Strategic Manipulation of RDP and RUP Supply to Meet the Protein Needs of Beef Cows

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Introduction

Protein nutrition of cows on pasture deserves special attention as protein costs/unit weight tend to be higher than those of energy, and choice of protein type and/or energy source interact to affect forage intake and performance. When discussing protein supplementation, level of energy nutrition must be at least described to determine the overall interaction between these two nutrients. Under grassland management, challenges of protein supplementation are not confined to only meeting protein requirements, but also to improving energy utilization to enhance calf growth and reproduction. This paper deals with requirements of protein for cows on pasture, and strategies to achieve protein supplementation under adequate or poor grass growing conditions while enhancing calf growth and reproduction.

Protein Requirements of Beef Females

Protein requirements of cows and growing replacement heifers are based on metabolizable protein (MP) requirements for maintenance, growth, milk production and pregnancy (NRC, 1996). Maintenance requirements are based on protein required to maintain body function (tissue protein turn-over, and urinary, hair and scurf losses). Growth requirements apply only to females up to 24 months of age; beyond this age, they are not expected to require additional protein for growth. However, in production situations where body weight (BW) is expected to fall below mature BW at body condition score (BCS, scale of 1, emaciated, to 9, fat), provisions need to be made to accommodate BW gain to re-gain condition.

Growth, fetal growth, and milk production requirements are derived from estimates of protein retained during growth and milk production. Table 1 lists total energy, protein, Ca and P requirements for BritishXBrahman cows and replacement heifers of various mature weights. Values are presented as daily totals; no estimate of dry matter intake (DMI) is listed to permit flexible adaptation of these values. It is clear that estimates of DMI will impact the quality of forage that best meets the needs of mature cows or replacement heifers.

Although several equations exist for prediction of intake, perhaps the easiest method to project intake is to use an estimate of the cow's BW. For the sake of formulation, late gestating primiparous and multiparous cows can be projected to

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consume from 1.6% to 1.7% and 1.7% to 1.8%, respectively, of their BW as forage. During early lactation, these estimates become 2.4% and 2.6%, respectively, for cows with a low or high propensity to milk. Lastly, during late lactation, cows are expected to consume the equivalent of 2.1% to 2.2% of their BW, regardless of milk production potential (Johnson et al., 2003). Supplement intake in this study was from 1 kg/day (2.2 lb/day) during gestation to 2 kg/day (4.4 kg/day) during lactation. Forage CP and TDN content were 5.3% and 52%, respectively.

Table 1. Energy (TDN), metabolizable protein (MP), calcium (Ca) and phosphorus (P) requirements of BritishXBrahman cows and first-calf heifers [ab].

	TDN, kg	MP, g	Ca, g	P, g
500-kg cow				
Early lactation	6.6	735.7	31.3	21.0
Mid-lactation	5.8	606.0	25.0	17.3
Weaned	4.0	424.3	15.0	12.0
Late pregnant	5.0	524.3	25.0	16.0
525-kg cow				
Early lactation	7.1	798.0	34.3	23.0
Mid-lactation	6.2	650.3	27.0	19.0
Weaned	4.1	443.0	16.0	13.0
Late pregnant	5.4	559.7	27.0	17.0
550-kg cow				
Early lactation	7.3	813.0	35.0	23.3
Mid-lactation	6.3	664.7	28.0	19.3
Weaned	4.3	458.0	17.0	13.0
Late pregnant	5.5	574.7	28.0	17.0
325-kg heifer				
First trimester	3.8	403.7	18.0	11.0
Second trimester	4.3	445.7	19.0	11.7
Last trimester	5.6	561.3	28.7	16.0
340-kg heifer				
First trimester	3.9	419.7	19.0	11.3
Second trimester	4.4	462.0	19.7	12.0
Last trimester	5.8	578.7	29.3	16.3
360-kg heifer				
First trimester	4.1	435.3	20.0	12.0
Second trimester	4.6	478.7	20.7	12.7
Last trimester	6.0	596.0	30.3	17.0

[a] Heifer body weight at conception for heifers with mature weights at 500, 525 or 550 kg, respectively.
[b] NRC, 1996.

Table 2. Crude protein and rumen degradable protein (RDP) of various warm season forages

Species	Description	CP, % DM	RDP, % CP	Source	MP to CP factor [a]
Aeschynomene a.	legume	24.5	92.9	Other[b]	65.1
Andropogon gerardii	156[c]	12.6	46.0	Other	72.6
Andropogon gerardii	224[c]	7.2	37.0	Other	74.1
Brachiaria brizantha	dry season	8.8	61.6	Other	70.1
Cynodon dactylon	fresh	9.4	88.1	CNCPS[d]	65.9
Cynodon dactylon	fresh	12.6	80.0	NRC, 1996	67.2
Cynodon dactylon	hay	7.8	77.0	NRC, 1996	67.7
Cynodon dactylon	hay	8.4	59.8	Other	70.4
Cynodon dactylon	hay	9.8	48.4	CNCPS	72.3
Cynodon dactylon	unfertilized	9.8	80.6	Other	67.1
Cynodon nlemfuensis	unfertilized	10.2	80.3	Other	67.2
Cynodon plectostachyrus	fresh	6.7	77.1	CNCPS	67.7
Cynodon plectostachyrus	summer	6.6	59.1	Other	70.6
Cynodon plectostachyrus	winter	5.4	53.3	Other	71.5
Digitaria decumbens	fresh	8.9	83.5	CNCPS	66.6
Digitaria decumbens	hay	8.7	34.1	CNCPS	74.5
Hemarthria altissima	60 cm	6.6	67.5	Other	69.2
Hemarthria altissima	grass	4.3	75.6	Other	67.9
Indigofera hirsuta	legume	19.0	89.6	Other	65.7
Macroptilium lathyroides		17.8	75.1	Other	68.0
Medicago sativa	hay	17.9	79.4	Other	67.3
Medicago sativa #1	hay	20.3	79.8	Other	67.2
Medicago sativa #2	hay	30.0	82.7	Other	66.8
Panicum maximum		15.6	64.0	Other	69.8
Panicum virgatum	156[c]	15.4	69.0	Other	69.0
Panicum virgatum	224[c]	6.6	50.0	Other	72.0
Panicum virgatum	hay	8.8	80.4	Other	67.1
Panicum virgatum	hay	11.1	82.7	Other	66.8
Paspalum notatum	fresh	10.5	77.5	CNCPS	67.6
Paspalum notatum	grass	8.3	84.6	Other	66.5
Paspalum notatum	unfertilized	9.0	75.4	Other	67.9
Pennisetum americana	summer	11.3	72.5	Other	68.4
Sorghum bicolor	hay	5.1	60.0	Other	70.4
Sorghum bicolor	silage	8.7	58.7	Other	70.6
Stylosanthes guianensis	hay	11.5	64.7	Other	69.6
Stylosanthes hamata	hay	17.8	72.1	Other	68.5
Trifolium pratense	hay	15.0	76.0	NRC, 1996	67.8

[a] Divide MP requirement by this factor to obtain CP requirement.
[b] Database compiled by the authors.
[c] Day of the year.
[d] Cornell Net Carbohydrate and Protein System Database.

Therefore, cows weighing 525 kg (1160 lb) are expected to consume 9.9 kg/d (21.9 lb/d) total dry matter [(BW X 1.7%) + 1 kg or 2.2 lb]. Gestating diets fed to the cow in this example are expected to contain 50.5% TDN, 0.27% Ca, and 0.17% P. The metabolizable protein requirement can be translated to a crude protein requirement when RDP of the diet is known. In this example, if we assume that cows will consume a diet with 75% RDP, then the crude protein requirement can be calculated by dividing the amount of MP (grams) by a factor (0.68) that takes into account MP supply in the small intestine [(RDP * 0.64) + (RUP * 0.80)]. For the example described, the diet should provide 771 g or 1.7 lb CP/day, or 7.8% CP.

Formulating diets of beef cows to meet both rumen RDP and MP requirements permits taking advantage of benefits derived from improving forage intake with protein supplementation, and prevents excessive protein feeding. When forage is low in CP (at or below 7%) and rumen degradable protein (RDP; at or below 70% of CP), meeting rumen bacterial RDP and the animal's MP requirements may be accomplished by utilizing the proper mix of RDP and RUP in the feed (Hollingsworth-Jenkins et al., 1996). Those authors supplemented beef cows grazing poor quality forages (4.75% CP and 36.5% RDP) with increasing supply of RDP (from 480 to 750 g/head/day) and obtained a positive, yet quadratic gain response. Thus, when formulating protein supplements for beef cows on pasture, it is important to obtain as much data as possible regarding degradability of CP in rumen, and energy content of forage.

Protein Supplementation of Poor-Quality Forages

A survey of data on degradability of protein from hay or native pasture under poor growing conditions indicated that CP content and content of RDP tend to be low (Stock et al., 1995). These values appear to range from 40% to 68% RDP, as a proportion of CP, for warm-season grasses in the late summer and fall, when CP concentrations range from 5% to 9.5%. Similar RDP estimates were obtained for samples of tropical forages such as king, elephant or napier grass (*Pennisetum purpureum*, 47%; Valenciaga and Martinez-Machin, 2000) and pangola grass (*Digitaria decumbens*, 47%; Aumont et al., 1994).

The authors conducted an extensive survey of cool- and warm-season forage and byproduct CP and RDP concentrations; the results of some of the warm-season forage data are presented in Table 2. Also, in Table 2 is a factor to convert MP requirements to CP requirements. Data indicated a moderate correlation between CP and RDP concentration. Also, there was a tendency for warm-season forages to have relatively lower RDP at low CP concentrations. Thus, when dealing with warm-season grasses typical of tropical conditions, two issues that relate to protein nutrition need to be considered: 1) low protein content, and 2) low RDP content. Thus, when formulating supplements for cattle grazing warm-season pastures, greater consideration as to the amount of supplemental RDP is likely needed. However, if pastures contain native or improved legumes, the need to supplement degradable protein may be reduced as some tropical legumes were found to have greater concentrations of RDP than tropical grasses (Aumont et al., 1994).

Supplementing RDP to gestating beef cows grazing dormant native range (4.75% CP and 63.5% RDP) resulted in improved gain in two studies (Hollingsworth-Jenkins et al., 1996). In those studies, researchers used highly degradable protein sources (corn steep liquor and soybean hulls) to provide supplement formulations that contained from 93% to 100% RDP (Table 3). Total RDP content of the diet ranged from 58% to 80% (Table 3). Gain followed a quadratic response to increasing RDP supplementation. Greatest gain responses were observed when supplements contained 96% to 98% RDP; concurrent with diet RDP concentrations of 64% to 75% RDP. In these treatments, supplemental RDP provided 30%, 40% or 50% of the total RDP in diets that contained 13%, 15%, and 16% CP, respectively.

Table 3. Summary of responses (Resp.) [a] by cows fed poor quality forages supplemented with various protein sources.

Treatment [b]	Diet CP, %	Diet RDP, %	Supp.[c] CP, %	Supp.[c] RDP, %	Resp.	Req.[d], % CP	Reference
50% RDP	13.9	65.1	21.7	68.4	-	5.6	NE 1996 MP-66
75% RDP	15.1	70.7	27.1	82.7	-	5.6	NE 1996 MP-66
100% RDP	16.2	75.7	33.2	93.3	+	5.6	NE 1996 MP-66
125% RDP	17.4	80.1	39.2	100.0	-	5.6	NE 1996 MP-66
29% RDP	11.8	58.3	14.4	57.4	-	5.6	NE 1996 MP-66
65% RDP	13.0	63.9	21.8	80.2	++	5.6	NE 1996 MP-66
100% RDP	14.1	68.8	29.6	92.4	+	5.6	NE 1996 MP-66
139% RDP	15.3	73.5	38.8	100.0	-	5.6	NE 1996 MP-66
Control	5.8	58.6	--	--	-	11.4	JAS 2000 78:449
Low RUP	8.4	74.8	25.1	98.4	+	9.8	JAS 2000 78:449
Med RUP	11.2	56.0	43.4	53.9	+	9.8	JAS 2000 78:449
High RUP	13.8	44.8	62.0	37.1	+	9.4	JAS 2000 78:449
Control	9.0	61.8	31.6	65.8	-	8.1	JAS 2000 78:449
Low RUP	10.8	69.4	28.9	77.4	+	8.4	JAS 2000 78:449
Med RUP	12.4	59.5	36.4	60.0	+	8.3	JAS 2000 78:449
High RUP	14.6	52.1	44.2	49.2	+	8.5	JAS 2000 78:449
No supp.	7.4	60.0	--	--	-	9.0	JAS 1996 74:1701
Supp.	11.7	66.0	30.0	74.0	+	8.5	JAS 1996 74:1701

[a] Response as determined by weight gain, calf performance or both (- indicates control or base response; + indicates better than control).
[b] Treatments within each study or reference.
[c] Supplement.
[d] Requirement obtained by dividing MP requirement by respective conversion factor.

Some concerns with supplementing low quality forages focus on effects of protein and energy supplementation and their respective effects on forage intake. A recent study demonstrated that forage intake of lactating beef cows supplemented with increasingly greater concentrations of RDP was not affected during gestation, but it was significantly lower for supplemented than non-supplemented cows during lactation (Sletmoen-Olson et al., 2000). However, total OM intake was not affected by supplementation during lactation, but was greater for supplemented cows during gestation. In that study, protein content of hay was 5.8% (59% RDP). Similarly, steers fed meadow hay containing 5% CP and 81% RDP consumed similar amounts of hay organic matter as steers supplemented with 53% CP and 82% RDP or 60% CP and 40% RDP (Bohnert et al., 2002a). In the studies of Sletmoen-Olson et al. (2000), BW during the last month of gestation and during the first three months of lactation, and body condition score during the last month of gestation and third month of lactation were greater for supplemented than non-supplemented cows (Table 3). However, there was no effect of protein supplementation on days to first estrus or to re-breeding. Average CP and RDP concentration of supplements were 43.5% and 63.1%, and 36.5% and 62.2% during gestation and lactation, respectively. Average CP and RDP content of diets of supplemented cows were 11.2% and 58.9%, and 12.6% and 60.3% during gestation and lactation, respectively (Table 3). It appears that at least in gestating cows where DMI is typically lower, forage intake is either unchanged or improved by RDP or RUP supplementation even when the forage contains 10% CP (Wheeler et al., 2002). In this study, masticate samples revealed that even supplemented cows selecting high-protein forage continued to consume similar amounts as those that were not supplemented.

Other data reported from studies conducted with native range supplemented every third day with 3 kg of a high-RDP supplement (30% CP and 74% RDP) indicate that BW or body condition score change was more positive for supplemented than non-supplemented cows whether they were suckling or not (Table 3; Short et al., 1996). Additionally, calf gains were 22% greater pre-weaning due to greater lactation persistency. These effects resulted in greater efficiency of production as measured by calf BW or cow plus calf BW relative to forage ME intake. Estimated average CP and RDP content of diets of supplemented and non-supplemented cows were 11.7% and 66% RDP, and 7.35% and 60% RDP. Indeed, supplementing beef cows every third day consuming low-quality meadow hay had similar effects on cow BW change, cow body condition score, calf birth date and weight as supplementing cows every day (Bohnert et al., 2002b).

It appears that cow BW gain and calf performance respond to supplementation of protein, even at moderate CP concentrations in forage. In support of this finding, cows grazing native range, ranging in CP from 5.8% to 12.5%, in Montana responded equally well to supplements (490 g CP/head/day) formulated with either 56% or 79% RDP (Dhuyvetter et al., 1993).

There is some evidence that slowly–degraded protein sources may be utilized more efficiently than more readily degraded, especially when supplementing diets of low CP and high-fiber content such as crop residues or late-season forages. Gestating cows fed urea to supply 0.17 kg supplemental CP/head while grazing corn stalks tended to gain less BW than cows fed soybean meal or dehydrated alfalfa and urea (Rock et al., 1991). During lactation, supplementing corn cobs and corn silage diets with dehydrated alfalfa sustained greater BW and milk production. However, supplementing steers (Brown and Ajei, 2001) or cows (Pate et al., 1990) consuming tropical forages with either urea alone, or urea and RUP (steers) or RDP (cows) sources had similar effects on gain and pregnancy rate, respectively. Differences in degradation rates between forages, and differences in protein requirements may explain contrasting results from these studies.

In summary, diets of cows grazing dormant range or poor quality forages need to be supplemented with protein sources containing at least 60% RDP derived mainly from a combination of non-protein nitrogen sources and pre-formed aminoacids. The choice of protein source is dependent on the rate of degradability of the forage to be supplemented. In the case of slowly-digesting forage sources such as mature hays, stockpiled forages or crop residues, supplementing with protein sources that present relatively slow ruminal degradation may be more appropriate to enhance BW and condition response, and calf performance. Effects of supplementing protein at or beyond levels recommended by NRC (1996) on reproductive performance are not well defined. In the study of Dhuyvetter et al. (1993), there was a trend ($P = 0.11$) for lactating late-calving cows fed lower RDP supplements (56% vs 79%) to have greater conception during the first 21 day of the breeding season. However, there were no effects of RDP content of supplements on overall pregnancy rates.

Protein Supplementation of High-Quality Forages

When forage growing conditions are ideal for growth and deposition of plant nutrients, supplementation strategies may have to be different than when supplementing poor quality forages. Cows fed meadow hay (8.6% CP and 79% RDP) supplemented with a high-RUP supplement (61% CP and 49% RDP) gained more BW post-calving than those fed a high-RDP supplement (32% CP and 94% RDP) supplement (Patterson et al., 2002). There were no effects of level of RDP on body condition score, milk production or calf performance. Because more than 63% of the protein was derived from urea in the high RDP supplement, it is likely that rumen bacteria were starved for pre-formed amino acids thus affecting cow performance.

When forage is high in CP and high in the RDP fraction, utilizing supplements with high RUP may complement the need to supply MP requirements. Brahman cows fed a moderate-RUP supplement containing 22% CP and 43.7% RDP (56.3% RUP) had greater milk production, and their calves had greater gains from birth to weaning than those fed supplements containing 21% CP (62% RDP and 38% RUP) or 23% CP (24% RDP and 76% RUP; Triplett et al., 1995). Additionally cows fed the moderate-RUP content supplement also had improved first-service conception rate, and tended to have greater pregnancy rates.

Without knowledge of RDP and RUP, or MP requirements, supplementation of high-protein forages would seem wasteful. Because modeling requirements of beef cattle is now based on the metabolizable protein system, formulations of protein supplements should be considered under poor and good growing conditions. It is in the latter that we expect to see positive gain, calf performance and reproductive responses to supplementation with “high-bypass” or RUP protein sources. However, astute producers and nutritionists must weigh the benefits and costs of designing supplementation strategies that enhance performance with protein sources that are typically high cost.

Conclusions

Warm-season grasses and mature forages of all types have lower CP and RDP concentrations. These factors can now be considered when formulating protein supplements for beef cows. In situations where low-quality forages are present, producers and nutritionists must first consider protein supplementation to rectify forage intake. The choice of protein fractions (RDP vs RUP) is not a difficult one, from a performance standpoint, when CP and RDP concentrations are below 7% and 70%, respectively. Once the protein deficiency is corrected, energy status needs to also be corrected as it is likely to be deficient for lactating cows. Supplementing every third day is a strategy that may save money and add convenience, and has no negative effects on performance. On the other hand, when forage quality is high, because of greater cost, response to protein supplementation with RUP sources must be evaluated against the benefit.

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