RUP Variation and Impact on MP Supply

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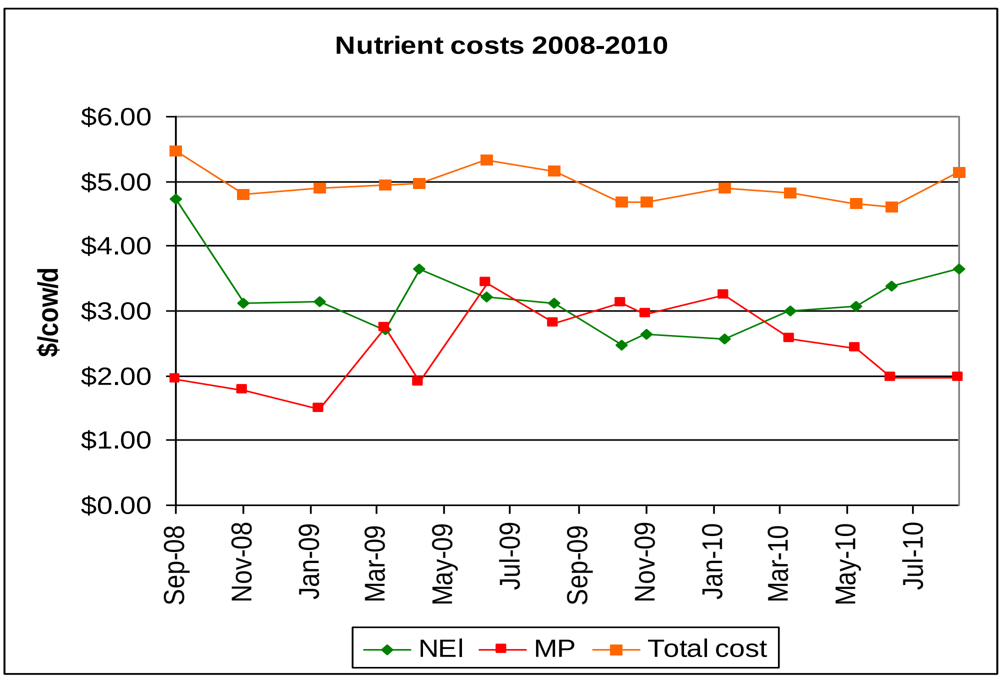
Summary

Variations in RUP and RUP digestibility affect metabolizable protein (MP) and metabolizable amino acid (AA) supplies to the cow, milk yields, and milk protein yields. This variation is not only due to protein meal ingredients, but to other feed ingredients as well. Animal protein meals are more variable than many plant protein meals, likely due to the heat processing involved in their production and the low concern with producing quality feed ingredients by the rendering industry. However, consistently high quality ingredients can be identified by testing. Managing variation in RUP and RUP digestibility to achieve more consistent MP and AA supplies will result in improvements in milk yield and profitability.

Introduction

In current dairy feeding programs in the U.S., digestible RUP (rumen undegradable protein) contributes 40 to 60% of the metabolizable protein (MP) requirements of lactating cows. MP is an expensive nutrient, and over the past two years has averaged $0.45/lb or 50% of total nutrient costs (Figure 1).

Figure 1. Nutrient costs for a 1500 lb. Holstein cow producing 75 lbs. milk/day with 3.80%milkfat and 3.1% true protein. Costs predicted using SesameIII software. NEl = Net Energy of lactation, MP = Metabolizable Protein.



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All feeds can supply MP through their contribution to microbial protein and to digestible RUP (aka as intestinally available dietary protein or IADP). Forages and energy concentrates are significant contributors to MP supply through microbial protein (Table 1), comprising 60 to 70% of the total supply. High protein forages such as alfalfa hay also contribute digestible RUP. Microbial protein flow to the small intestine is a function of organic matter digestibility in the rumen and passage rate of liquid and small particles out of the rumen. Good prediction equations have been generated (NRC 1989 and 2001), although there is a substantial amount of variation in the predictions (SE = 238 g/d microbial protein; NRC 2001).

Table 1. Contributions of individual feedstuffs in a lactating cow ration to MP supply and variation[a].

Feed	AF (lbs)	DM (lbs)	MP supply (g/d)	% variation in MP supply
Corn silage	50	16.5	587	28
Alfalfa haylage	35	14.4	523	46
Corn grain	12.0	10.6	534	5.8
Corn gluten feed	3	2.7	146	1.1
Wheat midds	3	2.7	120	0.2
Expeller SBM	1	.9	148	0.4
48% SBM	1.6	1.43	178	0.7
Ave. commodity Blood meal	1	.9	208	18.3
SmartamineM	.03	.03	10	0
Minvit pack	1.5	1.5	0	0
TOTAL		**51.7**	**2460**	

[a]MP supply and % variation predicted using PingPong (St-Pierre, unpublished).

With respect to digestible RUP, the amount supplied by each ingredient is a function of the inclusion rate of the feed ingredients, and their CP, RUP, and RUP digestibility (Table 1). Variations in moisture content and rumen digestibility of forages will comprise a significant proportion of the variation in MP supply (Table 1). Variations in RUP and RUP digestibility will also affect MP supply, as exemplified by commodity blood meal in Table 1. Current ration formulation programs set RUP as a constant for each feed; however, in reality it varies as a function of the rate of passage which likely varies with changes in dry matter intake. RUP can be estimated by *in situ* incubation of feedstuffs in the rumens of cannulated cows. RUP values for many feedstuffs have been widely published. They can be found in the 2001 NRC Nutrient Requirements of Dairy Cattle, and are embedded in feed libraries of ration formulation programs based on NRC 2001 and CPMDairy/CNCPS.

In comparison, RUP digestibility is measured or estimated much less often than RUP. RUP digestibility can be estimated using *in vivo* or *in vitro* methods. More details on these methodologies can be found in Stern et al. (2007). While all of these methods have advantages and disadvantages, the three-step procedure of Calsamiglia and Stern (1995) has been shown to be robust across feedstuffs and reasonably accurate when compared to *in vivo* RUP and RUP digestibility measurements. The procedure has been subsequently modified by Gargallo et al. (2006) utilizing the Ankom/Daisy apparatus to avoid the TCA precipitation required in the original 1995 method. Gargallo et al. (2006) showed very good agreement between the original and modified Three-Step Procedures for RUP digestibility of twelve different feedstuffs. Subsequently, however, two research groups have reported differences between the original and modified methods for RUP digestibility in distillers grain products (Boucher et al., 2009; Mjoun et al., 2010).

Feed ingredient variation in RUP and RUP digestibility

Variation in CP, RUP, and RUP digestibility of feedstuffs all contribute to the variation in MP and amino acid availability to the cow. Protein meals commonly used in dairy cattle nutrition can vary both within and between suppliers (Table 2). Sources of variation include the natural variation of the starting material since all of the proteins are by-products, variations in processing, and analytical variation. Processes used to produce feeds such as the animal proteins and expeller soybean meal and involve heating will contribute to substantial variation in RUP and intestinal digestibility. For the majority of ingredients, there is little correlation between RUP and RUP digestibility (Normand St-Pierre, personal communication; Mjoun et al., 2010). As a corollary, RUP digestibility cannot be predicted from RUP. As average RUP digestibility for a given feed ingredient approaches 90% or greater, there is less variation (smaller S.D.; Table 2). This indicates that there were few feedstuffs used in the analysis that were of poor digestibility.

Dr. St-Pierre and Venture Milling have amassed a large data set of test results over the past five years on commodity blood meal that would include ring- and batch-dried blood (Table 2). The average CP in that data is higher than that reported by Stern et al., 2007 and NRC 2001. The RUP is approximately the same as reported in the NRC for ring-dried blood (77.5 RUP %CP at DMI = 4%BW), but lower than that reported by Stern et al., 2007 for ring- and batch-dried blood meals. The intestinal digestibility reported by St-Pierre is approximately the same as NRC 2001 and Stern et al., 2007 for batch-dried blood meal. Note that it is ~15% lower than for ring-dried blood meal, however. The feed libraries in most ration formulation softwares have intestinal digestibility at 80% for blood meal.

With the evolution of the ethanol industry over the past five years, significant changes have been made in processing which result in distillers grain products with substantially different chemical composition (Kleinschmit et al., 2007; Mjoun et al., 2010). Processes include fat reduction by removing the germ before fermentation, addition of differing amounts of solubles back into the distillers grains, or fat extraction post-fermentation. These process differences are also reflected in differences in RUP and RUP digestibility (Table 2). The SDSU researchers have shown that there are substantial differences between different distillers grain products (Kleinschmit et al., 2007; Mjoun et al., 2010). Their data does not allow for an evaluation of how consistent distillers grain products are by process or supplier. In comparison to the RUP = 50.8 in NRC 2001, the RUP in dried distillers grains reported in the more recent research is equal to or higher than that (Stern et al., 2007; Kleinschmit et al., 2007; Mjoun et al., 2010). RUP digestibility was set at 80% in NRC 2001. Kleinscmhit et al. (2007) reported lower RUP digestibilities, ranging from 61.1 to 79.2%, using the original Three-Step Procedure. With the modified Three-Step Procedure, Mjoun et al. (2010) reported higher RUP digestibilities, ranging from 92.8 to 94% for distillers grains. It is unknown how well these reports on RUP and RUP digestibility represent the various distillers grain products available across the U.S.

Table 2. Variation in crude protein, RUP, and RUP digestibility of protein meals as determined by the Three-Step Procedure or its modifications and compiled from several sources. RUP is reported as the amount remaining after 16 hr. *in situ* rumen incubation unless otherwise noted.

Feedstuff	Source	n	CP (%DM) Ave.[a]	CP S.D.[a]	RUP (%CP) Ave.	RUP S.D.	RUP Dig. % Ave.	RUP Dig. S.D.	Estimated Digestible RUP (lbs/ton)[b]
Blood meal	St-Pierre/ Venture Milling	265	100.0	3.7	76.8	14.8	64.6	23.1	893
Blood meal, batch dried	Stern et al., 2007	12	*95.5*	--	88	6	63	17	953
Blood meal, Ring dried	Stern et al., 2007	10	*95.5*	*8.3*	83	4	81	6	1017
Corn gluten meal	Stern et al., 2007	2	*65*	*7.8*	83	2	89	4	864
Dried distillers' grains	Stern et al., 2007	5	*29.7*	*3.3*	56	8	81	5	242
Dried distillers' grains	Kleinschmit et al., 2007[c]	5	32.1	1.1	64.5	5.2	68.3	7.4	254
Dried & modified distillers' grains	Mjoun et al., 2010[d]	4	34.0	5.3	51.4	7.2	92.4	0.9	291
Feather meal	Stern et al., 2007	12	*92*	--	88	6	63	17	918
Fish meal, menhaden	Stern et al., 2007	13	*68.5*	*4.4*	65	4	80	5	641
Soybean meal	Stern et al., 2007	5	*53.8*	*2.1*	25	3	90	4	218
Soybean meal, expeller	Stern et al., 2007	6	*46.3*	*3.2*	47	6	93	7	364
Soybean meal, non-enzymatically browned	Stern et al., 2007	6	*50.0*	*1.6*	66	8	88	4	523

[a]Numbers in italics are from NRC, 2001.

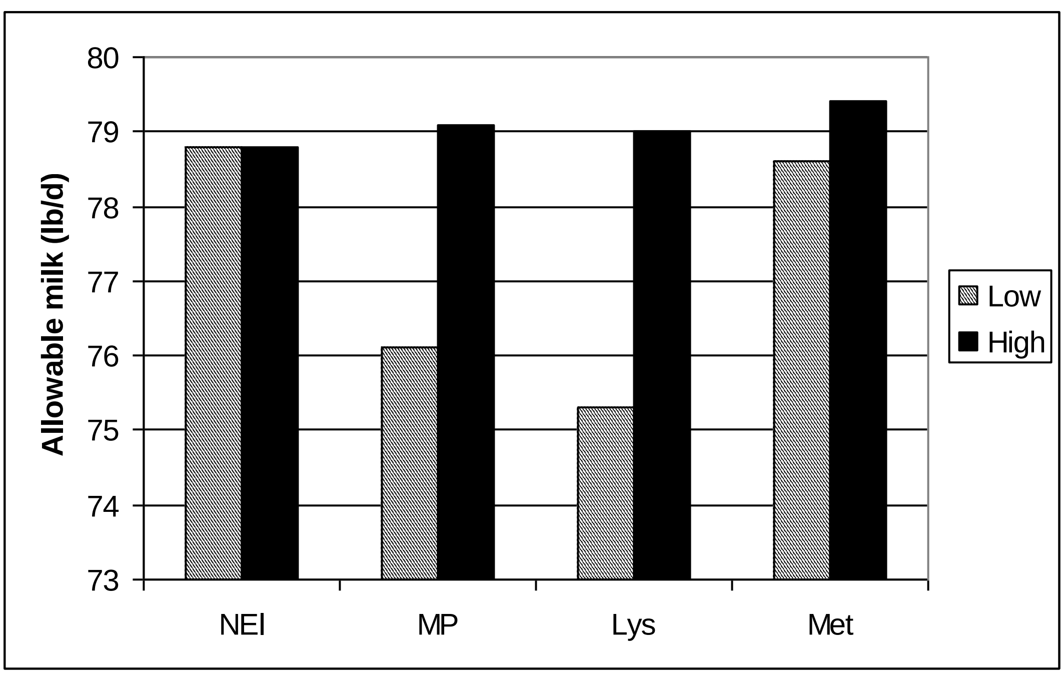
[b]Calculated as 2000 x Ave. CP x Ave. RUP x Ave. RUP digestibility x 0.90 (90%DM).
[c]Kleinschmit et al., reported a calculated RUP based on Kp = 6.8%/hr and used the original Three-Step Procedure.
[d]Mjoun et al., reported a calculated RUP, based on Kp = 6.17%/hr and used the modified Three-Step Procedure.

"Bypass" soybean meal ingredients also vary in CP, RUP, and RUP digestibility between and within suppliers (Table 2). With these ingredients, there is more variation in RUP than in RUP digestibility. Generally, the variation in RUP and RUP digestibility between suppliers is larger than within a supplier (Dr. Marshall Stern, personal communication), and the data provided here would represent the major name-brand suppliers in the U.S. The RUPs reported by Stern et al. (2007) for soy products are lower than those given by NRC 2001 (34.6, 69.0, 79.4 %CP at DMI=4%BW for 48%CP soybean meal, expeller SBM, and non-enzymatically browned SBM, respectively).

***Amino acid digestibilitie*s**

The intestinal digestion of individual amino acids (AA) parallels that of RUP, with the exception of lysine. Lysine is the very susceptible to heat damage. In the blood meal data from Dr. St-Pierre and Venture Milling, RUP digestibility of lysine was lower even at high RUP digestibilities (>80%) and becomes more pronounced at low RUP digestibilities (<40%) and approaches zero at RUP digestibilities < 20%. In the distillers grains data reported by Mjoun et al. (2010), lysine digestibility was ~8% lower than the digestibility of the other AA. In soy products, lysine digestibility was very high (96 to 98%) and not different from other AA (Mjoun et al., 2010). Current ration formulation softwares use a single digestion coefficient for RUP and cannot accommodate differential digestibilities for individual AA. Consequently, metabolizable lysine supply is likely to be over-estimated.

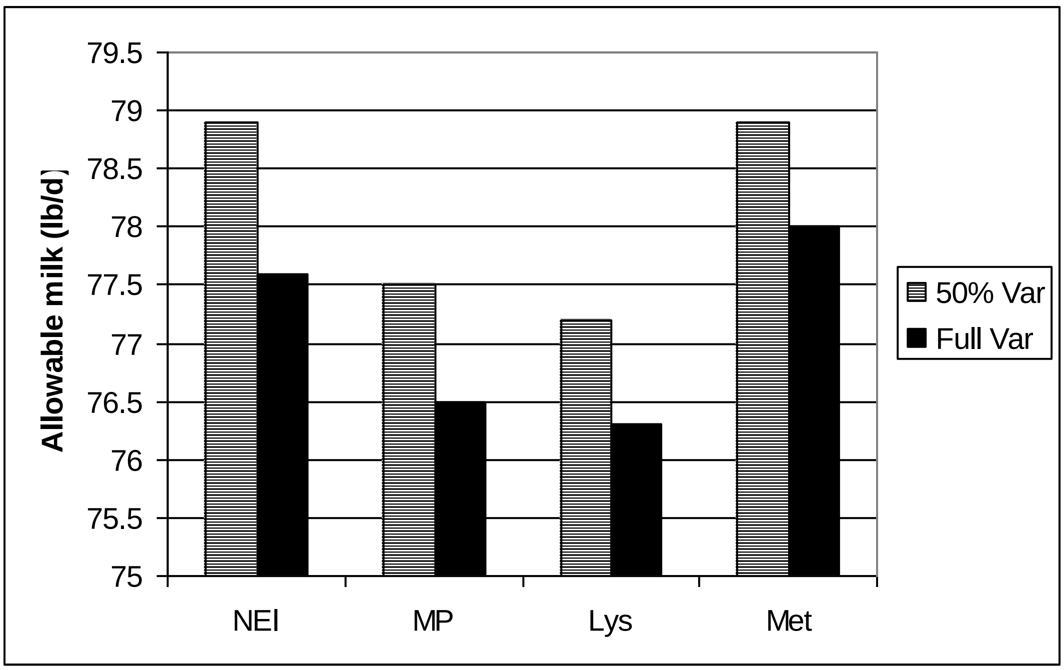
Figure 2. Predicted responses to variations in blood meal quality. Low quality blood meal fails to meet metabolizable protein (MP) and metabolizable lysine (Lys) requirements.



Impact on MP Supply

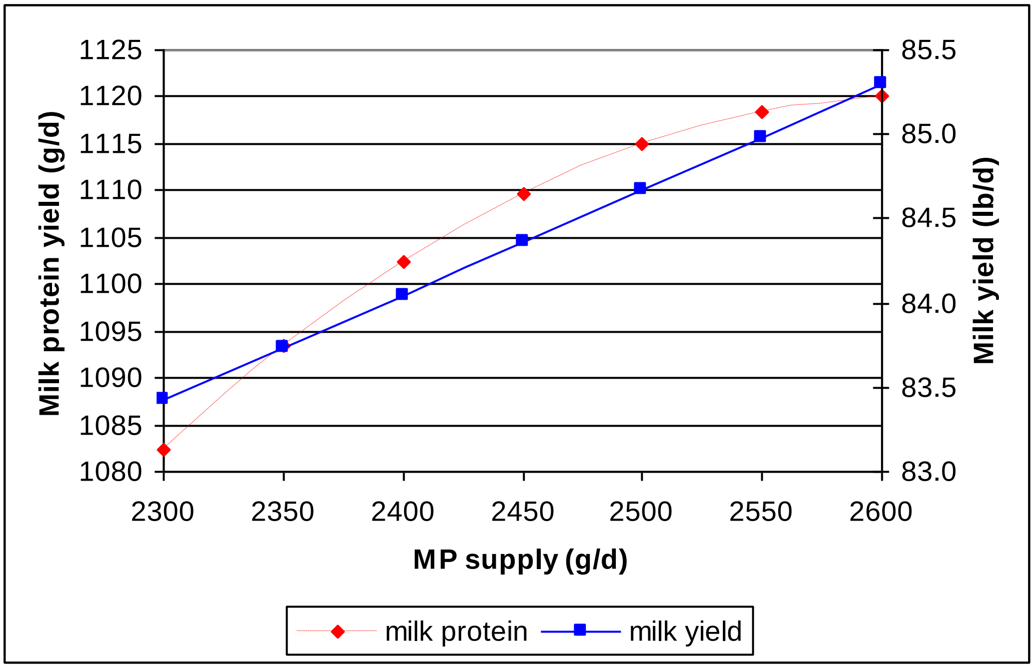
The impact of feed ingredient variation in DM, CP, RUP, and RUP digestibilities can be simulated to predict changes in MP supply and the impact on milk and milk protein yields. In the first example, rations were formulated as in Table 1 and the commodity blood meal was either from the lowest third of the data in terms of RUP and RUP digestibility or the highest third. The differences in RUP and RUP digestibility result in differences of ~100g. MP supply and 8g. metabolizable lysine supply, which affect MP and metabolizable lysine allowable milk (Figure 2). In the second example, the variation in forage DM, NDF, and CP contents was reduced by 50%. This affects both rumen function and intestinal nutrient supply and subsequent milk predictions (Figure 3). While on average, both rations provide the same amount of nutrients, the reduced-variation diet will meet the cow's requirements more consistently.

Figure 3. Predicted responses to variations in forage DM, CP and NDF. Reduced variation results in improved energy, MP, and AA supplies.



Based on the constant 67% efficiency of post-absorptive AA utilization in NRC 2001, a 50g. improvement in MP supply should result in a 33.5g increase in milk protein. This would equate to 2.5 lbs. more milk at 3.0% true protein. In the field, observed responses are not that large. Also, recent research has shown that MP supply is used at much lower efficiencies when supply is near calculated requirements (Metcalf et al., 2008; Weiss et al., 2009, Rius et al., 2010). Interestingly, all three of these publications have shown responses to MP <u>above</u> AFRC or NRC determined requirements. Using the equations from Weiss et al. (2009), a 50g. improvement in MP supply is predicted to increase milk yield 0.3 lbs/day and protein yield in diminishing increments (Figure 4).

Figure 4. Responses to MP supply predicted from Weiss et al. (2009). Milk protein responses were calculated with alfalfa at 40% of forage DM.



Measuring and Managing Variation in RUP, RUP digestibility and MP supply

In practice, several steps and considerations can be taken to reduce variation in RUP and RUP digestibility and improve the consistency of MP supply:

1. The most variable ingredients in rations are the forages. Managing them to reduce variations in DM, CP and NDF will result in improvements in both energy and MP supply.
2. Using more ingredients with the more variable ingredients at lower inclusion rates will reduce ration variation.
3. Identify high quality, consistent suppliers of protein meal ingredients by testing. Currently, testing using the Three-Step Procedure is not available at any commercial feed/forage testing laboratories, but is available in Dr. Stern's lab at the U. of Minnesota.
4. Use the test results in ration formulation wisely.
5. Don't spend a lot of time trying to be ultra-precise in balancing for amino acids. There's too many sources of variation that you can't control. Fortunately, they tend to counter-balance each other.

Acknowlegements
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