

Nonstructural and Structural Carbohydrates in Dairy Cattle Rations ¹

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Carbohydrates are the largest component in the dairy ration and contribute 60 to 70% of the net energy used for milk production. Carbohydrates may be divided into fiber and non-fiber components. The fiber or structural portion, commonly called neutral detergent fiber (NDF), includes cellulose, lignin, and hemicellulose (Table 1). The NDF fraction represents the slower digestible fibrous portion of the ration. The nonstructural or non-fiber carbohydrates (NFC) include starch, sugars and pectin.

Microorganisms ferment carbohydrates to volatile fatty acids (VFAs) in the rumen, where they are absorbed and utilized as energy sources for maintenance, synthesis of milk, and tissues. Also, the VFAs (acetic, propionic, and butyric) provide carbon units for synthesizing milk components such as milk fat. Glucose is needed by the mammary gland to synthesize lactose. The liver synthesizes glucose from propionic acid for use in other body tissues. Acetic acid is needed for about 50% of the milk fat produced in the mammary gland. The amount and ratio of volatile fatty acids (VFAs) produced in the rumen may alter milk composition. As an example, rapidly fermenting carbohydrates favor the production of

propionic acid; slowly degrading fibrous or structural carbohydrates promote acetic acid production.

Rations low in fiber may result in too little acetic acid being produced in the rumen, resulting in possible acidosis and reduced milk fat production. Adequate amounts of effective fiber are needed in the ration for the maintenance of health.

BALANCING NONSTRUCTURAL CARBOHYDRATE S (NSC)

The key to good, nutritionally-balanced and efficiently-utilized rations is to formulate diets with an optimum amount of both structural and nonstructural carbohydrates that maximize production performance. Aldrich et al. (1993) reported that diets containing 36% NSC resulted in the highest passage of bacterial nitrogen to the small intestine. Hoover et al. (1991) concluded from continuous culture studies that diets with an NSC level of about 37% of DM provided sufficient energy for optimum microbial growth. MacGregor et al. (1983) conducted a study where cows were fed low (24.9%) or high (32.9%) starch containing diets.

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Cows fed high-starch diets increased in milk production ($P < .07$) and DM1 ($P < .08$) compared to those fed the low-starch diet. Nocek (1993) concluded from his studies that appropriate nitrogen or protein fractions must be provided with these various carbohydrate fractions in order for optimal microbial synthesis and carbohydrate utilization to occur.

Nonstructural carbohydrates (NSC) represent the more rapidly digested fractions in the rumen. In plants, they are located mostly in the seeds. While different equations have been developed for calculating NSC, in this paper equation 1 is used where NDF = neutral detergent fiber.

$$NSC = 100 - (NDF + Crude\ protein + Fat + Ash)$$

equation 1.

The fibrous carbohydrates represent the portion of the ration that is more slowly digested. The fibrous carbohydrates occupy more space in the gut and require extensive chewing to reduce the particle size for passage to the lower digestive tract.

The fiber in a ration is analyzed by laboratory procedures for either crude fiber, acid detergent fiber (ADF) or neutral detergent fiber. The NDF procedure measures all the cellulose, hemicellulose and lignin. Crude fiber measures only cellulose and some lignin; ADF measures cellulose and all the lignin. For this reason, ADF appears to be more closely associated with digestibility and NDF to rumen fill or dry matter intake. Since dry matter intake and milk production correlate closely, any component of the ration affecting dry matter intake would affect milk production. Suggested fiber content of rations for high-producing cows is in Table 2.

An experiment was conducted by Staples et al. (1992) to evaluate the value of NDF concentration in diets in order to formulate the desired forage-to-concentrate ratio. Forages selected for the study included corn silage, elephantgrass silage, bermuda silage, and sorghum silage. The forages were adjusted in the diets to give NDF values of 31, 35 and 39 percent. The results are in Table 3.

Milk production averaged nearly 50 lb/day over the 84-day experiment. All silages, except for sorghum silage, supported similar amounts of milk production. Cows consuming sorghum-based diets produced about 3.3 lb/day less milk than cows on other diets. Similar amounts of milk were produced on 31% and 35% NDF rations, but production decreased when cows received diets containing 39% NDF.

Corn and alfalfa silage were used in a study by Purdue University workers to measure the performance of early lactation cows fed TMRs formulated to differ in NDF content by varying the amount of forage (silage) in the ration. The forage source used was a 50:50 mixture of corn and alfalfa silage at 41.2, 55.3 and 69.5% (DM) of diets containing 26, 31 and 36% NDF. The results are in Table 4.

The results in Table 4 show a significant difference in DM intake, milk yield and fat-corrected milk (FCM) between the two lower NDF values and 36% NDF. This is in contrast with studies by Staples et al. (1992) where 35% NDF diets performed equally as well as 31% NDF diets except in the sorghum silage diets. The differences are probably due to forage type since forages vary considerably in NDF content. In most forage type rations, NDF values from 31% to 36% appear to be acceptable for high producing cows. In contrast, lactating cows appear to perform better on lower NDF rations when alfalfa hay and similar legumes are the major forage types.

Formulating rations based on NDF values requires a good understanding of forage types and by-product feedstuffs. To effectively use NDF values in formulating rations containing large amounts of byproducts, discount values (Mertens, 1992) should be applied to certain by-product feedstuffs such as distillers' grains, hominy feed and soybean hulls. The reason is because the values given in the NRC publication on nutrient requirements of dairy cattle (1989) are higher for these feedstuffs than for alfalfa hay.

The physical form of a feed has a great impact on the effectiveness of the fiber in the diet. Chewing time is a good indication of that effectiveness for certain feedstuffs. For example, Sudweeks et al.

(1981) showed that long alfalfa hay containing 40% acid detergent fiber (ADF) was chewed at the rate of 28.2 min/lb of DM; ground and pelleted alfalfa hay was chewed at the rate of 16.8 min/lb. of DM. This demonstrated that long alfalfa hay was a more effective source of fiber than pelleted alfalfa. In contrast, both citrus pulp and cottonseed hulls stimulated chewing time at 14 min/Lb of DM which indicated they had equal effective fiber values. In reality, citrus pulp is low in effective fiber (12%) and cottonseed hulls are high in effective fiber (43%).

By-product feedstuffs are used extensively in dairy cattle diets throughout the country. Frequently, these by-product feedstuffs are used as major sources of fiber or as fiber extenders. in dairy cattle diets. While performance may remain good, the NDF content of the diet is sometimes higher than suggested in the 1989 NRC publication for high-producing cows. Attempting to lower the NDF content in the diet results in milk fat depressions, looseness in bowel and acidosis type conditions. The problem can frequently be avoided by adjusting or discounting the NDF content of the by-product feedstuffs being used in the

diets. Table 5 contains a list of selected feedstuffs with NRC values taken from the 1989 NRC publication, discount values (DV), and adjusted NDF (ANDF) values. Similar adjusted NDF values have been suggested and developed by Mertens (1992).

The key to a successful feeding program for high producing dairy cows is a balance between the needs for ruminally available protein and carbohydrates that will optimize microbial growth and metabolism in the rumen. As these needs are met, fine-tuning the ration with sources of bypass protein and fats may be advantageous. While the level of NSC needed in the ration will vary with forage type and use of byproducts feedstuffs, a suggested range is 35% to 45% NSC. The lower range's recommended when rations contain good quality hay and/or silage with natural grains such as corn and limited amounts of ingredients such as citrus pulp and soybean hulls. Using adjusted NDF and NSC values for by-product feedstuffs~ will help minimize the formulating problems encountered when attempting to use higher levels of by-product feedstuffs in the diet.

SELECTED REFERENCES

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Table 1.

Table 1. Carbohydrate fraction of the ration divided into two categories- structural and nonstructural.	
Structural (fiber)	Nonstructural (non-fiber)
cellulose, hemicellulose, lignin	starches, sugar, pectin

Table 2.

Table 2. Fiber guidelines for formulating diets for lactating dairy cows.		
Fiber Analysis	Minimum (NRC) ¹	Recommended
Crude fiber	15-17	15-21
Acid detergent fiber	19-21	19-24
Neutral detergent fiber	25-28	25-35 ²
Forage Program		% of DM
Corn silage (CS) (only forage)		45-55
CS + 7 lbs alfalfa hay		35-40
Bermuda haylage (35-40% DM)		20-30
CS + 7 lbs cottonseed hulls		35-40
CS + 5 lbs CSH + lbs alf hay		32-40
CS + 7 lbs bermuda hay		32-40
CS + 20-25% high fibrous by-products		40-45
Nonstructural carbonhydrates (NSC)		
Minimum		25-33
Optimum		34-38
Maximum		39-45
1National Research Council, 1989.		
2Range varies with forage type and use of by-products.		

Table 3.

Table 3. Dry matter intake, milk yield, milk composition and FCM production of lactating cows fed four silage-based diets.						
Diets	NDF(%)	DM ¹ ²	MY ²	FCM ³	Fat ⁴	Protein ⁵
		----- (lb/d) -----			----- (%) -----	
Corn silage	31	43.8	51.6	46.8	3.39	3.20
	35	43.0	51.6	46.3	3.38	3.10
	39	41.2	50.3	46.5	3.51	3.10
Elephantgrass	31	46.1	51.6	46.2	3.32	3.12
silage	35	45.1	51.3	46.0	3.33	3.08
	39	42.0	47.8	42.7	3.27	3.06
Bermudagrass	31	43.5	51.1	44.9	3.26	3.20
silage	35	41.4	51.0	45.8	3.35	3.04
	39	40.7	46.8	41.7	3.27	3.09
Sorghum	31	44.5	48.6	43.9	3.38	3.18
silage	35	41.4	46.2	41.5	3.32	3.10
	39	39.0	46.3	41.5	3.31	3.07
1 DM intake = decrease due to NDF, P = 0.16						
2 FCM yield = decrease due to % NDF, P = .005.						
3 Milk yield = decrease due to % NDF, P = .001.						
4 Percent milk fat = CS > elephantgrass, P = .003.						
5 Milk protein = increase due to % NDF, P = .003.						
Staples et. Al. (1992)., Proc. Fl. Dairy Prod. Conf.						

Table 4.

Table 4. Adjusted means for dry matter intake, milk yield, milk composition and FCM ² .					
Item	Total Mixed Rations			SE	Level of sig.
	26	31	36		
DM intake, lb/d	49.4	48.2	44.2	.06	.001
Milk yield, lb/d	74.6	76.1	70.2	.54	.001
FCM, lb/d	70.0	69.1	66.4	.40	.034
Milk fat, %	3.52	3.64	3.60	.08	.464
Milk protein, %	2.99	2.92	2.86	.04	.133
1 Colenbrander et al. (1988). Dairy Day, Purdue Univ.					
Sig. = significance; SE = standard error.					