Protein Nutrition Evaluation and Application to Growing and Finishing Cattle

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Protein Systems and Metabolizable Protein

Ruminants require amino acids to be supplied to organs and tissues for maintenance and productive functions (e.g., growth, lactation, pregnancy, etc). This paper will focus on growing and finishing cattle, thus maintenance and growth will be the primary target. Amino acid requirements are generally based on evaluation of amino acid uptake and retention of amino acids by organ/tissues and arterial-venous difference. Amino acids are classified into two categories, either essential (need to be absorbed or provided) or non-essential amino acids that can be synthesized. The requirements for essential amino acids are based on amino acids provided at the small intestine for absorption.

Burroughs et al. (1974) proposed a metabolizable protein (**MP**) system for ruminants because amino acids supplied at the small intestine are not just a function of dietary supply, which is different than non-ruminants. The MP system is in contrast to the crude protein (**CP**) system which refers to measuring protein based on the nitrogen content and a simple conversion by multiplying %N by 6.25. The logic for CP system is that the average of all amino acids contains 16% N by weight. Using a CP system simply refers to formulating diets based on a total %CP in the diet, which is still the most common approach used in the beef industry (Vasconcelos and Galyean, 2007). Clearly, the CP system is not logical in ruminants (although easy and simple) because not all protein are created equal in that certain amounts are required for meeting the microbial protein requirements and certain amounts are required in different scenarios in the small intestine that originate from the diet. While many nutritionists use terms like “natural” protein and non-protein nitrogen when supplementing protein, the MP system needs to be adopted.

In ruminants, predicting the amino acids supplied at the small intestine is complex. Dietary protein (including non-protein nitrogen such as urea) can be degraded in the rumen and resynthesized by microbes into new amino acids and proteins. This fraction of protein is referred to as rumen degradable protein (**RDP**) which is synonymous with degradable intake protein (**DIP**) used in the 1996 beef NRC. In essence, RDP supplies protein to meet the protein requirement for microbial growth or production of more microbial protein. However, microbes also require energy for growth (i.e., more microbial protein). Either protein (RDP) or energy limits microbial growth, just

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like energy or protein can limit growth of cattle themselves. The goal with formulation of diets is to ensure that energy is limiting microbial growth (not RDP). Meeting the RDP requirement is essential to maximize energy fermentation and microbial protein supply. Once the supply of microbial protein is predicted, then the balance of protein needed yet by the animal can be formulated.

For most feeds, a portion of protein “escapes” degradation by microbes, or “bypasses” the rumen intact either as proteins or amino acids. These fractions are called rumen undegradable protein (**RUP**), which is synonymous with undegradable intake protein (**UIP**) used in the 1996 beef NRC. The amount of RUP that is needed should be calculated as the difference between MP required at the small intestine minus predicted microbial supply.

Using the MP system illustrates that once RDP requirements are met, adding additional protein that is degradable will have no benefit on microbial growth, or the animal. Excess RDP (as ammonium in the rumen) is absorbed, converted to urea and excreted as urea in the urine. Adding more is useless, and in fact detrimental from a N excretion and ammonia loss perspective. Predicting RDP requirements is also challenging as dietary energy supply to microbes needs to be predicted, in addition to microbial efficiency. Microbial efficiency is simply the proportion of microbial protein relative to ruminally digested organic matter. In beef cattle, we have typically used total digestible nutrients (**TDN**) as a proxy for ruminally digested organic matter. As TDN increases, energy supply for the microbes increases, which increases the RDP requirement, but also may influence microbial efficiency of converting energy into protein from microbial growth. There are instances where TDN can increase without increasing ruminally digestible organic matter, such as the case with fat. Using fat-free TDN may be logical. Similarly, fermented feeds have already been partally fermented anaerobically, which logically leaves less energy available to rumen microbes. In many cases, lowering microbial efficiency has been recommended for fermented, ensiled feeds such as corn silage. Figure 1 provides the recommended microbial efficiencies we have used at the University of Nebraska-Lincoln. The1996 beef NRC predicts a decrease in microbial efficiency as dietary TDN is decreased below 65 due to decreased passage and predation. At dietary TDN above 77, microbial efficiency decreases due to low rumen pH and energy demands for microbes to maintain pH versus growth. These recommendations are based on numerous studies as outlined by Patterson et al. (2006) and the 1996 NRC. A microbial efficiency of13% agrees well with the 2001 Dairy NRC, Burroughs et al. (1974) and European data. In contrast, Galyean and Tedeschi (2014) recently proposed a simpler equation that is approximately 9% microbial efficiency which is not impacted by dietary TDN (Figure 2). Their review included data from 66 published papers with cannulated cattle fed diets that vary from 46 to 90% TDN.

Predicting microbial supply (and thus requirement for RDP) is essential in ration formulation. Microbial supply is dictated by rumen available energy and microbial efficiency, which dictates RDP required. Microbial supply also indirectly determines amount of supplemental RUP required. If the MP requirements are met by supply of microbial protein and RUP in the feed, then adding supplemental RUP is not necessary. In general, RDP supplementation is essential for high-grain finishing diets. In general, rapidly growing cattle fed forage-based diets that require a relatively large amount of MP cannot sufficiently maximize gain or efficiency without adding supplemental RUP. These will be presented in greater detail in the growing or finishing sections.

While overfeeding RDP (best example is urea) does not contribute more MP once microbial requirements are met, overfeeding RUP does contribute more and more MP as dietary supply increases. Overfeeding RUP from supplemental protein sources that contain a large proportion of RUP (as % of CP) has been very uncommon in the beef industry. Most supplemental protein sources that are good sources of RUP are very expensive, which has lead nutritionists and researchers to focus on providing the minimum amount to meet (and not exceed) requirements. There is one exception to this historical limitation. Distillers grains plus solubles provides the most cost-effective source of RUP simply because it contains approximately 30% CP which is approximately 65% RUP (% of CP) and yet has been priced relative to corn grain the past 10 years, as supply increased dramatically. As a result, overfeeding RUP has been possible even when RDP "appears" to be limiting. Historically, RDP was cheaper to overfeed than protein sources high in RUP, yet excess RDP has no "value" to cattle when overfed. When RUP is overfed relative to MP requirements, then excess protein is still absorbed. If the amino acids are not needed (i.e., required), then excess MP is deaminated and the urea recycled to the rumen (to supply RDP) or the large intestine or saliva. Once those pools have been recycled and if RDP is still not needed based on concentration gradients, then any excess is excreted as urea in the urine. Cattle are very efficient at recycling N in the form of urea to ensure adequate RDP before excreting excess. When RUP is overfed, most nutritionists readily understand the concept of N recycling. However, two key things are misunderstood related to overfeeding RUP. The first misconception is that the energy cost of recycling N and synthesizing urea is a large cost and will influence performance. The data do not support an appreciable or measurable energy cost related to deamination of excess RUP and synthesis of urea for recycling or excretion. The second missed issue related to excess RUP is the energetics and use of amino acids as an energy source. By definition, excess RUP used for energy bypassed ruminal fermentation and thus bypassed the associated energy losses of carbohydrate fermentation in the rumen. Some inefficiencies are noted when even starch is converted to VFA and subsequently used for energy. This inefficiency is greater for fiber fermented in the rumen due to the increased molar proportion (and presumably production) of acetate relative to propionate (keep in mind that fiber would be of little value unless fermented in the hindgut, so energy inefficiency is necessary with fiber fermentation). Regardless, RUP used as an energy source has approximately 140 to 160% the energy of corn starch, which can be calculated, has been measured in finishing cattle (Carlson et al., 2016), and has been known for a very long time (Kleiber cited data from 1918 in dairy cattle).

Applied Protein Supplementation for Growing Cattle

Cows and backgrounding cattle are fed diets consisting primarily of forages. Table 1 provides CP, RDP, and RUP contents of selected feeds. Most forage protein is very degradable, whereas corn protein is generally high in proportion of RUP. The exception for corn protein is high-moisture ensiled corn, which increases degradability. Degradability of protein (and energy) in the rumen is also increased by moisture content or harvesting early (Benton et al., 2005). In addition, the RUP digestibility is certainly not 80% as assumed by the 1996 NRC. Data using mobile bag technique and removal of bacterial protein (using a NDF procedure) suggest intestinal digestibility of RUP originating from forages is low, and decreases as forage maturity increases or in dormant, low-quality forage (Haugen et al., 2006). In addition to forages being low in proportion of RUP (% of CP), most is indigestible. If forage-based diets are fed to young, growing cattle, then RUP supplementation is likely to improve gain and efficiency because growing cattle have greater MP requirements, which cannot be met by naturally occurring RUP originating from the forages.

A few sources of RUP are available, but most of these are very expensive sources of protein. Over the past decade, a large increase in ethanol production has led to a large increase in supply of competitively priced distillers grains plus solubles. Distiller’s grains normally average approximately 30% CP (Buckner et al., 2011; Spiehs et al., 2002) that is 63% RUP (Castillo-Lopez et al., 2013). The benefit of distiller’s grains plus solubles is that pricing is normally competitive to corn which makes the price competitive to other protein sources, plus is a good RUP source. The amino acid balance is less ideal as a protein source in grain fed cattle (but is overfed to compensate for amino acid balance). However, in forage diets, the amino acid profile is beneficial, and again, protein is normally overfed to add energy in addition to protein. Lastly, in forage-based diets, no difference has been observed between wet (**WDGS**), modified (**MDGS**; partially dried), or dried distillers grains plus solubles (**DDGS**; Ahern et al., 2015) in terms of feeding value compared to corn (about 130% of corn energy when supplemented in a forage diet. In feedlot diets, WDGS is better than MDGS, which is better than DDGS with feeding values of 135-140, 120-125, and 110-112% of corn for WDGS, MDGS, and DDGS, respectively (Bremer et al., 2011; Nuttelman et al., 2011; Nuttelman et al., 2013; Watson et al., 2014).

Three examples of recent research from the University of Nebraska will be used to document the impact of RUP supplementation in growing cattle fed or grazing forage based diets. Growing calves were fed diets of ground cornstalks (64.5%) with 30% corn distillers solubles (liquid feed from dry mill ethanol plants) which should be a diet deficient in MP, and sufficient in RDP. Calves were then supplemented with either a combination of soyhulls and urea or 2.0% treated soybean meal (Soypass) and 1.3% corn gluten meal. Soypass is 50% CP and 65% RUP (% of CP) and the corn gluten meal used in this study was a branded product (Empyreal, Cargill) that is 75% CP and 65% RUP (% of CP). Both feeds are excellent and concentrated sources of RUP. Steer calves started at 617 lb and gained either 1.27 or 1.45 lb/d ($P = 0.14$) for cattle not given RUP (Control) or given RUP (Table 2). Calves tended ($P = 0.08$) to eat more if fed the Control compared to those given RUP. As a result, calves given RUP were more efficient ($P = 0.02$) than Control. For calves grazing corn residue, supplementation is common. A question is what supplementation is ideal for growing calves grazing residue, particularly whether RUP is limiting growth. Tibbitts et al. (2016) grazed calves weighing 516 lb initially with no supplement, corn, corn plus urea, DDGS, or RUP supplementation with soybean meal and soypass (SBM treated to increase RUP). Supplementation was formulated to provide the same amount of energy across supplements (Table 3). Calves given no supplement lost weight over the 60 day grazing. Supplementing corn to provide 3 lb of TDN allowed calves to gain 0.31 lb/d versus 0.53 lb/d with corn plus urea to meet the RDP requirement. However, feeding the same amount of energy from DDGS increased gain to 1.32 lb/d due to the RUP being provided. Lastly, feeding soypass and SBM yielded the best ADG at 1.48 lb/d which may be due to meeting both the predicted RDP and MP requirements. It is unclear whether the calves fed DDGS gained less than the SBM and Soypass treatments due to incorrect estimation of TDN of SBM/Soypass or whether calves fed DDGS were deficient in RDP that limited microbial growth or energy utilization of the diet. Either way, RUP has tremendous value with grazing calves. The best evidence of RUP supplementation benefiting growing calves is some recent data with calves fed corn silage growing diets. Corn silage growing diets is a common method used for backgrounding calves. Corn silage contains approximately 75% TDN which means if protein requirements are met, then gains and feed conversion will be better than many backgrounding programs. Another unique attribute of corn silage is the protein is mostly RDP which allows for greater opportunity for RUP supplementation to increase ADG and improve conversion. Hilscher et al. (2016) recently evaluated 0, 2.5, 5.0, 7.5 or 10.0% supplemental RUP which was a blend of Soypass and branded corn gluten meal (Empyreal, Cargill Inc.). Gain and feed conversion both improved linearly as supplemental RUP increased (Table 4). The trial was designed to determine a breakpoint for RUP supplementation or a point where ADG and F:G are improved and plateau. The greatest response was for the first 5% RUP, but ADG and F:G continued to improve but at a diminishing rate, which lead to a linear response to supplemental RUP.

These data suggest that with growing cattle, performance is dependent on energy content of the diet, but increasing gain may be realized with supplemental RUP even with adequate RDP in the diet. More research should optimize use of supplemental RUP sources and amounts in different backgrounding situations. Knowing the RDP/RUP makeup of feed ingredients is critical, as well as the energy content.

Applied Protein Supplementation for Finishing Cattle

Finishing cattle are different than backgrounding cattle as diets are mostly corn or corn and corn milling byproduct based. Because diets are high in grain, ruminally digestible organic matter or energy available in the rumen is quite high. In fact, ruminal acidosis is a result of too much and too rapid of energy digestion in the rumen. Much of the research focused on finishing cattle was targeting RDP supplementation to maximize gain and G:F (feed efficiency). Few studies have evaluated RUP supplementation as corn fed as either dry-rolled or steam-flaked corn is relatively high in RUP which may negate the need for supplemental RUP, except early in the feeding period. Few operations will phase feed (add different supplement ingredients with stage of growth) as most operations want to feed one base finishing diet.

Three studies have evaluated RDP supplementation with finishing diets based on dry-rolled corn (Shain et al., 1998; Milton et al., 1997) or dry-rolled corn, high-moisture corn, and steam-flaked corn (Cooper et al., 2002). The requirement for RDP in dry-rolled corn diets is approximately 6.8% of diet DM, 10.1% of diet DM for high-moisture corn, and 8.3% of diet DM for steam-flaked corn based on these studies. The differences reflect changes in energy available in the rumen. A few examples will be presented where protein supplementation has been evaluated in finishing cattle in addition to some phase-feeding of RUP for finishing cattle.

Take Home Points or Considerations

1. Overfeeding RDP above requirements has no value.
2. Overfeeding RUP has value, but has historically been cost prohibitive to use excess protein as an energy source.
3. TDN is only a proxy for ruminally digested organic matter.
4. Predicting microbial protein supply and efficiency of microbial protein production under diverse dietary regimens with large numbers and production settings would be beneficial.
5. Measuring microbial flow is a major challenge, and requires the use of microbial markers and flow markers that can be a challenge.
6. The metabolizable protein system is only partially adopted or considered. There is a need to make modelling the MP system easier and accurate for adoption by commercial nutritionists.
7. Growing cattle respond to RUP supplementation in many cases, but each situation varies and needs evaluation. Forages are generally high in RDP (as % of CP) and RUP that is present in forages is low in digestibility relative to concentrates.
8. Finishing cattle certainly require RDP due to energy available in the rumen. While models suggest that cattle should respond to RUP supplementation early in the feeding period, data are variable. Because corn (and corn byproducts) are relatively high in RUP and digestibility of RUP is high, RUP supplementation later in the feeding period has limited value.
9. A long-term need exists to adopt a metabolizable amino acid system in the beef industry, similar to the trend in the dairy industry.
10. Development of models is very useful, but should be informed and developed from research data and experimentation.

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Table 1. Selected feeds with CP, RUP (% of CP), and RUP digestibility

Feedstuff[1]	CP	RUP (% of CP)	RUP dig. UNL	RUP dig. NRC[2]
Corn	8.8	60	95	90
SBM	52.9	30	98	93
SoyPass	48.9	72	97	93
Blood Meal	100	90	90	80
CGM	68.2	70	95	92
DDGS	30.8	65	89	80
Sorghum silage	9.0	20	36	55
Alfalfa hay	19.8	13	38	70
Bromegrass hay	8.3	26	44	65
Sweet Bran	23.8	25	81	-

[1] Corn = dry-rolled corn; SBM = soybean meal; SoyPass = nonenzymatically browned SBM; CGM = corn gluten meal; DDGS = dry distillers grains plus solubles; Sweet Bran = Branded type of wet corn gluten feed.
[2] NRC predicted digestibility of RUP based on the 2001 Dairy NRC.

Table 2. Performance of growing calves fed harvested cornstalks with distillers solubles (30%) with (+RUP) or without (Control) supplemental RUP as 2.0% Soypass and 1.3% corn gluten meal (Empyreal, Cargill Inc.). Adapted from King et al. (2016)

	Control	+RUP	SE	P-value
Initial BW, lb	617	618	4.9	0.91
Ending BW, lb	724	740	7.5	0.14
DMI, lb/d	13.8	12.7	0.5	0.08
ADG, lb	1.27	1.45	0.07	0.14
Feed:Gain	10.5	8.65	-	0.02

Table 3. Performance of growing calves grazing corn residue and individually supplemented with corn, corn plus urea, DDGS, or a soypass/SBM blend. Supplements were formulated to provide equal energy (TDN) and vary in protein (none, RDP, or RDP/RUP). Adapted from Tibbitts et al. (2016)

	No Suppl	Corn	Corn+urea	DDGS	Soypass/SBM	SEM
Suppl. DM, lb	-	3.75	4.0	3.0	3.5	
TDN, %	-	83%	78%	104%	90%	
TDN, lb	-	3.11	3.12	3.12	3.15	
Initial BW, lb	516	516	516	516	516	3.5
Ending BW, lb	504	539	559	629	640	4.9
ADG, lb	-0.18[e]	0.31[d]	0.53[c]	1.32[b]	1.48[a]	0.06
RDP bal, g/d	-150	-259	0	-225	12	-
MP bal, g/d	61	78	75	229	364	-

Table 4. Performance of backgrounding calves on corn silage based diets and individually supplemented with 0 to 10% supplemental RUP. Supplement was included at 12% and soyhulls and some urea was replaced with a 60:40 blend of SoyPass and Empyreal (Cargill Inc.). Adapted from Hilscher et al. (2016)

	Supplemental RUP					Contrast	
	0%	2.5%	5%	7.5%	10%	Linear	Quad
Initial BW, lb	595	597	597	596	600	0.98	0.60
Ending BW, lb	791	824	855	842	868	<0.01	0.88
DMI, lb/d	16.9	18.3	18.9	17.4	18.4	0.05	0.84
ADG, lb	2.51	2.91	3.31	3.15	3.43	<0.01	0.82
Feed:Gain	6.74	6.26	5.71	5.52	5.35	<0.01	0.57

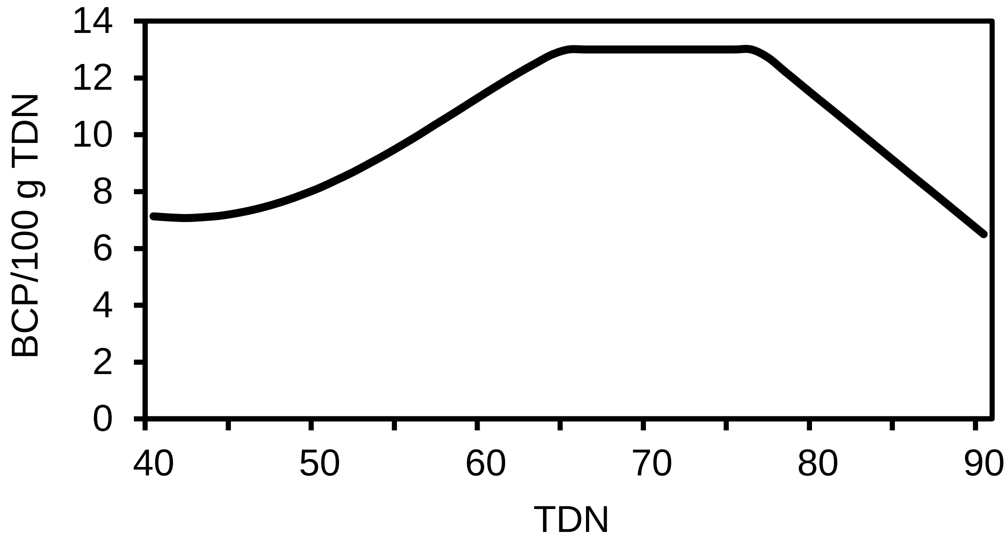

Figure 1. Microbial efficiency expressed as microbial protein (BCP) per 100 g of TDN. Efficiency varies as dietary TDN varies. Adapted from Patterson et al. (2006) and 1996 NRC. If TDN <65% then BCP=2.619948 + 1.78321X-.095981X^2 + .001777X^3 - .000010524X^4.

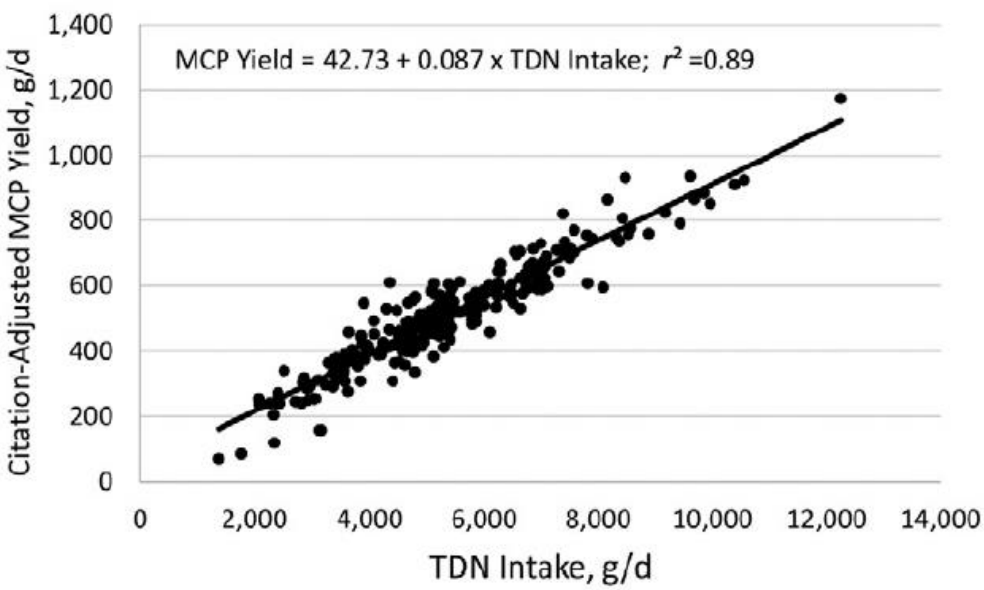

Figure 2. Proposed microbial efficiency of BCP = 42.73 + 0.087 (TDN intake, g) by Galyean and Tedeschi (2014) based on literature review including all studies.

SESSION NOTES