Effectiveness of Neutral Detergent Fiber in Whole Cottonseed and Dried Distillers Grains Compared with Alfalfa Haylage[1]

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ABSTRACT

Sixteen Holstein cows in midlactation were used in a 4 × 4 Latin square design to determine the effect of replacing alfalfa NDF with NDF from whole, linted cottonseed or dried distillers grains. Low and high fiber control diets (13 and 19% of dietary DM from alfalfa haylage NDF, respectively) were compared with diets designed to contain 13% of DM from alfalfa haylage NDF plus 6% of DM from either cottonseed NDF or distillers grains NDF. Dry matter intake, milk yield, and milk protein yield were lower for the high fiber control diet. Milk fat percentage was lower for the low fiber control diet. The cottonseed diet was equal to the high fiber control diet in stimulating rumination. Rumen acetate to propionate ratio was higher for the high fiber control and cottonseed diets. Replacing alfalfa with either of these high fiber by-product feeds increased feed intake and yields of milk fat and protein. The effectiveness of the NDF in distillers grains and cottonseed was not significantly different from that of alfalfa NDF for maintaining milk fat yield. Whole cottonseed and dried distillers grains appear to be good sources of effective fiber for maintaining milk fat test when they are substituted for alfalfa haylage fiber in lactating cow rations.
(**Key words**: effective fiber, cottonseed, dried distillers grains, milk fat)

Abbreviation key: **AH** = alfalfa haylage; **HFA** = higher fiber alfalfa diet; **DDG** = dried distillers grains; **NFFS** = nonforage fiber sources; **WCS** = whole, linted cottonseed.

INTRODUCTION

Dairy cattle require a minimum amount of effective fiber in their diet for optimal DMI, milk yield, and digestive tract health. Effective fiber has been defined as the actual capacity of the fiber to stimulate cud chewing, rate of digesta passage, salivation, ruminal acetate production, and, consequently, milk fat percentage (8). Lack of adequate effective dietary fiber can lead to metabolic disorders, such as acidosis and abomasal displacement, or, at least, depressed milk fat concentration.

Traditional recommendations for maintaining adequate effective fiber in dairy rations have been summarized (10). A common recommendation is to supply a minimum of 26 to 28% NDF in the total dietary DM with 75% of the NDF supplied from forages. These guidelines work well for traditional rations containing clearly defined forages and concentrates; however, several high energy, high fiber alternative feeds are difficult to categorize as either concentrates or forages. This heterogeneous group of by-product feeds includes whole, linted cottonseed (WCS); dried distillers grains (DDG); dried brewers grains; beet pulp; soy hulls, and others. These feeds can be economical sources of fiber, energy, undegradable and degradable protein, and other nutrients (4).

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TABLE 1. Chemical analysis of feeds.

Feed	Diet component				
	DM	NDF	ADF	CP	Fat
	(g/100 g of DM)				
Haylage[1]	45.8	43.1	37.9	17.8	1.2
Shell corn	78.0	12.6	3.0	10.9	3.9
Cottonseed	88.3	44.6	34.3	20.6	14.4
Distillers grain	85.8	31.5[2] 39.2[3]	16.3	27.0	9.5
Soybean meal	87.4	12.7	9.3	49.4	2.1
Soybeans	93.6	10.1	6.9	41.5	19.7
Meat and bone meal	94.1	9.8	3.1	37.8	3.8

[1]Mean particle length of haylage = 7.6 mm.

[2]Sulfite used in NDF procedure.

[3]Sulfite not used in NDF procedure.

The value of WCS (6) and DDG (5) fed as replacement protein or oil sources is well documented, but information is lacking concerning the effectiveness of the fiber in these feeds for maintainence of milk fat test and general ruminal health compared with a traditional fiber source such as alfalfa haylage (AH). For ration balancing, the NDF in these nonforage fiber sources (NFFS) is often assumed to be less effective than AH NDF. However, little information exists to justify this assumption or to quantify the effective fiber values of these feeds.

The purpose of this study was to determine the effectiveness of the NDF in WCS and DDG when used to replace AH NDF in lactating dairy cow diets.

MATERIALS AND METHODS

Experimental Cows and Diets

Sixteen multiparous Holstein cows in midlactation were used in four replications of a 4 × 4 Latin square design. Cows were blocked by stage of lactation and averaged 135 DIM at the beginning of the first period and ranged from 68 to 190 DIM. One cow was excluded because of chronic mastitis. Housing consisted of a conventional tie-stall barn; stall mattresses were used to prevent ingestion of bedding. Cows were fed a TMR twice daily at 0600 and 1700 h and milked twice daily prior to feeding. Feed refusals were weighed daily at 0600 h. Dry matter composition of orts was assumed to be equal to that of the diets for DMI calculations.

The composition of feeds and experimental diets is shown in Tables 1, 2, and 3. A basal, low forage, low fiber diet contained 13% of DM from AH NDF. A higher forage, higher fiber alfalfa diet (HFA) contained 19% of DM from AH NDF. The other two diets were the basal plus an additional 6% of DM from DDG NDF (the DDG diet) or WCS NDF (the WCS diet). The diets were designed to be equal in CP, degradable protein, and crude fat content but were not isoenergetic. Dietary NE_L density generally exceeded the requirements of all but the highest yielding cows.

The high moisture shelled corn was coarsely rolled before it was fed. All cows were fed the same pretrial adjustment diet containing 17% of DM from AH NDF for 14 d prior to the start of the 21-d experimental periods. All diets were available for ad libitum intake. Cows were switched immediately to a new diet at the beginning of each period. Dry matter intake data were collected on d 16 to 20 of each period.

Feed, Milk, and Ruminal Fluid Sampling and Analysis

The WCS, DDG, and roasted soybeans were batch sampled at the beginning of the trial. Other concentrates and AH were sampled weekly and composited at the end of each

TABLE 2. Ration composition.

Feed	Diet[1]			
	Basal	HFA	DDG	WCS
	(g/100 g of DM)			
Haylage	30.3	43.6	30.9	30.5
Shell corn	46.4	35.7	38.4	41.5
Whole cottonseed	0	0	0	12.9
Distillers grains	0	0	12.7	0
Soybean meal	6.2	3.7	7.1	11.3
Soybeans	13.6	13.1	7.5	0
Meat and bone meal	1.1	2.8	.9	2.3
Dairy mineral[2]	1.0	.40	1.0	.50
Limestone	.90	.30	1.0	.70
Trace-mineralized salt	.30	.30	.30	.30
Magnesium oxide	.15	.15	.15	.15
Vitamin A, D, and E premix[3]	.05	.05	.05	.05

[1]HFA = High fiber alfalfa, DDG = basal plus dried distillers grains, WCS = basal plus whole cottonseed.

[2]Contains 8% Ca, 18% P, 1% K, 1% Mg, .6% S, 8% NaCl, 440,000 IU of vitamin A, 110,000 IU of vitamin D, and 330 IU of vitamin E/kg.

[3]Contains 6.6 million IU of vitamin A, 2.2 million IU of vitamin D, and 11,000 IU of vitamin E/kg.

period. Dry matter determinations were made by oven-drying at 60°C for 48 h. Feed samples were ground in a Wiley mill (2-mm screen; Arthur H. Thomas, Philadelphia, PA). Feed fiber analysis was performed according to the method of Van Soest (18) with the following modifications recommended by D. R. Mertens (1992, personal communication): for all samples, sodium sulfite (.5 g per sample) was added, and 1205 U of amylase (A-3306; Sigma

TABLE 3. Chemical composition of diets.

Diet component	Diet[1]			
	Basal	HFA	DDG	WCS
DM, %	66.3	61.3	66.2	66.1
	(g/100 g of DM)			
CP	19.6	19.9	20.1	19.0
Fat[2]	5.0	4.7	4.7	4.2
ADF	14.5	18.9	16.2	18.4
NDF				
Total	21.2	25.4	24.0[3]	25.8
From alfalfa	13.0	18.8	13.3	13.1
From distillers grain	0	0	4.0	0
From cottonseed	0	0	0	5.7
ADF (from alfalfa)	11.5	16.5	11.7	11.6
UIP,[4,5] % of total CP	37.2	35.3	37.9	35.9
NE_L,[5] Mcal/kg	1.77	1.71	1.75	1.78

[1]HFA = High fiber alfalfa, DDG = basal plus dried distillers grains, WCS = basal plus whole cottonseed.

[2]Represents sum of C_{14} to C_{18} fatty acids.

[3]Represents NDF analysis with sulfite.

[4]Undegradable intake protein.

[5]Calculated from NRC values (10) for individual feedstuffs.

TABLE 4. Milk yield and composition and DMI.

Yield variable	Diet[1]					Effect[2]			
	Basal	HFA	DDG	WCS	SE	TRT	Basal vs. BP	HFA vs. BP	DDG vs. WCS
						P			
Milk, kg/d	32.2	30.6	32.5	31.5	.5	<.07	NS[3]	<.04	NS
4.0% FCM, kg/d	27.8	27.1	28.6	28.2	.4	NS	NS	<.03	NS
Protein, %	3.05	2.98	3.09	3.10	.02	<.01	<.07	<.01	NS
Fat, %	3.16	3.30	3.27	3.34	.04	<.01	NS	NS	NS
Protein, kg/d	.97	.90	.99	.97	.02	<.01	NS	<.01	NS
Fat, kg/d	1.00	.99	1.04	1.04	.02	<.07	<.04	<.03	NS
DMI, kg	23.8	22.8	24.3	24.0	.3	<.01	NS	<.01	NS

[1]HFA = High fiber alfalfa, DDG = basal plus distillers dried grains, WCS = basal plus whole cottonseed.

[2]TRT = Overall treatment effect, BP = combined effect of DDG and WCS.

[3]$P > .10$.

Chemical Co., St. Louis, MO) were added at boiling and again prior to filtration. Four acetone washes were used for fat extraction prior to NDF digestion for selected samples (roasted soybeans, WCS, DDG, and meat and bone meal). Crude protein was determined by Kjeldahl analysis. Fat percentages were determined by extraction and methylation of fatty acids, C_{14} to C_{18}, which then were quantified by GLC (15). The AH particle size was determined according to standard S424 on frozen-thawed wet AH of the American Society of Agricultural Engineers (1). Diet chemical composition was calculated from individual feedstuff analysis (Table 3).

Milk weights were recorded daily. Morning and evening milk samples were collected on d 16 to 20 of each period and analyzed individually for fat and protein by a commercial DHI laboratory (Wisconsin DHI Cooperative, Menomonie). Ruminal fluid samples were collected by stomach tube aspiration on d 21 of each period once between 1200 and 1400 h. Samples were acidified to pH 2.0 with 50% sulfuric acid and frozen until analysis for VFA (16). Chewing activity was monitored for one continuous 24-h period on d 19 of each period by observation of each cow once per 5 min.

Statistical Analyses

Data were analyzed by ANOVA, including period, square, cow within square, and treatment in the model. For milk fat concentration, square by treatment interaction was nonsignificant and was removed from the model. Type III sums of squares were used throughout, and the residual served as the error term for all tests. Three single degree of freedom contrasts were used to compare basal with DDG and WCS, HFA with DDG and WCS, and DDG with WCS. All means are least squares means.

RESULTS AND DISCUSSION

Milk yield, milk protein concentration, protein yield, and DMI were lower for the HFA diet (Table 4). The HFA diet provided less fermentable energy and less total energy because of lower energy density and lower DMI, which could have contributed to the lower milk yield and protein secretion.

Milk fat concentration was lowest for the basal diet, as expected, and was not different among the three higher fiber diets, suggesting that WCS and DDG were adequate substitutes for AH for supporting the milk fat test. The range of fat test means between the basal diet and the other diets was smaller in the current trial than in other similarly designed trials using other NFFS (17, 20). This difference may have been due to the higher fat percentages in DDG and WCS. Yield of FMC was lowest for the HFA diet and was not different among the other diets.

Both DDG and WCS have shown potential for stimulating FCM yield and milk fat percentage (2, 11, 22), especially when they were

TABLE 5. Rumen VFA percentages and chewing activity.

Rumen VFA	Diet[1] Basal	HFA	DDG	WCS	SE	Effect[2] TRT	Basal vs. BP	HFA vs. BP	DDG vs. WCS
						P			
Acetate (A)	61.6	66.3	61.6	62.8	.5	<.01	NS[3]	<.01	.07
Propionate (P)	23.1	18.5	22.9	22.1	.5	<.01	NS	<.01	NS
Butyrate	10.9	10.9	11.5	10.6	.2	.04	NS	NS	<.01
Isobutyrate	.9	1.1	.8	1.0	<.1	<.01	NS	<.01	<.01
Valerate	1.5	1.5	1.5	1.5	<.1	NS	NS	NS	NS
Isovalerate	1.9	1.8	1.7	2.0	<.1	.06	NS	<.01	<.01
A:P	2.81	3.68	2.74	2.95	<.1	<.01	NS	<.01	.09
	(min/d)								
Chewing activity									
Ruminating	405	455	389	464	11	<.01	NS	.03	<.01
Eating	276	302	262	286	8	<.01	NS	<.01	.03

[1]HFA = High fiber alfalfa diet, DDG = basal plus dried distillers grains, WCS = basal plus whole cottonseed.

[2]TRT = Overall treatment effect, BP = combined effect of DDG and WCS.

[3]$P > .10$.

added to diets that depressed milk fat. These feeds are unique because they have medium to high fat content and high fiber. Staples et al. (13) summarized a number of WCS studies and concluded that, when corn silage was the basal forage, use of WCS tended to suppress milk fat synthesis, an effect not observed with alfalfa-based diets. Smith et al. (12) also reported that the depressing effects on FCM of WCS fed with corn silage could be lessened by the addition of alfalfa.

Although the addition of DDG and WCS in our study increased milk fat concentration, ruminal VFA ratios did not change compared with that of the basal diet (Table 5); however, ruminal acetate to propionate ratio tended to be slightly higher for the WCS diet. Response of ruminal VFA to the addition of more alfalfa fiber in the HFA diet followed a normal pattern of increased acetate to propionate ratio. The apparently poor correlation of fat test with ruminal VFA patterns has been noted for other NFFS; response of fat test often exceeded the response in ruminal acetate to propionate ratio (17, 20).

Time spent eating and ruminating has been used as a measure of the effective fiber value of NFFS (3, 14). The WCS was much more effective in increasing eating and rumination activity than DDG (Table 5) and was comparable with HFA. Sudweeks et al. (14) reported that cottonseed hulls have a higher roughage value index than medium-cut AH. Harris (8) reported effective fiber of .85 for WCS and .90 for cottonseed hulls in relation to long alfalfa hay as a chewing time standard with an effective fiber of 1.0. Chewing time was not increased by DDG in our trial, and many other NFFS have been poor chewing stimulators (17, 20) but appear to have effective NDF based on milk fat concentration responses.

This trial was designed to compute NDF effectiveness factors for DDG and WCS. The relationship between effective dietary NDF and milk fat percentage has been well documented (7, 9, 19, 21). Previous studies (17) showed a linear response of fat test to dietary NDF from AH over the same range used in this study. The calculation of an effectiveness factor for a feed is best determined as a slope ratio using the milk fat test as a bioassay parameter to gauge the effectiveness of various dietary fiber percentages and sources. A slope coefficient was calculated (Table 6) for HFA, WCS, and DDG diets relating the increased milk fat percentage to the units of dietary NDF added compared with the BAS diet. In this calculation, the total ration NDF is not considered because the effectiveness of NDF from traditional concentrates is arbitrarily set to 0. Slope

TABLE 6. Calculating NDF effectiveness and effective NDF content.

	Fiber source[1]			
	HFA	DDG	DDG[2]	WCS
Increase in milk fat percentage (a)	.14	.10	.10	.18
Added NDF percentage (b)	5.7	4.0	5.0	5.9
Slope (a/b)	.025	.025	.020	.034
Effectiveness of NDF	1.0	1.0	.8	1.3
Chemical NDF, g/100 g of DM	43.1	31.5	39.2	44.6
Effective NDF, g/100 g of DM	43.1	31.5	31.5	58.0

[1]HFA = High fiber alfalfa diet, DDG = basal plus dried distillers grains, WCS = basal plus whole cottonseed.
[2]Dried distillers grains NDF determined without using sulfite.

ratios (Table 6) were calculated by dividing the slope coefficient for DDG or WCS by the slope for HFA. This slope ratio is the factor that describes the effectiveness of the NDF in DDG or WCS relative to a value of 1 for AH. For example, WCS contained 44.6% NDF, which was 1.3 times as effective as AH, resulting in an effective NDF content of 58.0% (44.6% × 1.3). Theoretically, .74 kg of WCS could replace 1.0 kg of 43.1% AH NDF (DM basis). Two different effectiveness factors were calculated for DDG, reflecting the difference in NDF, depending on whether or not sulfite was used in the NDF analysis. The use of sulfite lowers NDF for some heat-treated feeds. Therefore, omission of sulfite raised the NDF content and lowered the NDF effectiveness factor but did not change the absolute percentage of effective NDF in DDG on a DM basis.

The precision of the effectiveness factor calculation depends on the standard error for fat concentration and the range of fat tests. The range of fat tests in our work was small; the slope for added AH NDF was less than one-half that of similar previous trials (17, 20). Therefore, our ability to separate effectiveness factors statistically was low. No significant difference existed between fat tests with DDG, WCS, or AH; therefore, all of these feeds could be assigned an effectiveness factor of 1.

The reason for the smaller range in fat tests in the present trial may be the inclusion of fat in all diets, which was not done in similar previous trials. Fat inclusion was necessary to keep fat percentages in the total ration constant across diets. The actual WCS fat concentration (Table 3) was lower than anticipated because of an overestimation of the fat content of the WCS. The NDF percentages in the DDG and the WCS also were lower than anticipated (Table 1). Therefore, the actual contribution of NDF from these two feeds was not as high as anticipated when the DDG and WCS diets were originally formulated. The AH used in the current trial had a higher ADF:NDF ratio than the AH used in previous trials, which also may have contributed to the narrow range of fat tests. The primary effect of the narrow range of fat test was to lower the precision of the effectiveness factor but not its accuracy. Corroborating studies are needed before the use of an NDF effectiveness factor >1.0 for WCS can be recommended. These NFFS may also perform differently when used to replace other forages such as corn silage.

The maximum dietary amount at which NFFS can be safely used as forage replacement for an entire lactation is still unclear. Early lactation cows may have lower limits than mid to late lactation cows because of greater tendencies toward displaced abomasum and other metabolic disorders. No cows went off feed during this trial despite the abrupt ration changes.

In our experience, a close relationship exists between ruminal pH, ruminal VFA ratios, chewing time, and milk fat percentage when the amount of dietary fiber is varied by addition or removal of AH. These relationships do not hold as closely when NFFS are used. Many feeds that were very effective in increasing fat percentage did not stimulate chewing and changed ruminal VFA patterns very little. Because these relationships do not appear to be consistent, feeds that increase fat percentage may not prevent digestive and metabolic disorders.

CONCLUSIONS

Increasing the fiber content of a low fiber diet based on AH by the addition of DDG or WCS increased milk fat and protein yields and concentrations without affecting milk yield. Conversely, increasing the fiber content of the diet by addition of more AH increased milk fat concentration but decreased milk yield and milk protein concentration. Changes in milk fat concentration were used to calculate estimates of the effective NDF content of DDG and WCS. The NDF in both feeds was approximately as effective as AH NDF in stimulating milk fat synthesis. Both WCS and AH promoted more chewing activity than did DDG. The DDG and WCS can serve as effective fiber supplements for low forage AH diets.

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