,c] Means with unlike superscripts differ ($P < 0.08$).

[1] Methionine hydroxy analogue [DL-2-hydroxy-(4-methylthio) butanoic acid].

Table 2. Effects of supplemental energy source and level of undegradable intake protein on cow-calf weight changes, calf milk consumption and cow forage and total organic matter (OM) intake while grazing endophyte-infected (E+) tall fescue pasture

	Pasture only	Pasture and Supplement[a]				Effect[b]			
		Soybean hulls		Cracked corn					
		100	200	100	200	E	P	I	S
						———Pr > F[c]———			
Cows									
n	6	6	6	6	5	—	—	—	—
Initial weight, Kg	461	472	456	487	420	—	—	—	—
Gain, Kg	0.6	4.0	-5.7	-5.2	18.9	NS	NS	0.02	NS
ADG, Kg/d	0.01	0.07	-0.1	-0.1	0.33	NS	NS	0.02	NS
Calves									
N	6	6	6	6	5	—	—	—	—
Initial weight, Kg	89	99	102	105	94	—	—	—	—
Gain, Kg	32	28	35	38	29	NS	0.08	NS	NS
ADG, Kg/d	0.55	0.67	0.51	0.67	0.51	NS	0.08	NS	NS
Milk intake, Kg/d[d]	2.1	4.5	3.5	4.1	2.5	NS	0.07	NS	0.06
Cow intake, g of OM/Kg body weight									
N	6	6	6	6	5	—	—	—	—
Forage	16.0	17.7	15.2	14.8	15.9	NS	NS	NS	NS
Total	16.0	20.0	17.9	16.9	18.3	NS	NS	NS	NS

[a] Supplements consisted of cracked corn or soybean hulls as an energy source with either 100 g/d or 200 g/d of ruminally undegraded intake protein.
[b] Contrasts: E = cracked corn vs soybean hulls; P = 100 vs 200 g/d of UIP; I = interaction between source of energy by level of UIP; S =E+ vs average of supplement treatments.
[c] Only those contrasts for which P < 0.20 are shown. NS = not statistically significant
[d] Milk intake determined on July 16.

Table 3. Growth performance of stocker calves fed different levels of supplement balanced or unbalanced for amino acid to energy ratio

	0.75% body weight		1.5% body weight	
	DDG[1]	BAL[1]	DDG	BAL
Initial weight, Kg	272	273	273	271
End weight, Kg	382[c]	386[b,c]	395[b]	411[a]
ADG, Kg	1.18[c]	1.22[b,c]	1.32[b]	1.50[a]
Feed:Gain	7.1[a]	7.1[a]	6.7[a,b]	6.3[b]

[a,b,c] Means with unlike superscripts differ (P<0.05).
[1] DDG = dried distillers grains; BAL = balanced supplement.

Table 4. Potential for supplementation to improve growth performance of nursing calves

	Weaned			Cow-calf pairs
	No supplement		Supplement	
	Continuous	Rotation		
April BW, Kg	206[c]	205[b]	206[a]	205[a]
June BW, Kg	244[b]	255[b]	279[a]	279[a]
July BW, Kg	245	269	303	303
April to June ADG, Kg	1.6[c]	2.2[b]	3.0[a]	3.2[a]
June to July ADG, Kg	0.1[b]	0.7[a]	1.1[a]	1.1[a]

[a,b,c] Means with unlike superscripts differ (P<0.05).

Table 5. Effect of supplemental corn intake on digestion of Bromegrass hay by steers

	Corn (% of body weight)				P value (Q)
	0	0.2	0.4	0.6	
Rumen digestibility					
Dry matter, %	65.7	66.9	58.2	52.2	<0.01
NDF, %	55.8	59.9	53.6	47.3	<0.01
Microbial N flow, g/d	136	156	181	153	<0.01

Table 6. Effect of whole soybeans on reproduction in mature cows

	30 days prior		Calving	
	Soybean	Control	Soybean	Control
Cycling, %	75	56	50	46
First Service, %	76	62	60	56
Pregnant, %	93	86	87	86

Table 7. Performance traits of cows averaged across heifer residual feed intake (RFI) category

	Heifer RFI Category		
	Low RFI	Average RFI	High RFI
RFI	-1.10[b]	-0.22[ab]	1.46[a]
Dry matter intake, Kg	16.4	17.4	17.6
Daily gain, Kg	1.0	1.0	0.9
Initial body weight, Kg	615	632	594

[a,b] Means with unlike superscripts differ (P<0.05).

Table 8. Performance traits of cows grazing pasture phenotyped as low or high residual feed intake (RFI)

	Low RFI	High RFI
RFI	-0.42[b]	5.1[a]
Initial body weight, Kg	569	557
Dry matter intake, Kg	12.4	15.6
Calf daily gain, Kg	0.85	0.95

[a,b] Means with unlike superscripts differ (P<0.05).

Table 9. Milk production of cows grouped by heifer residual feed intake (RFI) category (beef)

	Low RFI	Average RFI	High RFI
RFI	0.1	-0.6	0.9
Intake, Kg	20.6	20.1	20.8
Milk, Kg	11.2	10.4	9.7
Milk efficiency	1.8[c]	1.9[b]	2.1[a]

[a,b,c] Means with unlike superscripts differ (P<0.05).

Table 10. Milk production of cows grouped by heifer residual feed intake (RFI) category (dairy)

	Low RFI	Average RFI	High RFI
RFI	-0.86	0.04	0.84
Intake, Kg	27.2	28.2	27.8
Milk, Kg	16.4[a]	15.7[ab]	14.9[b]

[a,b] Means with unlike superscripts differ (P < 0.05).

SESSION NOTES