Industry Presentation

Rumen Microbial Protein Production: Are We Missing an Opportunity to Improve Dietary and Economic Efficiencies in Protein Nutrition of the High Producing Dairy Cow?

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All of the newer dynamic models for balancing rations for cows no longer use the older more ill-defined parameter of crude protein (**CP**). Rather, they try to balance for what the cow truly needs, which is metabolizable protein **(MP)**. While CP is a catch-all measurement for all types of nitrogen in feeds, MP is the amount of true protein that arrives in the intestine of the cow. To illustrate the uselessness of CP, two diets with the same CP content can deliver vastly different amounts of MP to a cow. The MP provides the supply of amino acids to the cow for her true needs in biological functions, with our focus being on milk production.

There are two sources of MP available for the cow. One is the true protein in the diet that escapes degradation in the rumen. This is called rumen undegradable protein, or **RUP**. The second source is the bacterial protein produced by the rumen microbes. The rumen microbes produce their protein as they multiply in the rumen while fermenting various carbohydrates (fibrous and non-fibrous) and use the rumen degradable protein (**RDP**) as a source of nitrogen. Rumen undegradable protein seems to receive the most attention by many nutritionists, but by far the bacterial or microbial protein is the most important and reliable source of MP for the dairy cow for two reasons. First, microbial protein can satisfy more than 50 % of the total MP needs for even the highest producing cows in well-formulated diets. Intuitively, the higher the amount of MP from microbial protein, the more efficient is the cow's rumen at fermenting and digesting feeds. Secondly, the amino acid profile of the microbial protein is very consistent and is close to ideal in meeting the cow's needs. Therefore, every time we can increase microbial protein production in the rumen, we are making the cow more efficient in her use of feeds and supplying a more ideal protein source to the cow.

Why Is Microbial Protein Such an Important Source of Protein for Dairy Cows?

As illustrated in Table 1, the average amino acid composition of microbial protein is similar to the composition of milk. Typically, protein-rich feedstuffs have much greater dissimilarities in amino acid profiles for their RUP when compared to milk protein. When a large proportion of the total amino acids entering the intestine are from rumen microbial protein, then balancing diets for amino acids is reasonably simple.

Table 1. Comparisons between the amino acid profile of milk, rumen bacteria, and estimated rumen undegradable protein fractions of common protein sources.

	g/100 grams of amino acids					
Amino Acid	Milk[a]	Bacteria[b]	Blood meal[c]	Canola Meal[c]	Corn Gluten[c]	Fish Meal[c]
Arginine	3.4	5.1	4.1	5.0	3.3	5.7
Histidine	2.6	2.0	6.3	2.0	1.9	2.0
Isoleucine	5.8	5.7	1.5	3.2	3.8	2.7
Leucine	8.3	8.1	12.8	7.8	18.1	7.0
Lysine	7.5	7.9	8.8	5.1	2.0	7.5
Methionine	2.5	2.6	1.1	1.9	2.6	3.0
Phenylalanine	4.6	5.1	6.6	4.1	6.6	3.8
Threonine	4.4	5.8	4.3	4.7	3.5	4.3
Valine	6.3	6.2	7.5	4.0	4.3	3.3

[a]National Dairy Council, 2000.
[b]Clark et al., 1992 (average of 441 samples).
[c]Piepenbrink and Schingoethe, 1998 (profiles for residues of samples incubated for 12 h).

With few exceptions, Table 1 shows that the amino acid profile for microbial protein is extremely close to that of milk protein and; therefore, should be very close to what the mammary gland requires for milk and milk protein synthesis. The amino acids in the RUP from other feed sources present either deficiencies or excesses of amino acids required for milk production.

Bacterial protein is of great importance because poor quality protein, in terms of amino acid profile, as well as non-protein nitrogen can be converted to high quality protein for the cow. A poor amino acid profile in the RDP and for the rumen soluble protein fraction does not necessarily result in growth limitations to the rumen microbes (Atasoglu et al., 2003). This allows the rumen microbes to convert these degradable amino acids, peptides, and nucleic acids to a profile more suitable for the synthesis of milk. Furthermore, a good portion of the bacterial amino acids is produced from ammonia as well as other NPN sources (Cruz Soto et al., 1993).

The digestibility of MP from microbial protein is consistent, and is generally higher than the digestibility of MP from RUP sources. Very early research demonstrated that the intestinal digestibility of freeze-dried rumen microbes ranged from 75-80 % (Abdo et al., 1964), which is consistent with more recent findings (Larsen et al., 2001). This compares favourably with the intestinal digestibility of soybean meal. Stern et al. (2005) recently determined that the intestinal digestibility of soybean meal protein ranged from 57.7-83.8 %. The protein digestibility of many by-product ingredients is lower or much more variable (Maiga et al., 1996). The source of this variability lies in the fact that different processing facilities produce by-products or process oilseeds using slightly different procedures, which affect the digestibility of the RUP fractions.

Feed formulation systems calculate the amount of digestible protein entering the duodenum from microbial and feed ingredient RUP sources, and match the supply to the requirements. Optimizing the supply of digestible protein and amino acids from rumen microbial protein will reduce variability and can support a very high

Table 2. Theoretical contribution of microbial protein to the total protein requirement of the lactating dairy cow [1]

Microbial Efficiency[2]	Milk Yield, kg		
	25	35	45
		%	
20	49	42	39
30	73	64	59
40	98	85	79

[1] From Stern et al., 1994.
[2] Grams of N/kg organic matter digested in the rumen, assuming 55 % of total organic matter is truly digested in the rumen.

portion of the cow's total protein requirements.

Stern et al. (1994) estimated the percentage contribution that microbial protein can make to the total MP required by cows for different levels of milk production and different growth rates (efficiencies) for microbes. This microbial efficiency was calculated as the grams of microbial nitrogen produced per kilogram of organic matter fermented in the rumen. In other words, it is a measure of how well the microbes were using organic matter to make protein. In well balanced diets, the efficiency figure can range from 30-40 %. Table 2 shows that in well balanced diets for cows milking 100 pounds (45 kg) per day, microbial protein can contribute between 50 and 79 % of the total MP needs of that cow. Obviously, the closer that we can get to the 79 % value, the better our production performance and economics will become due to the excellent amino acid profile and high digestibility of microbial protein.

Why Else Is Microbial Growth Important to the Well-Being of the Cow?

Growth of the rumen microbes is required to affect rumen fermentation of other dietary nutrients. The ability of ruminants to consume and digest fibrous ingredients and to convert these into energy and protein via rumen microbial fermentation provides ruminants with their ecological edge over monogastrics. Energy derived from the digestion of fiber can fulfill a substantial portion of the cow's requirements as long as sufficient nutrients are available to support microbial growth and metabolism.

In addition to the rumen microbes acting as the premiere source of amino acids for milk production, they are also the principle suppliers of intestinal glucose (Cheng et al., 1973; Cheng et al., 1977). The amount of glucose in the form of glycogen stored by rumen microbes varies somewhat by species and by their energy status, but in general is roughly equal to the amount of protein (Lou et al., 1997; Russell, 1998; Stewart et al., 1981; Wallace, 1980). Glucose can be in critical supply, particularly in early lactation and any increase in rumen fermentative capacity becomes important from an overall health and production standpoint for the cow.

What Limits Microbial Growth?

Microbial growth is a variable that exerts a major influence upon animal performance. Like the host animal, rumen microbes require a constant supply of nutrients to support their growth. If such nutrients are not supplied, then the supply of microbial protein may be depressed, fiber digestion may be suboptimal and glucose supply can be variable.

The amount of microbial protein produced depends on the amount and availability of the N and energy-yielding substrate supplied such as starches, sugars, fiber, and organic acids (Clark et al., 1992; Stern et al., 1994). Until recently, energy-yielding compounds were considered to be most important for microbial yield, but these may need to take second place when looking at more recent findings. Using a stepwise regression technique, Gosselink et al. (2003) determined that even in a diet limited in the amount of carbohydrates available for fermentation by the microbes, *nitrogen available in the rumen* was the most important predictor of microbial yield.

Meng et al. (1999) demonstrated that a supply of CP nitrogen improved microbial efficiency to a greater extent than did either fiber or starch (Table 3) and that this effect occurred consistently at varying rumen dilution rates.

Dilution rate is the rate at which material, usually expressed as a fraction of the total rumen volume, enters and leaves the rumen. A value of one would be a full turnover of the rumen contents. Microbial growth and production of microbial protein usually increases with dilution rate. When the dilution rate is low, a greater number of the microbes remain in the rumen, consuming the available energy for maintenance and reducing overall efficiency. As this research shows, bacteria cannot survive and grow without a continuous supply of nitrogen.

It is likely that many models of microbial needs underestimate the amount of N available for microbial growth. It is frequently assumed that N that is soluble in the rumen is available for use by the rumen microbes. This is not entirely true. Soluble proteins are able to exit the rumen along with the fluid phase, which is more rapid than the solid phase (Evans and Patterson, 1985).

Table 3. Effect of dilution rate on microbial N production and microbial efficiency[1]

Item	Dilution rate, fraction/hr					
	.025	.050	.075	.10	.15	.20
Microbial N production, g/day						
100% soy hulls	.80	1.25	1.44	1.69	1.66	1.23
Mixed diet[2]	.27	.45	.54	.67	.68	.67
100% isolated soy protein	1.38	1.67	2.27	2.65	3.12	3.18
Microbial Efficiency[3]						
100% soyhulls	16.6	23.6	26.6	32.0	37.0	36.5
Mixed diet	11.2	18.9	23.9	31.1	41.8	49.8
100% isolated soy protein	27.0	34.8	47.1	56.2	65.2	71.7

[1] Meng et al., 1999.
[2] 78 % corn, 14 % soy hulls, and 8 % isolated soy protein.
[3] Grams of microbial N/kg of organic matter truly digested in the rumen.

Given and Rulquin (2004) found that up to 10 % of the soluble N from silages escapes rumen fermentation via the liquid phase. Also, molecules of protein can be soluble, but still be too large for rumen bacteria to digest.

Compounds within feedstuffs that contain soluble N are present in a variety of forms, which can change with feeding conditions. Proteins are reduced to amino acids, and then the amino acids are split into volatile fatty acids and ammonia. With the use of feed additives, such as ionophores and some of the essential oil products, both the rate of protein break down and the rate of amino acid destruction can be reduced (Newbold et al., 1990; Chen and Russell, 1990). Thus, solubility overestimates rumen availability of nitrogen as some proteins may be soluble but not available, and some soluble proteins may exit the rumen before the bacteria can capture them.

What N Compounds Do Rumen Microbes Require?

Ammonia, amino acids, and peptides (very short chains of amino acids) are used for protein synthesis by rumen microbes. Nucleotides (DNA and RNA) are used to support cellular growth. Although ammonia alone will allow rumen microbes to flourish, peptides and amino acids are important because they stimulate additional growth of the bacteria (Cotta and Russell, 1982; Cruz Soto et al., 1993). This is also the case with nucleotides (Sanchez-Pozo and Gil, 2002).

Argyle and Baldwin (1989) supplemented individual or groups of amino acids or peptides to rumen microbial cultures. These researchers determined that small amounts of individual or groups of amino acids increased microbial yield by 25-37.5 %. When all amino acids were provided, growth increased by 47.5 %. Atasoglu et al. (2003) similarly found that microbial yield was increased by 42 % when amino acids were included in the growth media. In this study, amino acids were deleted from the media one at a time. Leucine was the only amino acid to affect microbial protein yield, relative to the full complement of amino acids, decreasing yield by 10 %. Significant declines in gas production (an index of fermentation activity) only occurred when glutamate, glutamine, isoleucine, leucine, phenylalanine, serine, tryptophan, or tyrosine were deleted from the amino acids mixture.

Under continuous culture conditions, microbial growth has been shown to be optimum when approximately 10 % of the nitrogen available to rumen microbes is in the form of peptides, with the rest from ammonia (Jones et al., 1998). When levels were greater than 10 %, fiber digestion was depressed. The reason for the depression in fiber digestion when microbial growth is high is enigmatic. It is possible that the very rapid microbial growth results in some form of substrate limitation at a later time after feeding. This may be in the form of depletion of available carbohydrate or nitrogenous compounds needed at a later stage of fermentation when fiber should be digested resulting in reduced fiber digestibility.

Cellular growth by rumen microbes entails either the synthesis or acquisition of nucleotides. Nucleotides are synthesized from amino acids, consuming a significant portion of the energy and available nitrogen, which could have been used for microbial growth. This synthesis of nucleotides by the microbes can be a step that limits growth (Sanchez-Pozo and Gil, 2002). Nucleotides are often provided in high concentrations with fermented by-products. These compounds are recycled by rumen microbes (Shin et al., 2004); thereby saving synthetic costs in terms of nutrients that could be used for other purposes, namely, microbial growth.

How Do Carbohydrates Support Microbial Growth?

As indicated above, mixed rumen microbes can grow when provided with intact proteins, peptides, amino acids, or ammonia; but growth is improved when a mixture of these nutrients is provided. The same is the case with carbohydrates; whereby microbes can grow using starches, sugars, and fiber but grow best when all are supplied.

Microbial production appears to be maximized when carbohydrate is provided along with protein, providing both energy and N for microbial growth. Cameron et al. (1991) demonstrated that urea increased rumen ammonia, but that ammonia decreased substantially with the addition of starch; presumably through additional microbial protein synthesis.

Can Microbial Production Be Enhanced?

The discussion above provides the basis for answering this question.

There is no scientific evidence that microbial growth (and protein production by default) can be enhanced beyond the biological limits of the microorganisms without genetic engineering of the microbes or by supplying substances that would mimic growth enhancing drugs in mammals. For various reasons beyond the scope of this article, neither of these possibilities is likely to occur in the near future for food producing animals.

However, we can and should optimize the growth rate of rumen microbes to obtain the highest efficiencies of fermentation and microbial growth possible. In order to achieve this goal, feedstuffs should be identified that supply the peptides, amino acids, and nucleotides; as non-protein nitrogen sources (**NPN**) enhance the microbial growth and efficiency for any given diet, as discussed above. All three of these NPN sources optimize microbial growth by supplying preformed nutrients that the microbes can use directly, rather than having to use precursors and energy in synthesizing them themselves.

Obviously, the microbes can and do grow well without all of these NPN sources. However, under conditions where our expectations and desire are for maximum growth to achieve high levels of milk production through MP supplied by microbes, the synthetic rate of the microbes is not fast enough to realize this goal. Supplying these NPN sources in a preformed format reduces the microbes' need to keep pace with their ability to grow.

In addition to these NPN sources, other substrates are needed to assure optimal microbial growth. Values shown in Table 4 are the optimal dietary specifications for a cow producing 100 lbs. of milk per day (3.5 % fat and 3.07 % true protein) and consuming 54 lb of dry matter. These nutrient specifications were derived using iterations of the CPM/CNCPS model and recent data reported in the literature (W. Chalupa, C. Sniffen, E. Evans, E. Block, personal communication).

Meeting the specifications in Table 4 may be awkward, but not impossible, for the carbohydrate fractions in some instances. Sugars may need to be added intentionally if all-ensiled forages are used; grains may need

Table 4. Nutrient specifications to optimize production and rumen fermentation efficiency for cows producing 100 lb of 3.5 % fat corrected milk at 3.07 % protein and consuming 54 lb of dry matter (DM) daily.

Nutrient	Lb	Kg	% Fraction	% DM	Min. % DM	Max. % DM
Dry Matter	54	24.5				
Fermentable Dry Matter	23.2	10.5	43	43	41	44
Total NDF	16.2	7.4		30	28	36
Forage NDF	11.3	5.2	70	22	20	28
peNDF	12.4	5.6	76.6	23	21	24
Lignin	1.89	0.9	11.7	3.5	3	5
Fermentable NDF	5.67	2.6	>32	10	9	12
Fermentation Acids		0.0		<5		
Sugar	2.7	1.2		7	5	9
Fermentable Sugar			98	6	5	8
Starch	13.5	6.1		25	21	27
Fermentable Starch	11.3	5.1	84	21	20	22
Starch + Sugar	16.2	7.4		30	27	33
Fermentable Starch + Sugar	16.2	7.4	86.6	26	24	28
Soluble Fiber	3.2	1.5		7	5	11
Fermentable Sol Fiber	2.7	1.2	84	6	4	9
Starch + Sugar +Sol Fiber	18.3	8.3		34	32	38
Ferm St+S +Sol Fiber	16.7	7.6	86.6	31	29	34
Rumen Degraded Protein (RDP)	6.2	2.8		11.5	11	12
Soluble Protein	3.1	1.4	50	5.75	5.5	6.0
Peptide balance, % of Requirement				110	105	120
NH_3 balance, % of Requirement				120	115	130

processing (popping, steam flaking, fine-grinding) to achieve the starch fermentabilities desired; or by-products containing soluble fiber may need to be supplemented (citrus or beet pulp, for example). However, the carbohydrate fractions are attainable.

The nitrogen fractions are a bit more problematic. Meeting the RUP specification is uncomplicated. The RUP fractions of most feeds are fairly well defined along with their amino acid profiles. Similarly, the soluble protein and RDP fractions are fairly uncomplicated. The peptides and free amino acids become more difficult to meet. Ingredients, such as soybean and canola meals, can contribute substantial portions to the rumen pool of peptides; however, under many conditions it is still difficult to meet the specifications in Table 4. Furthermore, there is no established specification for the nucleotide fraction of NPN that has been shown to improve microbial efficiency by sparing the microbes the need to synthesize these (see above). The objective would be to identify or create a feedstuff that can supply free amino acids, peptides, and nucleotides that would not be degraded in the rumen in a short time frame but would allow the microbes to grow at optimal rates.

An example of such a feedstuff is FERMENTEN® (ARM & HAMMER Animal Nutrition, Church & Dwight Co., Inc., Princeton, NJ). FERMENTEN is produced by combining co-products from specifically selected fermentation streams, adsorbing these onto a carrier system and drying by a patented process that reduces the degradability of the NPN sources, but not to the point of either adding to the RUP fraction or the indigestible fraction. In other words the NPN in FERMENTEN is slowly available to the microbes. By virtue of the raw materials (fermentation co-products), FERMENTEN contains about 7.8 % nitrogen (49 % CP) on a dry basis with almost 75 % of the nitrogen as *NPN.* Some of this NPN is in the form of ammonia nitrogen and the remainder is as peptides, amino acids, and nucleotides.

In a recent study published by Lean et al. (2005), the fermentation optimizing effects of FERMENTEN were shown to be approximately 15 % over all diets evaluated in the study. The approximate value is given because the value varies between 12 and 28 % depending upon the parameter being evaluated (microbial N produced, or microbial N produced per unit of carbohydrate, organic matter, or DM digested). The study evaluated over 30 different diets in 118 continuous culture fermentations with diets formulated for high milk production both within and slightly outside of the specifications in Table 4.

Realize that the *average* increase in microbial growth capacity was for diets both within and marginally outside the range for the specifications in Table 4. By examining one data set, we can begin to develop an appreciation for the potential increase in growth capacity for the microbes to contribute to MP with a balanced amino acid profile.

Table 5 shows the diets used in one trial where the diets were formulated to be within specifications for all nutrients listed in Table 4 except sugar. Without adding sugar, basal dietary levels were 3.3 % (diet S1). This is very typical of most rations where ensiled forages are the main fiber source. Sugar was then added at two levels: 4 % (diet S2) and 8 % (diet S3) added sugar for a total dietary sugar level of 7 or 11 % for these two treatments. The control diet contained the same amount of sugar as diet S2, but this diet contained no added FERMENTEN.

FERMENTEN had positive effects on CP digestion, microbial protein production and all measures of microbial efficiency, irrespective of sugar level, compared to the control diet at 7 % sugar. Within the FERMENTEN diets, the diet with 7 % sugar (S2) appears to have optimized the FERMENTEN response. The greatest increase in these parameters was between the 3 and 7 % sugar diets, with no or small improvements between the 7 and 11 % sugar diets (Table 6).

The most interesting comparison is between the Control and FERMENTEN S2 diet at the same sugar content (7 %). This comparison shows the FERMENTEN response when other dietary parameters are held constant. There was a 34.5 % increase in the amount of microbial protein produced per unit of carbohydrate digested. More carbon was used in the synthesis of protein than volatile fatty acids **(VFA)**, resulting in a decrease (-22 %) in total VFA/ unit of microbial protein produced.

FERMENTEN increased CP digestion by 22.6 % (Control vs. S2 FERMENTEN). While part of this increase is because of the high soluble and degradable protein in FERMENTEN, the

Table 5. Diet composition and analysis, % dry matter basis, for diets fed to continuous culture fermenters (3 fermenters per diet) to determine effects of dietary sugar on microbial fermentation.

Ingredient	Diets			
	Control	FERMENTEN		
	Sugar 2 (S2)	Sugar 1 (S1)	Sugar 2 (S2)	Sugar 3 (S3)
Alfalfa Balage	6.06	5.87	6.07	6.12
Corn Silage	25.05	24.48	25.30	25.50
Mixed Haylage	16.93	16.96	17.53	17.67
Cottonseed	0.59	0.59	0.59	0.59
Fermenten	0.00	3.00	2.99	2.99
Soybean Meal 44	18.57	14.14	14.76	16.24
Soybean Hulls	1.56	1.57	1.57	1.56
Sucrose	4.11	0.00	4.12	8.23
Flaked Barley	5.59	7.19	5.60	4.11
Steam Flaked Corn	16.78	21.54	16.80	12.32
Corn Gluten Meal	0.68	0.69	0.69	0.68
Urea	0.66	0.57	0.57	0.57
Megalac	1.74	1.74	1.74	1.74
Magnesium Oxide	0.01	0.01	0.01	0.01
Dicalcium Phosphate	0.29	0.29	0.29	0.29
Sodium Bicarbonate	1.00	1.00	1.00	1.00
TMIN Salt	0.20	0.20	0.20	0.20
ADE Mix	0.12	0.12	0.12	0.12
Vitamin E	0.06	0.06	0.06	0.06
Analyses:				
(% DM Basis)				
Crude Protein	18.3	18.5	18.5	18.6
Soluble Protein (% CP)	33.7	41.5	43.1	42.3
NDF	31.8	31.3	31.8	31.4
ADF	19.3	19.1	19.6	19.3
NSC[1]	32.9	30.9	31.3	31.6
Starch	25.3	27.7	24.4	20.4
Sugar	7.7	3.3	6.9	11.2
Soluble Fiber	7.0	6.6	6.6	6.7
Ether Extract	3.6	3.5	3.6	3.5
Ash	6.7	6.4	6.3	6.5
NFC[2]	39.6	40.3	39.8	40.0

[1]Nonstructural Carbohydrate (starch + sugar)
[2]Calculated Non-Fiber Carbohydrate

contribution to the total dietary CP from this ingredient was less than 8 % of the CP. Even if 100 % of the FERMENTEN CP were digested, it would only account for 1/3 of the response witnessed.

FERMENTEN increased microbial protein production by 25 % in this comparison. It is interesting that this nearly matched the increase in CP digestion.

Table 6. Nitrogen partitioning, microbial growth and microbial efficiency when FERMENTEN containing diets had 0 (S1), 4 (S2) or 8 (S3)% added sugar for a total of 7, 7, or 11 % total sugar in the dietary DM.

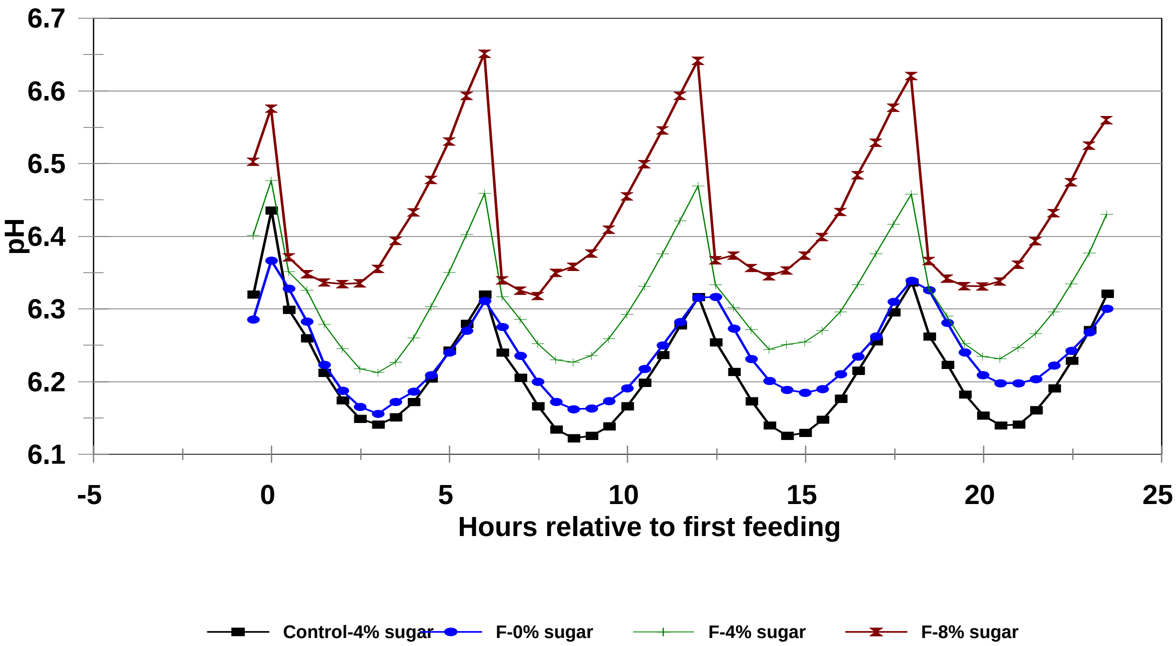
Item	Diets				P =	
	Control	FERMENTEN			Sugar x Fermenten	
	S2	S1	S2	S3	Linear	Quad
Crude Protein digested, %	70.8[b]	82.0[a]	86.8[a]	86.1[a]	0.4688	0.5082
Microbial N, g/d	1.77[b]	2.00[a,b]	2.21[a]	2.20[a]	0.2706	0.4137
Efficiencies:						
Mic. N/kg DMD[1]	27.40[b]	29.01[a,b]	30.54[a,b]	32.36[a]	0.1439	0.9351
Mic. N/kg OMD[2]	34.45[b]	39.71[a]	42.01[a]	42.42[a]	0.2999	0.6271
Mic. N/kg CHOD[3]	39.58[b]	50.84[a]	53.36[a]	55.48[a]	0.2233	0.9429
Mic. N/kg CHOD+S[4]	34.21[b]	43.52[a]	46.02[a]	47.44[a]	0.2368	0.8288
TVFA/kg Mic N[5]	255[a]	220[b]	200[b]	191[b]	0.0665	0.6244

[1] Grams microbial N produced per kg dry matter digested.
[2]Grams Microbial N produced per kg total organic matter digested.
[3]Grams Microbial N produced per kg total carbohydrate digested.
[4]Grams Microbial N produced per kg total carbohydrate digested (+soluble fiber).
[5]Moles VFA produced/kg Microbial N produced.
[a,b] Values with different superscripts differ, P < 0.05

In practical nutritional terms, a high producing cow fed a well balanced diet can produce at least 1500 g/day of MP from microbial protein, contributing over 60 % to the MP required with an excellent amino acid profile. In this case, FERMENTEN increased MP from microbes by 375 g/day. Over four pounds of soybean meal would be needed to achieve the same results without FERMENTEN. In terms of microbial efficiency, the g of microbial nitrogen produced per kg of carbohydrate digested increased by 34.5 % in the FERMENTEN (S2) vs. the Control (S2) diet. This is reflected in the total volatile fatty acids produced per kg of microbial nitrogen produced. FERMENTEN decreased this value by 22 %. Since VFAs are the bacterial waste products (end product) of fermentation, decreasing this value indicates that more carbon from carbohydrate digestion was used to grow bacteria with FERMENTEN, resulting in lower VFA produced per unit of bacterial growth. Because FERMENTEN causes lower VFA per unit of microbial fermentation, rumen pH does not drop as dramatically with FERMENTEN, even though total rumen digestion coefficients have increased.

Figure 1 shows that not only was rumen pH higher when FERMENTEN (diet S2) is compared to Control (S2), but that when sugar is increased to as high as 12 % of the diet, FERMENTEN helped support rumen pH at a higher value than one should theoretically expect. The example study in Fig. 1 illustrates and typifies the 118 fermenter studies evaluated in the report by Lean et al. (2005).

Figure 1. Rumen pH profiles for 24 hours of continuous culture with fermenters fed diets 4 times daily (See Tables 5 and 6 for diet descriptions).



To summarize the take-home messages are:

1. Metabolizable protein (MP) is the intestinal protein received by the cow that has to be of sufficient quantity and quality (amino acid profile) to assure high milk and milk component production by cows;
2. Rumen microbial protein should supply more than 50 % of the MP in cows and, because of its ideal amino acid profile, should be maximized in any given animal;
3. Rumen microbes can grow at more maximal rates if supplied with free and degradable amino acids, peptides, and nucleotides used as cellular precursors and sparing the microbes the need to synthesize these;
4. Other nutrient specifications, especially within the non structural carbohydrate fractions of diets, can be optimized to assist the microbes with more rapid growth;
5. Feedstuffs that afford a slowly but completely available source for the rumen microbes of amino acids, peptides, and nucleotides can and will improve microbial protein production and efficiency by as much as 30 %; and
6. FERMENTEN has been used as the model to demonstrate this in practical diets.

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