OPTIMIZING CARBOHYDRATE FERMENTATION IN THE RUMEN

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INTRODUCTION

Following an extensive review of studies on starch utilization n dairy cattle, Nocek and Tamminga (1991) concluded that post-ruminal starch digestion did not increase plasma glucose or enhance lactation performance. They did point out that post-ruminal starch digestion provided glucose that was used extensively by visceral tissue, and that this could spare some blood glucose for the other productive purposes. On the other hand, Hoover and Stokes (1991) reported that starch digestion in the rumen was needed for optimum microbial growth, and that high levels of microbial protein and other fermentation products were positively related to milk production.

OPTIMUM RUMEN FERMENTATION

The potential importance of rumen fermentation to lactation performance is shown in Figure 1. Milk components are dependent on high levels of fermentation end-products.

MILK PROTEIN - Of the total protein in milk, 60% or more should be provided by microbes grown in the rumen. The remainder must be supplied in the feed as by-pass protein.

MILK SUGAR (lactose) - Nearly all milk sugar is made from rumen fermentation products. About 50% is from propionic acid alone. Other major sources are amino acids and lactic acid.

MILK FAT - Fermentation products (acetate and butyrate) account for about 30% of milk fat. Most is from feed fat and some from body fat (in early lactation).

OPTIMUM FERMENTATION IS NOT AUTOMATIC

The daily flow of sufficient fermentation products from the rumen to guarantee high levels of milk production depends on how well the rumen is fed.

EXAMPLE - A cow producing 90 lbs of milk/day requires 7.9 lb. protein. Current feeding standards estimate 5.5 lb. will be provided by rumen microbes,

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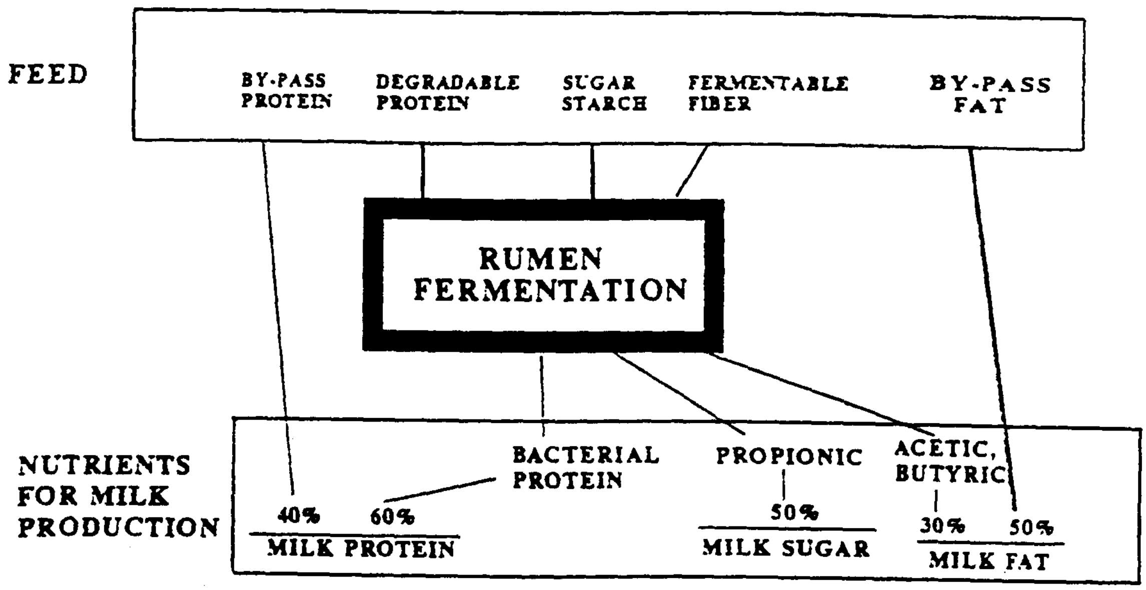
so by-pass protein recommended will
be 2.4 lb.

Figure 1. THE IMPORTANCE OF OPTIMUM RUMEN FERMENTATION[1]



[1] Adapted for Oldham and Emmans (1989)

Actual measurements of microbial protein in high-producing cows range from 2 to 6 lb./day. Most of the variation is due to feeding.

The principles involved in growing rumen microbes are fairly straightforward. Microbial yield, ie., the pounds of microbes flowing from the rumen/24 hours, is a function of microbial efficiency and carbohydrate fermented per day. Microbial efficiency is similar to any efficiency measurement; that is, it is the pounds of gain/pound of feed. In the case of rumen microbes, it is the pounds of microbes produced per pound of carbohydrate fermented in the rumen. The impact of changes in microbial efficiency on the protein supply to the cow is illustrated in Table 1. Efficiency is not a fixed value, and can be altered by nutrients provided to the microbes.

REQUIREMENTS OF RUMEN MICROBES

PROTEIN - Rumen microbes need large amounts of protein for maximum growth. Of the total dry matter eaten by a cow per day, 11-12% must be protein that is available to rumen microbes. This is the DEGRADABLE PROTEIN in the diet. The remainder is by-pass protein.

EXAMPLE - If the total crude protein in the diet is 16%, then 11-12% must be degradable, and 4-5% bypass. Another way of stating this is that 65-70% of the feed protein should be degradable and 30-35% UNDEGRADABLE PROTEIN.

Further, 40-50% of the degradable protein should be from very rapidly degraded sources. This is measured as the SOLUBLE PROTEIN.

TABLE 1. THEORETICAL CONTRIBUTION OF MICROBIAL PROTEIN TO TOTAL PROTEIN REQUIREMENT OF THE LACTATING DAIRY COW[1]

Efficiency of microbial synthesis, (lb. protein/lb. OM digested)[2]	Theoretical contribution of microbial protein when daily 4% FCM production (lb.) equals:		
	55	77	99
		%	
.125	49	42	39
.188	73	64	59
.250	98	85	79

[1]Requirements determined using NRC (1989)
[2]Assumed that 55% of OM intake is truly digested in the rumen.

The reason for feeding high levels of degradable protein is because it increases the efficiency of growth of the rumen microbes. Our current goal is to get over .30 lbs. of microbial protein per pound of carbohydrate fermented in the rumen. To do this, 11 to 12% of the diet DM must be degradable protein. If, for example, only 8 to 10% of the diet is degradable protein, efficiency will be about .25 lbs. microbial protein/lb. feed fermented. The reason it is important to have a high efficiency is because the total amount of microbial protein produced per day, which is what we want to maximize, is determined by multiplying the efficiency by the total lbs. of carbohydrate fermented in the rumen. Let's look at an example of how this works. Assume, in a well-balanced diet, we have 18 lb. of carbohydrate ruminally fermented. Using the two efficiency values mentioned previously, the microbial protein produced daily at an efficiency of .25 would be: .25 x 18 = 4.5 lbs. microbial protein. At an efficiency of .30, the quantity would be: .30 x 18 = 5.4 lbs., a difference of .9 lbs. Most ration balancing programs assume a high level of microbial protein will produced, and add by-pass protein accordingly. As a result, many rations end up short in total protein reaching the small intestine.

This brings us to the other aspect of maximizing rumen function, which is being sure we have balanced the ration for optimum dry matter intake and carbohydrate fermentation.

CARBOHYDRATES - Carbohydrates in cattle diets are in two forms:

FIBROUS CARBOHYDRATES which contain cellulose, hemicellulose and other compounds such as lignin. This fraction is best measured as Neutral Detergent Fiber or NDF. Since the fibrous carbohydrates act more or less as the skeleton of the plant, they are often referred to as Structural Carbohydrates.

NONSTRUCTURAL CARBOHYDRATES, or NSC are made up of sugars and starches. The NSC content of feeds can be chemically determined using an enzymatic technique. While the NDF and enzymatic methods help identify the carbohydrate content of forages and grains from a chemical standpoint, there are limitations. First, there are specific compounds that are not included in either assay, such as pectins, gums, ß-linked glucans, and, in ensiled products, fermentation acids. These can be significant components of such feeds as beet pulp, alfalfa, soyhulls and silages. Second, the analytical procedure for NSC is difficult and time-consuming. A more practical alternative is to determine NSC by difference, using a formula such as:

NSC = 100 - (% NDF + % Crude protein + % fat + % ash).

Using either of these methods, it can be shown that most plant materials contain both NSC and NDF (Table 2). Examination of Table 2 reveals not only the amounts of NSC as determined by difference and by enzyme methods, but permits you to note that in some feeds, the two values are quite different.

Table 2. NUTRIENT ANALYSES OF FEEDSTUFFS

Sample	DM	ADF	NDF	CP	ASH	EE	NSC DIFF.	NSC ENZ.
	(%DM Basis)							
SILAGES:								
Renaissance Samples 1993:								
Alfalfa	31.0	33.8	40.5	22.7	9.5	6.1	21.2	5.2
Alfalfa	50.2	30.9	38.7	23.8	10.4	4.1	23.0	11.3
MM Legume	47.1	39.3	50.1	20.5	9.7	2.6	17.2	10.1
Legume:Grass	45.1	34.2	48.1	16.6	9.9	4.5	21.0	9.4
Alfalfa:Tripper	35.8	39.2	50.7	19.5	10.7	4.1	15.0	10.2
Corn Silage	35.7	22.9	40.6	7.1	3.2	2.5	46.8	33.3
Corn Silage	35.4	23.2	39.3	8.1	3.6	3.4	45.7	32.6
Corn Silage	28.9	24.2	41.7	6.8	3.5	3.3	44.8	30.3
Corn Silage	39.4	22.0	41.3	7.1	3.1	2.9	45.6	35.3
Corn Silage	35.3	25.2	43.2	7.8	3.8	1.6	43.7	29.9
WVU Samples 1993:								
MM Legume	37.9	42.9	51.9	14.7	12.8	2.7	18.0	5.2
Corn Silage	34.9	23.5	41.2	7.4	3.5	2.7	45.3	32.1
Comyn - Va. Herd Management 1993:								
Earlage		16.6	35.2	10.3	3.9	1.4	49.4	51.1
Earlage	60.1	11.6	24.3	9.1	1.7	2.5	62.4	64.3
Corn Silage	41.6	21.9	38.5	8.0	3.4	2.8	47.3	44.5
Comyn - Va. Herd Management 1994:								
Corn Silage	35.5	24.7	44.0	8.8	4.1	3.4	39.6	35.3
Corn Silage	35.2	27.6	49.0	8.9	3.2	3.4	35.4	31.5
Corn Silage	36.5	26.9	47.1	8.8	4.3	3.1	36.7	33.8
Corn Silage	43.5	24.5	43.3	7.6	3.1	1.7	44.3	41.0
Earlage	49.6	13.3	26.7	8.2	2.4	3.3	59.4	59.3
Earlage	65.5	15.8	33.4	9.3	1.7	1.9	53.7	52.1
Haylage	30.1	39.9	46.2	24.4	11.7	2.8	15.5	6.3
Barley Silage	38.3	7.9	46.3	15.4	8.2	2.9	27.3	23.4
Wheat Silage	23.5	35.0	59.8	14.0	7.7	3.6	14.9	14.0
Triticale Silage	37.7	40.3	67.0	12.2	8.7	2.9	9.3	12.0
Direct Ct Barley	36.2	26.2	50.2	10.6	6.9	2.0	30.3	30.4
HAY:								
WVU 1993:								
Alfalfa	89.0	29.0	40.0	20.0	9.2	3.0	27.8	22.0
Grass	89.4	42.7	63.9	10.3	6.8	1.8	17.2	8.7
Texas Samples 1993:								
2nd Ct. Coastal	88.8	36.7	73.8	6.7	4.9	1.3	13.3	16.7
3rd Ct. Coastal	85.8	33.1	69.6	15.4	7.7	1.9	5.4	5.1
Comyn Va. Herd Management 1993:								
Orchg:Clover Hay	78.2	33.8	61.7	17.3	6.2	3.1	11.7	16.0
Tim:Orch. Hay	82.0	37.3	66.8	11.2	5.7	2.0	14.3	18.0
PASTURES WVU, ROTATED:								
Clover 4/11/93		11.0	18.8	24.5	8.3	4.3	44.6	26.0
Clover 9/31/93		29.3	43.7	15.5	7.6	2.7	30.6	16.1
Fescue 4/11/93		18.7	34.9	22.8	8.1	4.0	30.2	21.1
Fescue 5/10/93		34.1	58.3	12.3	7.9	2.5	19.2	13.6

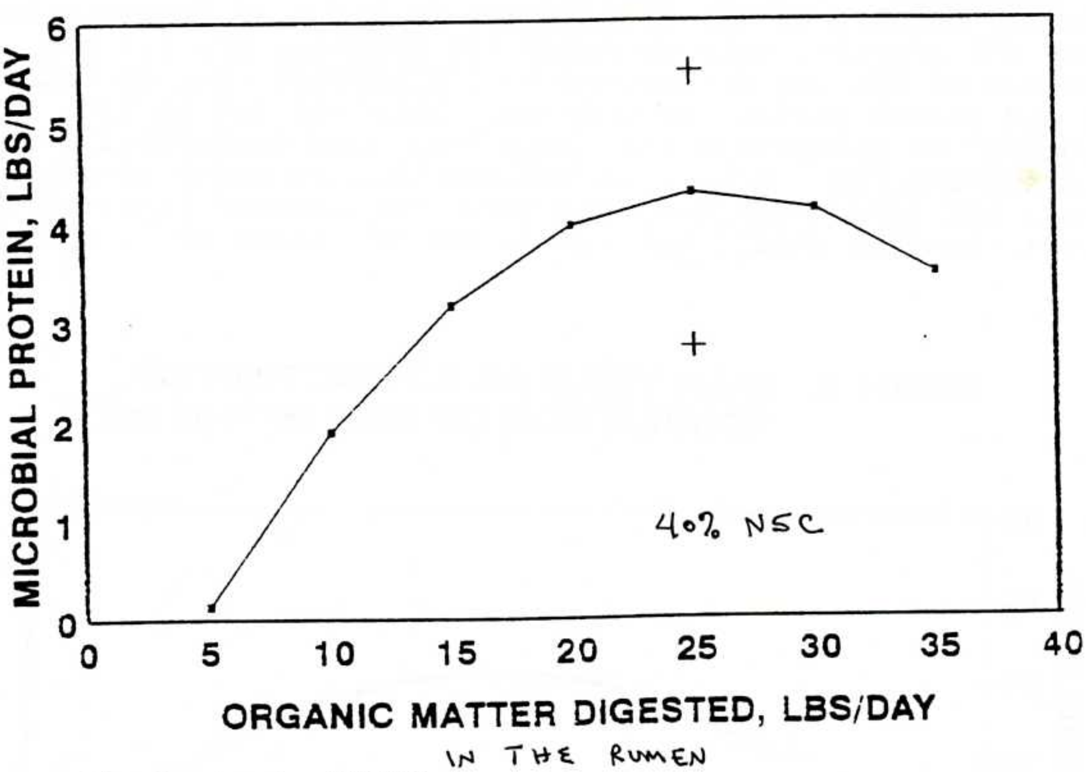
NUTRIENT ANALYSES OF FEEDSTUFFS (continued)

Sample	DM	ADF	NDF	CP	ASH	EE	NSC DIFF.	NSC ENZ.
	(%DM Basis)							
GRAINS:								
Barley, ground	87.1	7.7	22.0	11.8	3.0	1.4	61.8	56.1
Corn, ground	89.1	3.3	13.4	9.9	1.5	3.8	71.4	73.3
Oats	89.9	19.1	40.3	14.1	2.9	2.4	42.4	43.9
Wheat	87.8	3.3	12.1	10.9	1.8	1.4	73.8	65.8
Texas Samples 1993:								
Stm. Flaked Milo	84.1	6.1	14.5	11.4	1.5	3.2	69.4	73.5
Renaissance Samples 1993:								
HMEC	67.0	8.7	19.6	7.7	1.2	2.6	68.8	69.0
HMEC	67.4	7.9	19.2	7.3	1.2	2.2	70.2	68.8
HMEC	65.3	7.5	17.7	7.9	1.3	1.8	71.4	65.4
HMEC Snapplage	59.7	8.0	17.5	7.8	1.7	1.9	71.0	64.9
HMSC	64.3	3.3	11.1	8.6	1.4	3.0	75.9	73.8
Ditzen Samples 1994:								
HM Corn	75.8	2.1	11.7	9.5	1.6	3.6	73.7	75.6
HM Barley	70.8	7.8	22.1	10.5	2.4	2.1	62.9	68.8
Comyn - Va. Herd Management 1994:								
TMR	44.0	25.1	40.5	20.7	7.7	4.8	26.3	23.9
TMR	42.6	25.0	42.1	14.4	6.5	2.6	34.4	29.9
BYPRODUCTS:								
Beet Pulp	90.4	26.7	48.1	9.8	4.6	1.3	36.1	12.8
Canola	89.4	15.1	20.7	42.0	7.1	4.4	25.8	14.7
Corn Cobs	91.9	37.0	79.9	4.7	2.2	1.3	11.9	12.1
Corn Distillers	85.5	22.6	41.1	30.0	5.9	12.7	10.3	12.3
Corn Gluten Fd.	88.5	12.7	49.2	18.5	4.5	3.1	24.7	18.5
Corn Gluten Ml.	90.8	8.9	7.0	72.3	2.2	1.3	17.3	12.0
Hominy	87.4	5.6	23.3	10.8	2.2	3.9	59.9	53.5
Hominy	86.7	7.5	26.4	12.0	3.6	10.3	47.8	45.6
Soyhulls	89.8	48.9	66.6	13.7	4.8	0.8	14.1	5.3
SBM 44%	89.4	6.4	9.6	48.2	7.3	0.5	34.4	17.2
SBM 48%	90.7	6.6	9.5	52.6	7.2	1.4	29.3	16.5
Wheat Bran	88.3	8.7	32.8	15.7	4.7	1.8	45.0	46.8
Wheat Midds	88.4	12.4	42.3	19.0	5.3	2.2	31.2	31.5
Wheat Straw	92.2	55.9	83.7	3.5	3.0	1.3	8.6	5.1
Ohio Co., WV Samples 1993:								
Bakery Waste	70.0	0.7	4.3	13.4	3.0	5.2	74.2	78.8
Salad Waste	8.9	21.9	29.5	17.8	11.6	2.6	38.7	28.6
Green Giant Samples 1993:								
Broccoli Fines	8.7	14.0	16.1	36.7	6.9	6.1	34.1	20.1
Corn Fines	4.4	17.5	19.3	24.4	6.0	7.4	42.9	32.6
Garlic Rework	9.8	13.2	15.4	33.1	6.5	5.6	39.3	23.2
Garlic Pasta	61.5	2.1	0.4	5.0	5.8	76.5	12.3	7.5

UTILIZATION OF NONSTRUCTURAL CARBOHYDRATES

Unless otherwise noted, the NSC values referred to in this section will be the "difference" values. The optimum NSC levels for high producing cows are currently under investigation. Work at West Virginia (Stokes et al., 1991) and Purdue (Eastridge et al., 1988) suggest that NSC at 20-25% of DM intake is insufficient to support high production. Recently, Clark et al. (1992) at Illinois summarized a number of studies on effects of level of organic matter digestion in the rumen on microbial growth (Figure 2). The greatest microbial growth, as measured by microbial protein production, corresponded to about

Figure 2. MICROBIAL PROTEIN RESPONSE TO RUMINAL ORGANIC MATTER DIGESTION



Clark et. al., (1992)

25 lbs. of OM digested in the rumen. At a given level of DM intake, the usual way to increase digestion in the rumen is to increase the NSC and decrease the NDF. Based on the relative extents of digestion of NSC and NDF as shown in Table 3, it can be estimated that microbial protein production was maximized in Figure 2 when NSC was 30-40% of diet DM. The NSC level needed to

TABLE 3. RUMINAL NDF AND NSC DIGESTION BY LACTATING CATTLE.[1]

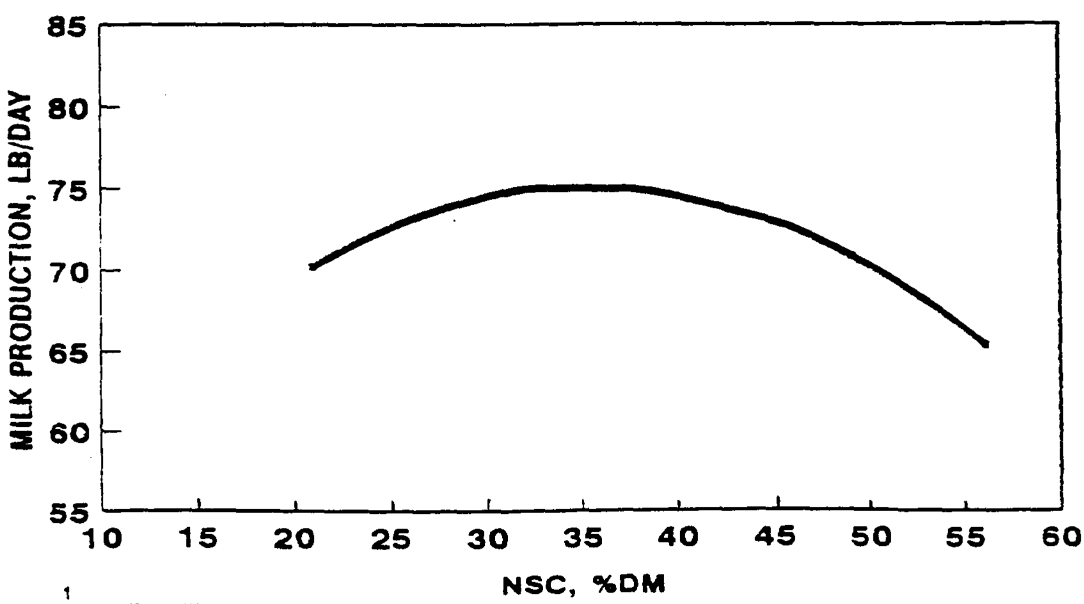
Carbohydrate fraction	Average percent digested	Range
Starches and sugars	67.7	46.6 - 87.4
NDF	43.6	11.4 - 62.8

[1] From: Feng, (1993); Herrera-Saldana et al. (1990); McCarthy et al. (1989); Stokes (1991); Waltz et al. (1989); Windschitl and Stern (1988).

maximize microbial growth corresponds very well with the level of NSC that maximized milk production in a summary of data by Nocek and Russell (1988) as shown in Figure 3.

Application of this information to specific rations is difficult, because of (1) differences in rates of fermentation of various NSC sources, many of which are unknown, and (2) the proportion of NSC (as determined by difference) that is true sugar and starch varies among feeds. This has led to the development of guidelines that have been used successfully in ration formulation. First, we believe that in order to avoid acidosis and other metabolic problems, the maximum level of true sugars + starches should not exceed 30% of ration DM. Since

Figure 3. MILK YIELD AS A FUNCTION OF PROPORTION OF NSC IN THE DIET[1]



[1] For diet with 70% total CHO
ADAPTED FRCM: Nocek and Russell (1988)

there are so few enzymatic analyses available for various feeds, this recommendation must be adapted to NSC values as determined by difference. This has resulted in the following guidelines:

35 - 40% of DM as NSC when the diet ingredients are high in sugar and starch, such as hay, barley, corn, and corn silage.

40 - 45% of DM as NSC when the forage is all hay crop silage and contains by-products such as CGF and soyhulls.

Results of recent studies by Batajoo and Shaver (1994) are generally supportive of these recommendations. They concluded that, for cows producing over 88 lbs. of milk, the diet should contain more than 30% NSC, but found little benefit of 42% over 36% NSC.

In addition to total starch level, the rate and extent of ruminal starch digestion also may affect the amount of a particular starch source that can safely be added to a diet. Herrera-Saldana (1990) ranked the degradability of starch from various sources as follows:

oats > wheat > barley > corn > milo

Ruminal availability of starch also may be altered by processing methods, such as fine grinding and steam flaking. Results of lactation studies comparing starch sources with differing digestibilities are somewhat inconsistent. Herrera-Saldana and Huber (1989) reported higher milk production with a barley-cottonseed meal diet than with a milo-cottonseed meal diet, while McCarthy Jr., et al. (1989) found milk production higher in diets containing corn than those containing barley. Some of the variation in results may be related to the effects of rapidly degradable starch on ruminal digestion of fiber, which can decrease the differences between diets relative to total carbohydrate digestion, as shown in Table 4.

TABLE 4. MILK PRODUCTION AND RUMINAL DIGESTION OF CARBOHYDRATES

	Diets	
Component	Ground corn	Steam rolled barley
Ruminally digested, %		
Starch	49.3	77.1
NDF	30.3	17.5
Total CHO	41.5	51.0
Milk production, LBS	78.2	71.5

McCarthy, Jr., et al., (1989).

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UTILIZATION OF FIBROUS OR STRUCTURAL CARBOHYDRATES

TOTAL FIBER INTAKE

Neutral detergent fiber (NDF) represents the total cell wall or fibrous carbohydrates, with the exception of pectins. Pectins, however, ferment rapidly compared to the other NDF components (Hall, 1994) so from this standpoint are more appropriately included in the NSC fraction (which they are when NSC is estimated by difference). Of the other components in NDF, cellulose and hemicellulose each have different rates of fermentation, while lignin is not fermented at all. Because of the differing fermentation rates, the variation in NDF composition across species of forage is an important determinant of the fermentation characteristics of the fiber in the rumen. Lignin is negatively correlated with the total amount of fiber that can be fermented, while hemicellulose is negatively correlated with the rate at which the fiber fraction is fermented. This fits with what we see in feeding programs. Table 5 shows that legume silage is high in lignin and low in hemicellulose. This means that the total amount of fiber that can be fermented is limited, but that the rate of fermentation, due to low hemicellulose, will be rapid. Thus, in the short time (18-24 hours) feeds spend in the rumen of a lactating cow, alfalfa fiber will be more extensively fermented than corn silage fiber, which is high in hemicellulose. On the other hand, we know that wintering beef cattle do well on corn stover. These cattle have very long rumen retention times, so fiber digestion, while slow, will be extensive due to low lignification.

TABLE 5. FIBER PARTITION IN VARIOUS FORAGE TYPES

Forage	NDF	ADF	Hemicellulose	Cellulose	Lignin
	%DM	-----------% of NDF	--------------		
Legume Silage	47	83.0	18.9	66.0	16.4
Mostly legume Silage	52	75.0	25.7	61.5	13.1
Mostly grass Silage	56	69.9	30.4	58.9	12.3
Grass Silage	62	66.1	33.8	54.8	10.3
Corn Silage	45	57.8	42.0	51.0	6.2

Studies at West Virginia, Rutgers, Penn State, University of Georgia and the University of Wisconsin indicate that it is important to optimize NDF in a ration in order to maximize dry matter intake. Mertens' (1983) suggestions are in Table 6. This table gives a guideline for both NDF and ADF.

TABLE 6. OPTIMAL NEUTRAL DETERGENT FIBER (NDF) AND ACID DETERGENT FIBER (ADF) CONTENTS OF RATIONS[a]

Lbs 3.5% milk produced by 1320 lb cow	NE_L	NDF	ADF[1]
	Mcal/lb	----- % DM	-------
<31	.65	45	31
31 - 46	.69	39	28
46 - 64	.74	33	24
> 64	.76	27	21
Dry	.61	49	34

[a]Mertens (1983). [1]ADF recommendations based on legume forage.

Another way of expressing the NDF capacity is shown in Table 7, which indicates that NDF must be limited to 1.2 % of body weight or less in order to avoid intake depression.

TABLE 7. NDF CAPACITY AS A PERCENTAGE OF BODY WEIGHT

Animal	Growing		Lactation Number		
	prebred	bred	1	2	3
Replacement	0.9	1.0	-	-	-
Pregnant cow					
early			1.0	1.1	1.2
late (last 2 weeks)			0.7	0.8	0.9
Milking cow					
0-30 DIM			0.85	.95	1.05
30-60 DIM			0.90	1.0	1.1
>60 DIM			1.05	1.1	1.2

OPTIMIZING TOTAL CARBOHYDRATE INTAKE

At a fixed value for microbial efficiency, total microbial yield per day is dependent on total carbohydrates digested in the rumen. It has been established that exceeding the recommended levels of either NDF or NSC will have negative effects on intake or production. The question is, how can the pounds of carbohydrate digested per day be increased without increasing the total level of either NDF or NSC? The answer is to replace feedstuffs of low NDF degradability with more rapidly degradable NDF sources. In considering this option, it is important to recognize three factors:

(1) for optimum fermentation, ruminal protein and carbohydrate digestion should provide a continuous supply of nitrogen and energy to the microbes,
(2) the rate of carbohydrate digestion should not depress rumen pH excessively, and
(3) the digestion of carbohydrates must continue at moderately low rumen pH, ie., 6.0 - 6.2.

While rapidly degraded starch sources such as steam-flaked or high moisture grains will enhance ruminal digestion (Zinn 1993), there is a risk of low rumen pH as well as a decrease in digestible carbohydrate levels soon after eating. Substitution of rapidly degradable fiber sources for some of the more resistant fiber is a practical alternative. As shown in Table 8, the NDF from some by-product feeds and immature forages have degradation rates considerably higher than that of average forages. By-products with rapid degradation rates include midds, wheat bran, soyhulls and beet pulp.

TABLE 8. NDF AS A CARBOHYDRATE SOURCE

Carbohydrate Source	Rate of Degradation, %/HR
Sugars	100 - 200
Starches	25 - 35
NDF, selected by-products[1]	6 - 15
NDF, immature forage	5 - 10
NDF, average forage	2 - 5

[1] Varga and Hoover (1983)

A kinetic representation of the contribution of rapidly digested fiber is presented in Figure 4.

In studies at West Virginia, (Miller et al., 1990) diets were prepared to compare rapidly and slowly degraded fiber sources. The major ingredients and analyses of the diets are in Table 9.

Figure 4. DIGESTION RATES OF STARCH, FORAGE NDF AND BYPRODUCT NDF

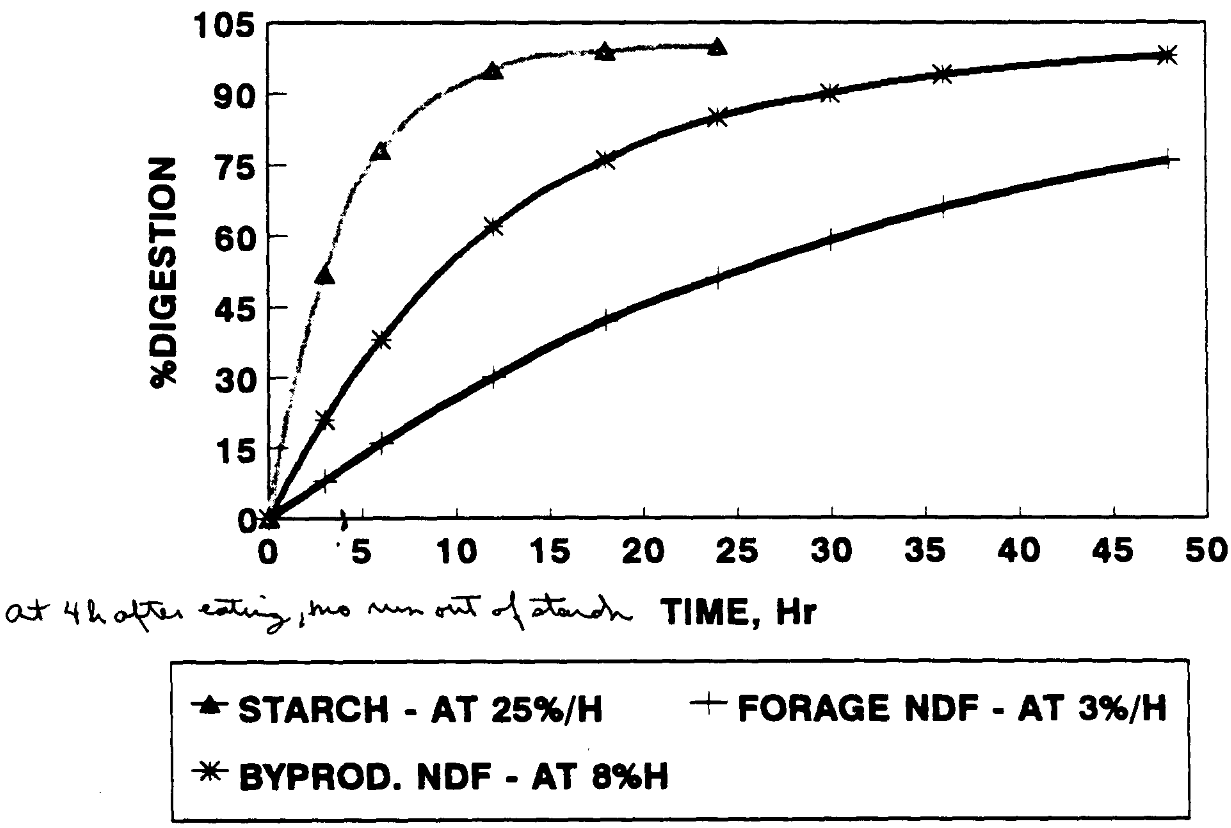


TABLE 9. MAJOR INGREDIENTS AND ANALYSES OF DIETS FORMULATED TO HAVE RAPID AND SLOW NDF DEGRADATION RATES[1]

	NDF degradation		
	Rapid		Slow
INGREDIENTS, % of DM			
Beet pulp	28.8	Barley	24.0
Corn	18.0	Corn	4.0
Wheat midds	25.0	Corn cobs	6.0
Hominy	7.0	Corn gluten feed	27.0
Soy hulls	5.4	Hay crop silage	25.0
Hay crop silage	5.9		
ANALYSES			
Total NDF, %	33.7		34.2
NSC, % DM	43.0		42.5
Forage NDF, % NDF	10.6		59.2
Effective NDF % of NDF[2]	25.9		59.3

[1] Miller et al., 1990
[2] Fox et al., 1990

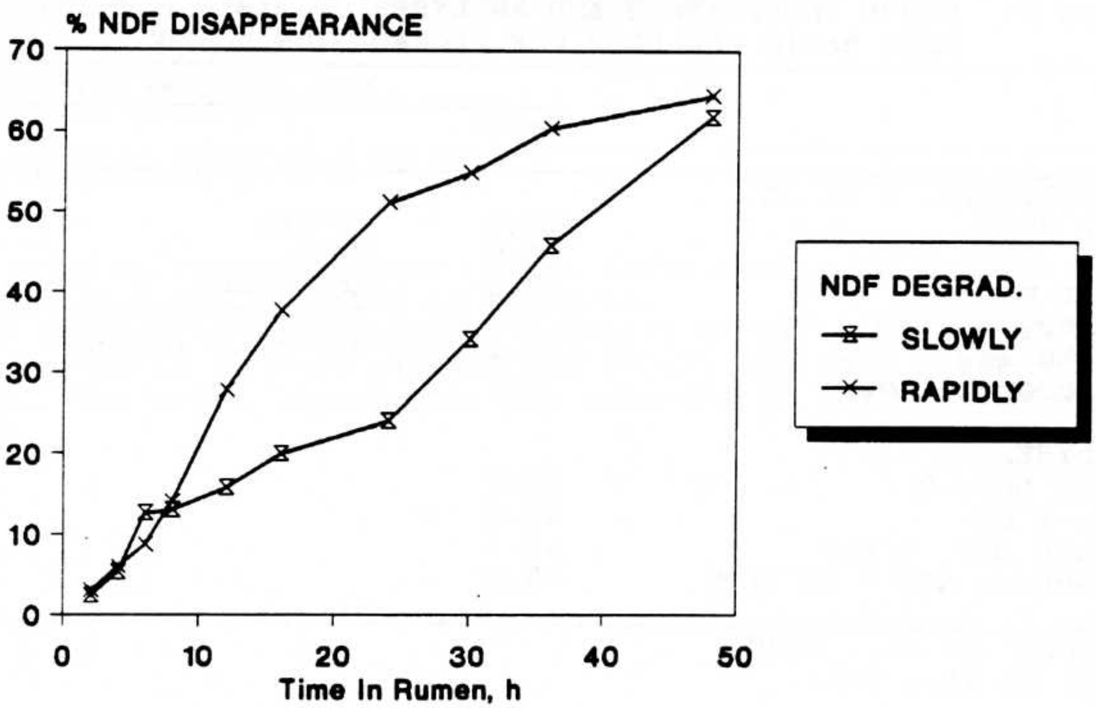
When these diets were fermented in continuous cultures, both diets caused equally low pH levels. Digestion of NDF from the rapidly degraded fiber sources was less susceptible to inhibition due to low pH, allowing this diet to have more total carbohydrate digestion, as shown in Table 10. When subjected to in situ evaluation, the rapidly degraded NDF fermented at a greater rate than did the slowly degraded NDF (Figure 5).

TABLE 10. FERMENTATION OF RAPID AND SLOWLY DEGRADED FIBER IN CONTINUOUS CULTURE

Item	Diet NDF Digestion Rate	
	Rapid	Slow
pH	6.02	6.05
Digestion:		
NDF, %	66.2	56.2
NSC, %	40.7[a]	25.2[b]
Total CHO, g/d	41.0[a]	31.6[b]

[a,b] $P < .05$

Figure 5. IN SITU NDF DEGRADATION OF DIETS FORMULATED TO HAVE RAPID AND SLOWLY DEGRADED FIBER
Miller et. al., (1990)



*

Rec → 15-18% of diet NDF come from rapidly ferm. byproduct NDF & not depress Milk Fat %

The results of feeding these diets to lactating cows are shown in Table 11.

TABLE 11. EFFECTS OF RAPIDLY AND SLOWLY DEGRADED NDF ON INTAKE AND PRODUCTION[1,2]

Item	NDF Degradation Rate Rapid	Slow
Intakes		
DM, LBS	40.9	39.4
NDF, % BW	1.16	1.04
Production		
Actual lbs	77.4[a]	70.6[b]
4% FCM, lbs	66.0	60.9
Protein, lbs	2.4[a]	2.1[b]
Composition		
% Fat	3.14	3.15
% Protein	3.10	3.03

[1] Miller et al., 1990
[2] First 10 wks of lactation
[a,b] $P < .03$

When the rapidly degraded sources of fiber from wheat by-products and beet pulp were substituted for more slowly degraded fiber, total milk production and milk protein production increased significantly. Effective fiber, as measured by either percentage of fiber from forage or as effective NDF, was low in both diets. As a consequence, milk fat also was low on both diets. While animal health was not impaired in these short (10 week) experiments, further studies are needed to determine long-term effects.

Intake of the rapidly degraded NDF was only slightly higher, as percentage of BW, than the slowly degraded NDF. This indicated that, while the small-particle NDF may not promote rumination activity, it retains much of its bulk characteristics and contributes to rumen fill.

ASSOCIATIVE EFFECTS

The combined quantities of NSC and rapidly degraded fiber that will optimize flow of nutrients from the rumen while maintaining normal physiological function is an important question. We have conducted one study to address this question (Feng et al., 1993). In this project, diets were formulated to contain either rapidly (R) or slowly (S) degraded fiber combined with either 29% or 39% NSC (enzyme analyses). These diets were fed to four ruminally and duodenally cannulated dairy cows in late lactation.

Examination of the rumen responses (Table 12) revealed that, although fiber digestion was 7% higher for the R diets, total rumen carbohydrate digestion was affected most by NSC level. Based on the results of this study, when diets contained moderate levels of NSC, 29% by the enzymatic method, rumen function was not impaired by changing from slowly degraded fiber sources(29% alfalfa hay and 27% corn silage) to rapidly degraded sources (16% each of wheat midds, wheat bran and beet pulp). When the diet contained high levels of NSC, 39% by the enzymatic method, providing fiber from a combination of ingredients (alfalfa, oats and barley) to give an intermediate overall rate of NDF degradation enhanced total carbohydrate digestion compared to diets with 29% NSC, but resulted in moderately impaired rumen function as indicated by reductions in both rumen turnover rate and microbial protein production. When the diet with 39% NSC was combined with rapidly degraded fiber (28% each of midds and bran), rumen carbohydrate digestion was high, but microbial yield was severely decreased. Interestingly, the decrease in microbial output apparently was not due to low pH, but reduced rumen turnover rate.

TABLE 12. RUMEN RESPONSES TO RATE OF NDF DIGESTION AND LEVELS OF NSC[1]

DIET	NDF DIG.,%	CHO DIG.LB	pH	SOLIDS FLOW,%/H	MICROB. PROT.LBS
S-29% NSC	39	13.6[a]	6.1[a]	4.5[a]	3.54[a]
S-39% NSC	35	15.0[b]	5.9[b]	3.7[b]	2.88[b]
R-29% NSC	45	13.2[a]	5.7[a]	4.1[a]	3.50[a]
R-39% NSC	43	17.2[b]	5.8[b]	2.6[b]	2.57[b]

[1]Feng et al., 1993
[a,b]$P < .05$

SUMMARY

The need to balance a diet to maximize rumen fermentation becomes greater as production reaches or exceeds 80 lbs/day. For this level of production, NDF must be limited to 32% or less and NSC, as determined by the difference method, should be 35% or more of diet dry matter. This will help assure the proper balance of rapidly and slowly degradable carbohydrates. For diets in which fibrous by-product feeds (beet pulp, midds, bran, soyhulls, etc.) contribute significantly to the diet, NSC levels (by difference) must be limited to less than 35% of DM. At these NSC levels, there always is a risk of rumen acidosis and reduced milk fat, so feeding management, such as buffering and use of a total mixed ration, is recommended. If enzymatic NSC analyses are available, which is a measure of true sugar and starch, limited data suggest that NSC should not exceed 30% of DM.

Proteins must be provided in the proper forms and amount in order to get maximum microbial yields from the available carbohydrates. Using conventional protein sources, current recommendations are that 11-12% of the diet dry matter should be as degradable protein in order to maximize microbial efficiency. For example, if the NRC requirement is 18% total crude protein, 11-12% should be degradable and the remaining 6-7% should be by-pass protein. To assure that there is an adequate supply of rapidly available protein to match the rapidly available carbohydrate in the NSC fraction, 40-50% of the degradable protein should be soluble protein.

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