FEEDING FOR MAXIMUM RUMEN FUNCTION

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INTRODUCTION

Following an extensive review of studies on starch utilization in 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

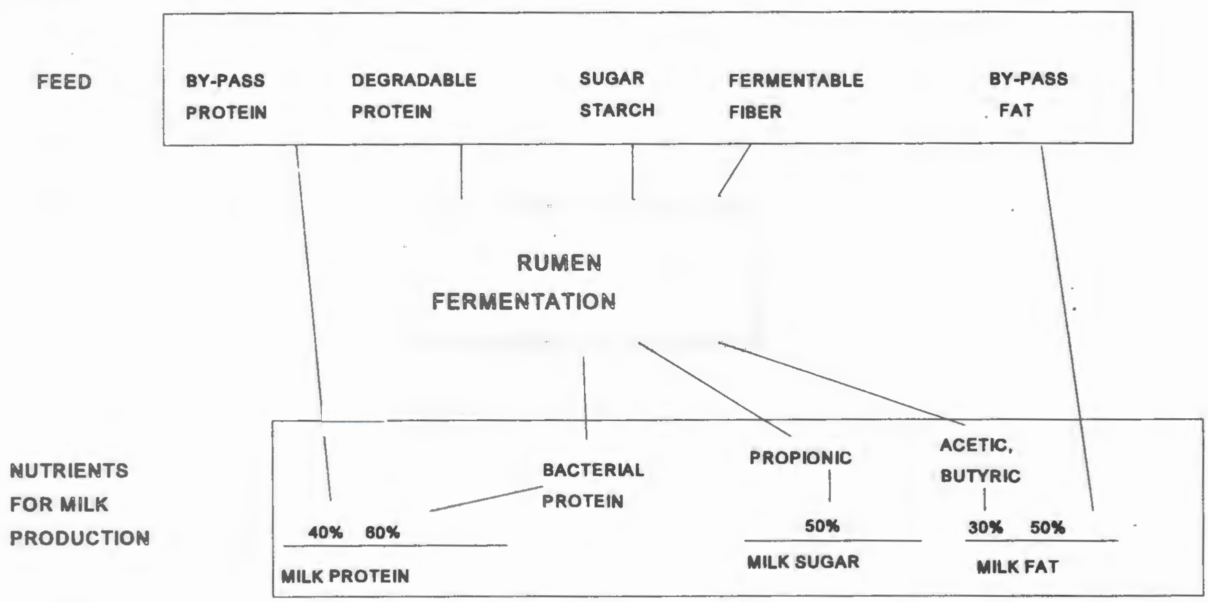
The potential importance of rumen fermentation to lactation performance is shown in Figure 1. Milk components are dependent upon high levels of fermentation end-products.

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. As much as 50% can be 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)

Figure 1 . The importance of optimum rumen fermentation[1]



[1]Adapted from Oldham and Emmans (1989).

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

Efficiency of microbial synthesis, (lb protein/lb CHO digested)[2]	Theoretical contribution of microbial protein when daily 4% FCM production (lb) equals		
	55	77	99
	------------- % -------------		
.19	49	42	39
.28	73	64	59
.37	98	85	79

[1] Adapted from Stern et al., 1994.
[2] Assuming 58% of carbohydrate intake is ruminally digested.

OPTIMUM FERMENTATION IS NOT AUTOMATIC

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

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, i.e., the lbs 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 lbs of gain/lb of feed. In the case of rumen microbes, it is the lbs of microbes produced per lb 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 **(DM)** 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 NRC refers to this fraction as degradable intake protein **(DIP)**. The remainder is by-pass protein, also called undegradable intake protein **(UIP)**.

> EXAMPLE - If the total crude protein **(CP)** in the diet is 16%, then 11 - 12% should be DIP, and 4 - 5% UIP. Another way of stating this is that 65 - 70% of the feed protein should be DIP and 30 - 35% UIP. Further, 40 - 50% of the DIP should be from very rapidly degraded sources. This is measured as soluble protein **(SP)**.

The reason for feeding high levels of DIP is because it increases the efficiency of growth of the rumen microbes. Table 1 illustrates the importance of high microbial efficiency. Although the highest level of efficiency shown in Table 1 (.37 lb microbial protein/lb carbohydrate digested) is difficult to attain, the middle level is easily accomplished by proper feeding. A realistic goal is to have microbial efficiency reach .28 to .30 lb microbial protein/lb of carbohydrate fermented in the rumen.

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 **(DMI)** and carbohydrate fermentation.

Carbohydrates - Carbohydrates in cattle diets are in two forms: ***Fibrous Carbohydrates***, which contain the carbohydrates cellulose and hemicellulose as well as non-carbohydrate compounds such as lignin. Analytically, these can be measured as acid detergent fiber **(ADF)**, which contains cellulose and lignin, but omits the hemicellulose, and neutral detergent fiber (**NDF**), which includes the hemicellulose in addition to cellulose and lignin and, therefore, is the most complete measure of fibrous carbohydrate. The older measurement, crude fiber, is the least chemically accurate. It includes the cellulose, but omits the hemicellulose and about half of the lignin. Since fibrous carbohydrates act as the skeleton of the plant. They also are referred to as structural carbohydrates or cell wall carbohydrates.

Nonstructural Carbohydrates (NSC) contain sugars and starches. Due to the difficulty of the analytical procedures for sugar and starch determination, most values available are calculations based on the following formula: NSC = 100 - (%NDF + %CP + %Fat + %Ash).

This *by difference* estimate is provided by most feed analysis services. There are specific components that, since they are not included in the NDF, CP, fat or ash, can cause falsely high estimates of NSC. In particular, the fermentation acids in ensiled feeds cause overestimates of NSC. This error can be avoided by the analytical method, which uses the enzyme amylase to convert starch to sugar, followed by a total sugar analysis. Few analytical services currently offer this analysis.

Using either of the methods (enzymatic or by difference) it can be shown that most plant materials contain both fibrous and non-fibrous carbohydrates (See Appendix, page 42). In this table, non-fibrous carbohydrate is presented as determined by both methods, by difference and by enzyme. For some feeds, the values are quite different. Because of this difference, there is currently a movement to use different terms to identify which analytical technique was used. These are: NSC to identify analyses by the enzymatic method, and non-fiber carbohydrate (NFC) when the analysis is by difference.

Since this terminology has yet to be universally accepted, the term NSC is used in this paper, and identified as to whether the values are by enzyme or by difference.

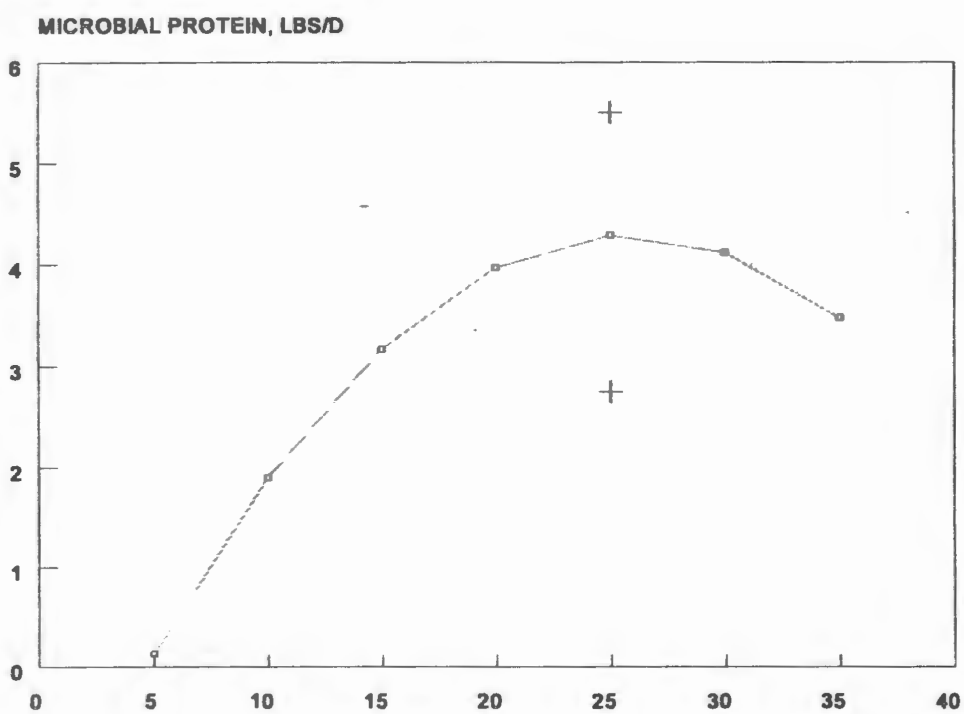


Figure 2. Microbial protein response to ruminal organic matter digestion
(Clark et. al., 1992)

UTILIZATION OF NONSTRUCTURAL CARBOHYDRATES

Unless otherwise noted, the NSC values referred to in this section will be the *by difference* values. The optimum 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 DMI 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 (**OM**) digestion in the rumen on microbial growth (Figure 2). The greatest microbial growth, as measured by microbial protein production, corresponded to about 25 lbs of OM digested in the rumen. At a given level of DMI, 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 2, 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 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, in order to avoid acidosis and other metabolic problems, themaximum level of true sugars plus starches should not exceed 30% of the ration DM. Since 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 corn gluten feed (**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 et al. (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

Table 2. 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 et al. (1993); Herrera-Saldana et al. (1990); McCarthy et al. (1989); Stokes et al. (1991); Waltz et al. (1989); Windschitl and Stern (1988).

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 3.

UTILIZATION OF FIBROUS OR STRUCTURAL CARBOHYDRATES

Total Fiber Intake

Neutral detergent fiber 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, 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 4 shows that legume silage is high in lignin and low in hemicellulose. This means that the total amount of fiber that can be

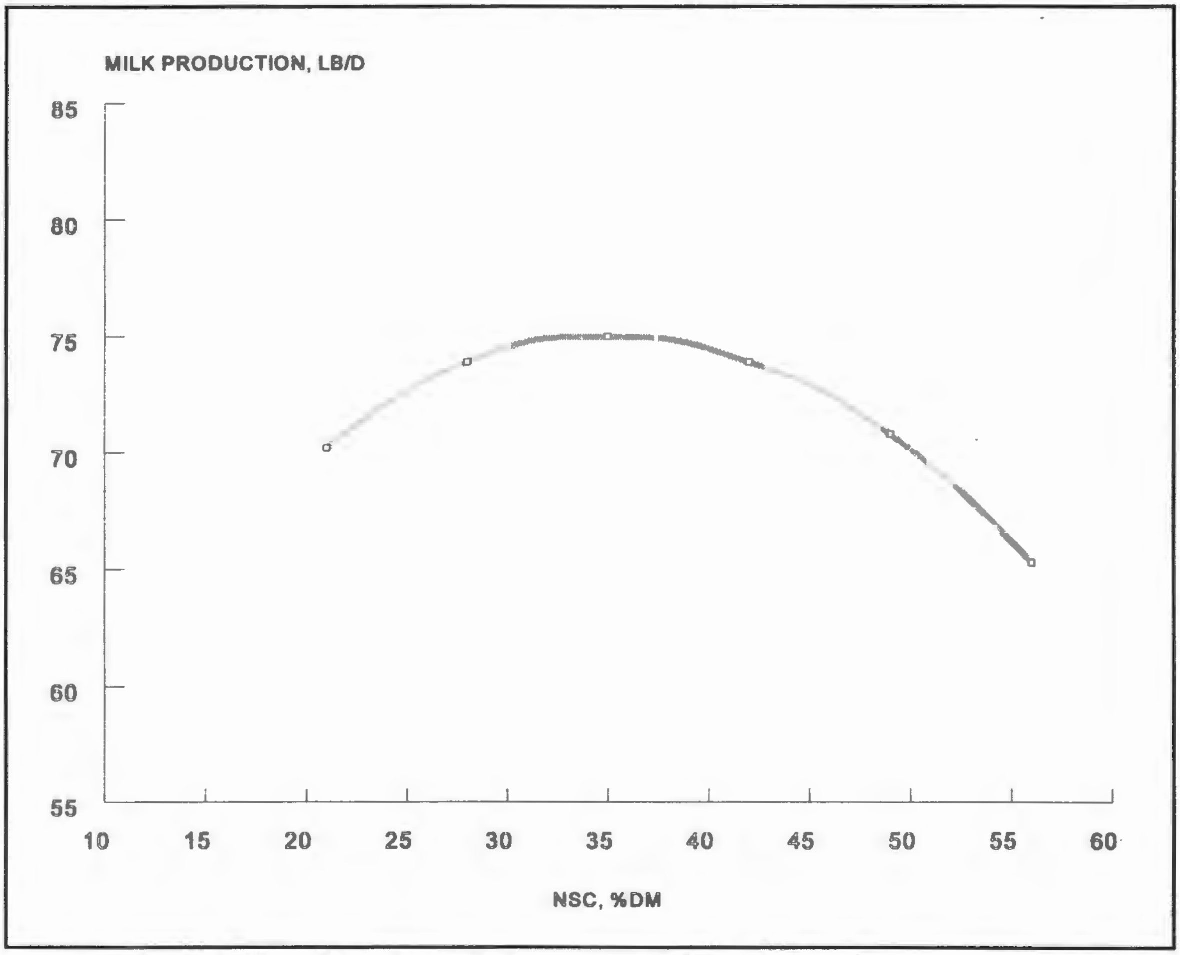


Figure 3. Milk yield as a function of proportion of NSC in the Diet[1]
(Adapted From: Nocek and Russell, 1988)

Table 3. Milk production and ruminal digestion of carbohydrates.[1]

Component	Diets: Ground corn	Steamed 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

[1]McCarthy, Jr. et al. (1989)

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.

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 DMI. Mertens' (1983) suggests that the NDF capacity ranges from .85% of body weight for first calf heifers in early lactation to 1.2% of body weight for multiparous cows in late lactation.

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 levels of NSC? The answer is, while staying within the recommended levels of both NDF and NSC, increase the rates of digestion of each. Remember, usually there is ample room to improve ruminal digestion of both NSC, which averages 67.7%, and NDF, which averages 43.6%.

Table 4. 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

Table 5. NDF as a carbohydrate source.

Carbohydrate Source	Rate of Degradation, %/Hour
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)

Figure 4 shows what we are trying to achieve in the rumen by providing a variety of sources for both NSC and NDF.

The second suggestion is to substitute rapidly degradable fiber sources for some of the more resistant fibers. As shown in Table 5, 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 wheat midds, wheat bran, soyhulls, beet pulp and distillers dried grains.

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 6. The results of feeding these diets to lactating cows are in Table 7.

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 a percentage of body weight, 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.

Figure 4. Ruminal Availability of Carbohydrates

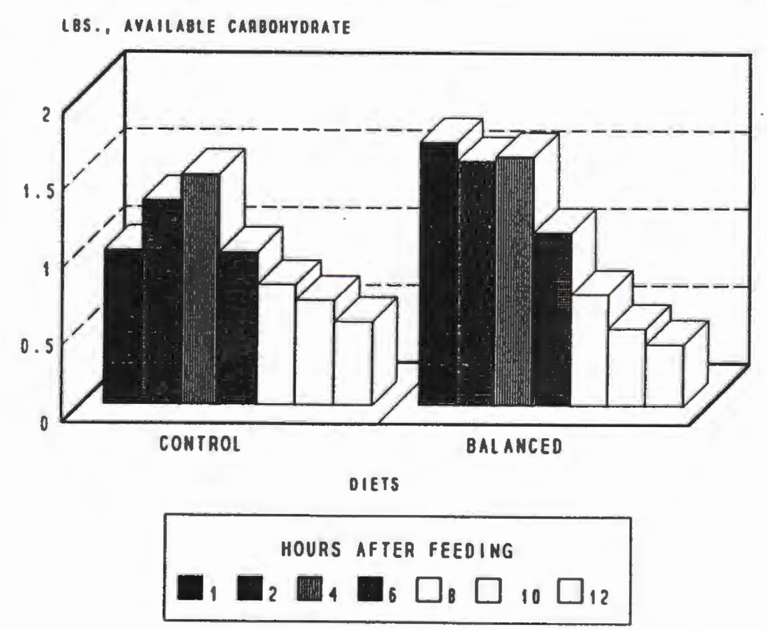


Table 6. Major ingredients and analyses of diets formulated to have rapid and slow NDF degradation rates.[1]

	NDF Degradation		
	Rapid		Slow
Ingredients	% DM	Ingredients	% 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, % DM	33.7		34.2
NSC, % DM	43.0		42.5
Forage NDF, % NDF	10.6		59.2
Effective NDF, % NDF[2]	25.9		59.3

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

SUMMARY

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 DM should be DIP in order to maximize microbial efficiency. For example, if the NRC requirement is 18% CP , 11 - 12% should be DIP and the remaining 6 - 7% should be UIP. 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 DIP should be SP.

Carbohydrates must be balanced to provide a continuous source of energy for microbes. Non-fiber carbohydrates should provide 35 - 40% of diet DM. It should be from sources that

Table 7. Effects of rapidly and slowly degraded NDF on intake and production.[1,2]

	NDF Degradation Rate	
Item	Rapid	Slow
Intakes		
DM, lbs	40.9	39.4
NDF, % BW	1.16	1.04
Milk Production		
Actual lbs	77.4[a]	70.6[b]
4% FCM, lbs	66.0	60.9
Protein, lbs	2.4[a]	2.1[b]
Milk 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

range in rates of fermentation from fast to moderate. Fast fermenting carbohydrates such as steam flaked or high moisture grains can be used to replace 1/3 to 1/2 the dried ground grains to achieve a more continuous fermentation rate.

Neutral detergent fiber should provide 27 - 34% of DM, and should also contain both rapid and slowly fermented sources. When rapidly fermented sources are used, they should provide 15 - 20% of total NDF. Such sources include wheat midds, wheat bran, soyhulls, dried distillers grains and beet pulp. In order to meet the effective fiber requirement, average quality forage should provide 40 - 50% of NDF.

REFERENCES

Batajoo, K.K., and R.D. Shaver. 1994. Impact of nonfiber carbohydrate on intake, digestion and milk production by dairy cows. J. Dairy Sci. 77:1580.

Clark, J.H., T.H. Klusmeyer, and M.R. Cameron. 1992. Microbial protein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. J. Dairy Sci. 75:2304.

Eastridge, M.L., M.D. Cunningham, and J.A. Patterson. 1988. Effect of dietary energy source and concentration on performance of dairy cows during early lactation. J. Dairy Sci. 71:2959.

Feng, P., W.H. Hoover, T.K. Miller, and R. Blauwiekel. 1993. Interactions of fiber and nonstructural carbohydrates on lactation and ruminal function. J. Dairy Sci. 76:1324.

Fox, D.G., C.J. Sniffen, J.D. O'Connor, J.B. Russell, and P.J. Van Soest. 1990. The Cornell Net Carbohydrate and Protein System for evaluating cattle diets. Search: Agriculture No. 34, Cornell University Ithaca, NY.

Hall, M.B. 1994. Pectin, the structural non-structural carbohydrate. Proc. Cornell Nutr. Conf. p. 29.

Herrera-Saldana, R., and J.T. Huber. 1989. Influence of varying protein and starch degradabilities on performance of lactating cows. J. Dairy Sci. 72:1477.

Herrera-Saldana, R.E., J.T. Huber, and M.H. Poore. 1990. Dry matter, CP and starch degradability of five cereal grains. J. Dairy Sci. 73:2386.

Hoover, W.H., and S.R. Stokes. 1991. Balancing carbohydrates and proteins for optimum rumen microbial yield. J. Dairy Sci. 74:3630.

McCarthy, R.D., Jr., T.H. Klusmeyer, J.L. Vicini, J.H. Clark, and D.R. Nelson. 1989. Effects of source of protein and carbohydrate on ruminal fermentation and passage of nutrients to the small intestine of lactating cows. J. Dairy Sci. 72:2002.

Mertens, D.R. 1983. Using neutral detergent fiber to formulate dairy rations and estimate the net energy content of forages. Proc. Cornell Nutr. Conf. p. 60.

Miller, T.K., W.H. Hoover, W.W. Poland, Jr., R.W. Wood, and W.V Thayne. 1990. Effects of low and high fill diets on intake and milk production in dairy cows. J. Dairy Sci. 73:2453.

Nocek, J.E., and J.B. Russell. 1988. Protein and energy as an integrated system. Relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci., 71:2070.

Nocek, J.E., and S. Tamminga. 1991. Site of digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. J. Dairy Sci. 74:3598.

Oldham, J.D., and G.C. Emmans. 1989. Prediction responses to required nutrients in dairy cows. J. Dairy Sci. 73:3212.

Stern, M.D., G.A. Varga, J.H. Clark, J.L. Firkins, J.T. Huber, and D.L Palmquist. 1994. Evaluation of chemical and physical properties of feeds that affect protein metabolism in the rumen. J. Dairy Sci. 77:2762.

Stokes, S.R., W.H. Hoover, T.K. Miller, and R. Blauwiekel. 1991. Ruminal digestion and microbial utilization of diets varying in type of carbohydrate and protein. J. Dairy Sci. 74:871.

Varga, G.A., and W.H. Hoover. 1983. Rate and extent of neutral detergent fiber degradation of feedstuffs in situ. J. Dairy Sci. 66:2109.

Waltz, D.M., M.D. Stern, and D.J. Illg. 1989. Effect of ruminal protein degradation of blood meal and feather meal on the intestinal amino acid supply to lactating cows. J. Dairy Sci. 72:1509

Windschitl, P.M., and M.D. Stern. 1988. Evaluation of calcium lignosulfonate-treated soybean meal as a source of rumen protected protein for dairy cattle. J. Dairy Sci. 71:3310.

Zinn, R.A. 1993. Influence of processing on the comparative feeding value of barley for feedlot cattle. J. Anim. Sci. 71:3.

Appendix Table. NUTRIENT ANALYSES OF FEEDSTUFFS
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							NFC	NSC (ENZYMATIC)		
Sample	DM	ADF	NDF	CP	ASH	EE	DIFF.	TOTAL	SUGAR	STARCH
	(%DM Basis)									
SILAGES:										
Renaissance Samples 1993:										
Alfalfa	31.0	33.8	40.5	22.7	9.5	6.1	21.2	5.2	2.3	2.9
Alfalfa	50.2	30.9	38.7	23.8	10.4	4.1	23.0	11.3	3.9	7.4
MM Legume	47.1	39.3	50.1	20.5	9.7	2.6	17.2	10.1	2.6	7.5
Legume:Grass	45.1	34.2	48.1	16.6	9.9	4.5	21.0	9.4	4.4	5.0
Alfalfa:Tripper	35.8	39.2	50.7	19.5	10.7	4.1	15.0	10.2	2.3	7.9
Corn Silage	35.7	22.9	40.6	7.1	3.2	2.5	46.8	33.3	1.4	31.9
Corn Silage	35.4	23.2	39.3	8.1	3.6	3.4	45.7	32.6	1.6	31.0
Corn Silage	28.9	24.2	41.7	6.8	3.5	3.3	44.8	30.3	1.5	28.8
Corn Silage	39.4	22.0	41.3	7.1	3.1	2.9	45.6	35.3	1.9	33.4
Corn Silage	35.3	25.2	43.2	7.8	3.8	1.6	43.7	29.9	1.7	28.2
WVU Samples 1993:										
MM Legume	37.9	42.9	51.9	14.7	12.8	2.7	18.0	5.2	2.7	2.5
Corn Silage	34.9	23.5	41.2	7.4	3.5	2.7	45.3	32.1	2.0	30.1
WVU Samples 1994:										
Fresh Chop:										
Alfalfa, 4th cut	46.2	26.4	34.1	22.4	11.8	2.4	29.3	13.8	2.7	11.1
Grass, 3rd cut	41.1	34.5	48.7	11.6	9.7	2.4	27.6	15.8	3.3	12.5
Comyn - Va. Herd Management 1993:										
Earlage		16.6	35.2	10.3	3.9	1.4	49.4	51.1	2.6	48.5
Earlage	60.1	11.6	24.3	9.1	1.7	2.5	62.4	64.3	1.3	63.0
Corn Silage	41.6	21.9	38.5	8.0	3.4	2.8	47.3	44.5	1.6	42.9
Comyn - Va. Herd Management 1994:										
Corn Silage	35.5	24.7	44.0	8.8	4.1	3.4	39.6	35.3	2.1	33.2
Corn Silage	35.2	27.6	49.0	8.9	3.2	3.4	35.4	31.5	3.9	27.6
Corn Silage	36.5	26.9	47.1	8.8	4.3	3.1	36.7	33.8	2.8	31.0
Corn Silage	43.5	24.5	43.3	7.6	3.1	1.7	44.3	41.0	2.5	38.5
Earlage	49.6	13.3	26.7	8.2	2.4	3.3	59.4	59.3	2.7	56.6
Earlage	65.5	15.8	33.4	9.3	1.7	1.9	53.7	52.1	2.4	49.7
Haylage	30.1	39.9	46.2	24.4	11.7	2.8	15.5	6.3	2.4	3.9
Barley Silage	38.3	7.9	46.3	15.4	8.2	2.9	27.3	23.4	2.5	20.9
Wheat Silage	23.5	35.0	59.8	14.0	7.7	3.6	14.9	14.0	3.9	10.1
Triticale Silage	37.7	40.3	67.0	12.2	8.7	2.9	9.3	12.0	2.8	9.2
Direct Ct Barley	36.2	26.2	50.2	10.6	6.9	2.0	30.3	30.4	1.7	28.7
Animal Health Management Samples, Kentucky 1994:										
Corn Silage		26.9	45.5	7.1	3.1	2.6	41.7	40.1	1.9	38.2
Corn Silage		22.7	39.3	7.8	3.0	3.3	46.6	46.1	2.5	43.6
Corn Silage		28.4	48.0	9.2	5.1	2.9	34.8	29.9	3.5	26.4
Farmland Ind. Samples 1994:										
Corn Silage		30.1	46.7	7.3	5.1	3.3	37.6	35.5	2.1	33.4
Corn Silage		31.3	49.9	9.1	5.7	2.8	32.5	25.5	2.6	22.9
High Oil Corn Silage		45.1	73.6	5.9	3.6	3.7	13.2	12.7	0.7	12.0
Moundsville, WV 1994:										
Sorghum/C. Sil.	23.7	43.2	69.4	8.4	8.4	1.9	11.9	6.7	1.5	5.2
Chalupa Samples 1995:										
Corn Silage	33.8	19.9	36.2	8.5	3.3	3.5	48.5	41.4	1.9	39.5
Haylage	39.6	41.3	53.7	16.2	8.5	3.1	18.5	9.1	3.5	5.6
Moorefield, WV Samples 1995:										
Corn Silage/Chicken Litter:										
Sample #1	56.9	23.6	31.2	10.5	9.5	2.7	46.1	38.9	2.7	36.2
Sample #2	46.5	27.1	46.3	6.9	3.6	2.5	40.7	35.4	1.7	33.7

NUTRIENT ANALYSES OF FEEDSTUFFS (continued)

Sample	DM	ADF	NDF	CP	ASH	EE	NFC DIFF.	NSC (ENZYMATIC) TOTAL	SUGAR	STARCH
	(%DM Basis)									
SILAGES (continued):										
Homestead Ag. Prod., WI 1995:										
Haylage	49.4	32.4	38.3	22.4	11.0	3.4	24.9	8.9	3.8	5.1
Haylage	35.3	32.4	37.6	21.7	10.3	3.8	26.6	8.7	3.2	5.5
Ditson Samples, MD & WV 1995:										
Corn Silage	33.5	26.7	49.0	7.8	3.9	2.9	36.4	34.3	2.6	31.7
Corn Silage	32.0	25.4	44.0	7.4	3.2	3.2	42.2	28.0	2.8	25.2
Sorg/Sudan Baglg	59.1	39.6	67.3	7.5	6.9	3.9	14.4	11.7	4.4	7.3
Rocky Mtn. Nutr. Consult., WI 1995:										
Haylage 1st cut	39.2	31.7	35.3	25.7	11.6	3.9	23.5	5.1	2.7	2.4
Corn Silage	33.0	28.4	42.9	11.6	5.0	4.4	36.1	32.3	1.3	30.9
Anderson Dairy Managment., PA 1995:										
Triticale Silage	27.3	39.9	62.3	14.0	7.4	3.4	12.9	12.1	2.5	9.6
Corn Silage +NH_3	31.1	22.9	38.0	8.3	3.4	3.4	46.9	43.8	2.0	41.8
W.B. Fleming Co., KY 1995:										
Corn Silage	35.0	24.1	42.2	6.9	3.8	3.0	44.1	37.5	2.4	35.1
Jarrett, NY 1995:										
4th.Ct.Alf.HCS	54.0	26.2	32.1	23.3	12.1	2.7	29.8	14.4	4.4	10.0
1st.Ct.Alf.HCS	48.6	37.1	42.0	21.5	10.8	2.2	23.5	7.5	4.0	3.5
Haylage	26.8	39.4	48.3	22.1	10.8	4.2	14.6	5.0	2.2	2.8
Corn Silage	28.4	22.6	41.6	8.2	3.6	3.5	43.1	38.8	1.6	37.2
Corn Silage	38.9	21.9	37.6	7.8	3.1	2.9	48.6	47.3	1.5	45.8
Biovance Tech., WI 1995:										
Corn Silage	36.8	26.7	42.1	7.5	4.2	3.6	42.6	41.2	5.3	35.9
Corn Silage	40.9	22.6	38.0	8.2	4.1	3.2	46.5	44.2	2.0	42.2
Corn Silage	42.2	22.3	38.9	8.1	3.6	3.8	45.6	41.2	3.0	38.2
Renaissance Samples, PA 1995:										
Corn Silage	35.4	28.4	49.5	6.9	4.0	2.4	37.2	32.2	4.0	28.2
Corn Silage	45.9	29.0	51.9	6.9	2.9	2.6	35.7	30.7	2.4	28.3
Corn Silage	39.0	24.6	44.0	6.4	3.4	3.7	42.5	39.7	1.1	38.6
HAY:										
WVU 1993:										
Alfalfa	89.0	29.0	40.0	20.0	9.2	3.0	27.8	22.0	4.2	17.8
Grass	89.4	42.7	63.9	10.3	6.8	1.8	17.2	8.7	4.8	3.9
Texas Samples 1993:										
2nd Ct. Coastal	88.8	36.7	73.8	6.7	4.9	1.3	13.3	16.7	5.0	11.7
3rd Ct. Coastal	85.8	33.1	69.6	15.4	7.7	1.9	5.4	5.1	4.0	1.0
Comyn Va. Herd Management 1993:										
Orchg:Clover Hay	78.2	33.8	61.7	17.3	6.2	3.1	11.7	16.0	4.7	11.3
Tim:Orch. Hay	82.0	37.3	66.8	11.2	5.7	2.0	14.3	18.0	4.8	13.2
Farmland Ind. Samples 1994:										
Alfalfa Hay		35.5	44.0	19.0	9.8	2.2	25.0	14.5	4.4	10.1
Alfalfa Hay		25.0	31.8	21.5	12.3	2.1	32.3	11.4	3.8	7.6
Moundsville, WV Sample 1994:										
Rnd.Bale 1st ct.	80.8	47.9	76.4	6.7	8.1	2.0	6.8	6.2		
Rocky Mtn. Nutr. Consult., WI Samples 1995:										
Mixed Hay	87.5	32.1	44.3	19.6	9.9	3.2	23.0	12.3	5.1	7.2
Alf. Hay Cubes	91.8	36.0	46.1	20.5	9.5	2.5	21.4	9.0	4.3	4.7
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		

NUTRIENT ANALYSES OF FEEDSTUFFS (continued)

Sample	DM	ADF	NDF	CP	ASH	EE	NFC DIFF.	NSC (ENZYMATIC) TOTAL	SUGAR	STARCH
	(%DM Basis)									
PASTURES WVU, ROTATED (continued):										
Fescue 5/10/93		34.1	58.3	12.3	7.9	2.5	19.2	13.6		
GRAINS:										
Barley, ground	87.1	7.7	22.0	11.8	3.0	1.4	61.8	56.1	2.6	53.5
Corn, ground	89.1	3.3	13.4	9.9	1.5	3.8	71.4	73.3	1.1	72.2
Oats	89.9	19.1	40.3	14.1	2.9	2.4	42.4	43.9	2.8	41.1
Soybeans	88.7	10.8	20.8	35.3	5.8	18.4	19.7	20.8	1.1	19.7
Speltz	88.3	14.3	26.5	10.0	3.0	1.6	58.9	60.1	1.5	58.6
Wheat	87.8	3.3	12.1	10.9	1.8	1.4	73.8	65.8	2.0	63.8
Texas Samples 1993:										
Stm. Flaked Milo	84.1	6.1	14.5	11.4	1.5	3.2	69.4	73.5	0.7	72.8
Renaissance Samples 1993:										
HMEC	67.0	8.7	19.6	7.7	1.2	2.6	68.8	69.0	0.8	68.2
HMEC	67.4	7.9	19.2	7.3	1.2	2.2	70.2	68.8	1.2	67.6
HMEC	65.3	7.5	17.7	7.9	1.3	1.8	71.4	65.4	1.2	64.2
HMEC Snapplage	59.7	8.0	17.5	7.8	1.7	1.9	71.0	64.9	1.3	63.6
HMSC	64.3	3.3	11.1	8.6	1.4	3.0	75.9	73.8	1.6	72.2
Ditson Samples, MD & WV 1994:										
HM Corn	75.8	2.1	11.7	9.5	1.6	3.6	73.7	75.6	0.9	74.7
HM Barley	70.8	7.8	22.1	10.5	2.4	2.1	62.9	68.8	2.5	66.3
Comyn - Va. Herd Management 1994:										
TMR	44.0	25.1	40.5	20.7	7.7	4.8	26.3	23.9	2.4	21.5
TMR	42.6	25.0	42.1	14.4	6.5	2.6	34.4	29.9	2.9	27.0
Farmland Ind. Samples 1994:										
Corn		3.8	13.3	9.3	1.6	3.7	72.1	74.7	1.1	73.6
"		3.0	11.3	8.7	1.6	5.4	73.0	75.3	1.2	74.4
"		2.5	11.3	8.1	1.3	4.1	75.2	74.9	1.2	73.7
High Oil Corn		4.0	14.4	10.5	2.5	13.2	59.4	60.1	2.0	58.1
" " "		4.0	12.5	10.6	1.9	13.6	61.4	652	1.5	63.7
" " "		3.3	13.5	10.0	2.5	13.8	60.2	61.7	1.8	59.9
" " "		3.1	13.8	10.4	2.3	11.9	61.6	61.2	1.6	59.6
Moundsville, WV 1994:										
Feed Ration	84.3	5.8	17.7	16.4	6.1	3.0	56.8	55.0	4.2	50.8
Chalupa Samples 1995:										
HM Corn	76.8	2.4	10.2	8.6	1.3	3.6	76.3	75.0	0.8	74.2
Homestead Ag. Prod., WI 1995:										
TMR	57.0	19.2	29.7	19.3	8.0	6.3	36.7	32.9	3.9	29.0
TMR	55.3	21.2	24.9	17.3	12.5	5.2	40.1	30.7	2.5	28.2
Rocky Mtn. Nutr. Consult., WI Samples 1995:										
HMSC	70.9	4.2	15.0	9.7	2.0	6.3	67.0	57.9	1.0	56.9
W. Cottonseed	90.5	37.5	47.2	19.9	3.9	19.0	10.0	9.3	2.2	7.1
Protein Mix	92.2	8.7	16.4	.50.0	5.2	8.7	19.7	22.5	1.1	21.4
Dry Cow Springer (grain)	86.4	12.7	31.1	14.3	7.1	4.8	42.7	46.7	5.2	41.5
TMRS:										
Dry Cow Far Out	56.6	34.6	48.3	14.9	8.4	2.9	25.5	14.1	3.6	10.5
Dry Cow Springer	62.9	26.5	41.4	16.2	8.1	3.5	30.8	22.2	3.8	18.4
Post Fresh Pen 1	45.7	26.8	37.3	17.2	9.3	5.0	31.2	20.7	2.5	18.2
Post Fresh Pen 2	61.8	25.5	38.7	15.5	7.6	3.4	34.8	23.7	3.2	20.5
High Cow	51.2	22.2	34.4	18.9	9.1	6.6	31.0	21.2	2.5	18.7
Low Cow	56.1	24.1	37.8	17.5	9.2	5.3	30.2	21.4	2.5	18.9
Anderson Dairy Management, PA Samples 1995:										
Snap Ear Corn (w/husks stave)	60.9	11.9	25.1	8.2	2.1	3.1	61.5	63.0	1.1	61.9

NUTRIENT ANALYSES OF FEEDSTUFFS (continued)

							NFC	NSC (ENZYMATIC)		
Sample	DM	ADF	NDF	CP	ASH	EE	DIFF.	TOTAL	SUGAR	STARCH
	----------	----------	----------	----------	----------	(%DM Basis)	----------	----------	----------	----------
GRAINS (continued):										
Snap Ear Corn (w/husks)	55.8	12.6	28.4	7.9	3.3	3.2	57.2	57.6	0.7	56.9
Farmland Ind.,1995										
Popcorn	88.0	4.9	19.4	13.3	1.6	3.3	62.4	58.9	1.6	57.3
HMC	76.4	2.5	10.6	8.7	1.3	3.2	76.3	75.1	0.8	74.3
HMC	71.7	3.6	14.4	11.1	1.8	5.0	67.7	66.8	0.8	66.0
Ditson, MD, 1995										
Barley	87.0	8.2	25.6	11.9	3.0	2.0	57.5	61.1	2.6	58.5
BYPRODUCTS:										
Almond Hulls	78.9	21.2	26.0	7.1	6.3	3.8	56.8	48.3	3.0	45.3
Beet Pulp	90.4	26.7	48.1	9.8	4.6	1.3	36.1	12.8	1.2	11.6
Buckwheat Hulls		48.7	62.0	9.2	2.2	1.2	25.4	26.1	1.5	24.6
Wet Brewers	20.7	22.5	57.5	31.4	4.3	8.3	0.0	10.4	0.6	9.8
Dried Brewers		19.2	52.4	34.5	3.8	6.1	3.1	18.4	5.1	13.3
Canola	89.4	15.1	20.7	42.0	7.1	4.4	25.8	14.7	2.8	11.9
Corn Cobs	91.9	37.0	79.9	4.7	2.2	1.3	11.9	12.1	2.4	9.7
Corn Distillers	85.5	22.6	41.1	30.0	5.9	12.7	10.3	12.3	3.4	8.9
Corn Gluten Fd.	88.5	12.7	49.2	18.5	4.5	3.1	24.7	18.5	4.1	14.4
Corn Gluten Ml.	90.8	8.9	7.0	72.3	2.2	1.3	17.3	12.0	1.2	10.8
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	3.5	42.1
Peanut Meal		6.0	18.2	51.3	5.0	7.3	18.2	26.9	1.8	25.1
Soyhulls	89.8	48.9	66.6	13.7	4.8	0.8	14.1	5.3	1.6	3.7
SBM 44%	89.4	6.4	9.6	48.2	7.3	0.5	34.4	17.2	1.7	15.5
SBM 48%	90.7	6.6	9.5	52.6	7.2	1.4	29.3	16.5	1.4	15.1
Wheat Bran	88.3	10.8	42.1	16.3	5.7	3.0	32.9	44.8	2.4	42.4
Wheat Midds	88.4	12.4	42.3	19.0	5.3	2.2	31.2	31.5	3.7	27.8
Wheat Straw	92.2	55.9	83.7	3.5	3.0	1.3	8.6	5.1	1.4	3.7
Ohio Co., WV Samples 1993:										
Bakery Waste	70.0	0.7	4.3	13.4	3.0	5.2	74.2	78.8	5.1	73.7
Salad Waste	8.9	21.9	29.5	17.8	11.6	2.6	38.7	28.6	4.9	23.7
Green Giant Samples 1993:										
Broccoli Fines	8.7	14.0	16.1	36.7	6.9	6.1	34.1	20.1	5.3	14.9
Corn Fines	4.4	17.5	19.3	24.4	6.0	7.4	42.9	32.6	8.3	24.3
Garlic Rework	9.8	13.2	15.4	33.1	6.5	5.6	39.3	23.2	5.2	18.0
Garlic Pasta	61.5	2.1	0.4	5.0	5.8	76.5	12.3	7.5	3.6	3.9
Nutrena 1995:										
Bakery Waste	91.2	2.3	5.1	10.6	3.7	11.4	69.2	60.8	4.7	56.1
Miracle/McNess Co. 1995:										
Kellogs Waste (cereal)	92.7	3.3	16.3	10.1	3.8	2.5	67.3	66.2	4.5	61.7
Kalmbach Feeds, Ohio 1995:										
Cookie Meal	91.0	4.6	13.5	13.1	3.9	10.1	59.4	59.1	4.6	54.5
Rocky Mtn. Nutr. Consult., WI Samples 1995:										
Beet Pulp Pell.	88.2	30.0	46.4	8.4	8.0	1.0	36.2	26.1	1.6	24.5
Wet Brew (Pabst)	28.4	22.5	56.8	28.5	4.7	8.2	1.8	9.7	1.0	8.7
Farmland Ind., Samples 1995:										
Milo DDG	86.0	24.4	42.9	34.9	4.7	10.1	7.4	15.1	1.9	13.2
Corn DDG	89.0	18.6	42.9	32.0	4.4	12.3	8.4	11.8	1.6	10.2
Homestead Ag. Prod., WI 1995:										
Wet Brew (Kratz)	23.7	26.2	60.8	26.6	4.6	7.4	0.6	16.7	0.9	15.8
Michigan State Univ., 1995:										
AR Soy	88.8	12.4	43.2	35.8	4.0	0.4	16.6	27.0	0.3	26.7

NUTRIENT ANALYSES OF FEEDSTUFFS (continued)

Sample	DM	ADF	NDF	CP	ASH	EE	NFC DIFF.	NSC (ENZYMATIC) TOTAL	SUGAR	STARCH
	-----------------------				(%DM Basis)		-----------------------			
BYPRODUCTS (continued):										
W.B. Fleming, Co., KY 1995:										
Wet Gluten Feed	52.1	10.7	37.6	23.8	6.2	2.1	30.3	28.8	4.4	24.4
Hominy (?)	87.5	3.5	12.2	9.5	1.7	4.6	72.0	70.3	1.7	68.6
Lacto-Whey	59.6			83.3		8.3		1.06	1.03	0.03