Effects of alfalfa hay inclusion rate on productivity of lactating dairy cattle fed wet corn gluten feed-based diets^{1,2}

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ABSTRACT

An experiment was conducted to evaluate the effects of varying the alfalfa inclusion rate in diets containing 31% (dry matter basis) wet corn gluten feed (Sweet Bran, Cargill Inc.). Eighty primiparous and multiparous Holstein cows averaging 178 ± 90 d in milk (mean $\pm$ SD) were randomly assigned to 1 of 4 sequences in a 4×4 Latin square design with 28-d periods. Treatments were diets containing 0, 7, 14, or 21% alfalfa on a dry matter basis, with corn silage, corn grain, soybean meal, expeller soybean meal, and mineral supplements varying across diets to maintain uniform nutrient densities. Diets were formulated for similar crude protein, neutral detergent fiber, and nonfiber carbohydrate concentrations. Feed intake, milk production, body weight, and body condition score were monitored, and linear and quadratic effects of increasing the alfalfa inclusion rate were assessed using mixed model analysis. As the alfalfa inclusion rate increased, dry matter intake tended to increase linearly (26.7, 27.3, 27.4, and 27.5 kg/d for 0, 7, 14, and 21% alfalfa, respectively), and solids-corrected milk (29.9, 30.2, 30.8, and 30.5 kg/d) and energy-corrected milk production (32.9, 33.3, 33.8, and 33.6 kg/d) tended to increase linearly. Body weight gain decreased linearly (22.9, 18.0, 11.2, and 9.5 kg/28 d) with increasing alfalfa inclusion rate. Although increasing the inclusion rate of alfalfa increased the proportion of large particles in the diets, treatments had no effect on milk fat yield or concentration. Feeding more alfalfa (up to 21% of dry matter) tended to increase milk yield while decreasing body weight gain, suggesting that metabolizable energy utilization shifted from body weight gain to milk production in these treatments. However,

adding alfalfa to the diet had only minor effects on productivity.

Key words: by-product, dairy cattle, alfalfa, wet corn gluten feed

INTRODUCTION

Alfalfa is a cool-season perennial legume that serves as a source of protein and fiber in dairy cattle rations. Dairy nutritionists have traditionally relied heavily on alfalfa; results from a 1995 survey revealed that 62% of dairy cattle in the United States were fed alfalfa (Mowrey and Spain, 1999). Since 1995, however, the number of acres devoted to alfalfa production has declined by nearly 4 million acres (National Agricultural Statistics Service, 2008). Not surprisingly, as the availability of alfalfa has decreased, its cost has increased by nearly 50% in the last 20 yr (National Agricultural Statistics Service, 2008). Increased pressure for land use, including greater use of corn in the corn milling industry, has contributed to the loss of alfalfa acres. As a result, nutritionists and producers are reconsidering the role of alfalfa in dairy rations.

Scientific reports as far back as 1933 show that diets using corn silage (CS) as the only forage can support milk and milk fat production equivalent to diets incorporating both alfalfa hay (AH) and CS (Hayden et al., 1933). Thomas et al. (1970) reported that cows fed CS or AH as the only roughage source produced similar amounts of FCM across 3 lactations. More recent studies have also supported the conclusion that diets can be formulated to support high milk production without the use of AH (Kleinschmit et al., 2007; Kowsar et al., 2008).

Although an increasing amount of corn is being consumed by the corn milling industry, coproducts of this industry provide an opportunity for dairy producers to adopt novel diet formulation strategies. One such coproduct, produced from the wet-milling process, is wet corn gluten feed (WCGF). Wet corn gluten feed is a high-fiber, low-lignin feedstuff that can be easily incorporated into dairy cattle diets (NRC, 2001; Wickersham et al., 2004). Armentano and Dentine (1988)

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found that feeding WCGF at up to 36% of ration DM did not affect milk production, composition, or DMI in one study. On the other hand, Staples et al. (1984) showed a decrease in DMI and milk yield but an increase in milk fat percentage when WCGF was fed at high levels. It is important to note that in both studies, diets contained large proportions of forage and that WCGF was used in place of concentrates, resulting in higher dietary NDF concentrations as WCGF was added. In contrast, Kononoff et al. (2006) found that feeding a ration containing 38% WCGF (DM basis) decreased milk fat concentration but increased milk yield, resulting in similar milk fat yields across treatments. In this study, forage decreased from approximately 60% of ration DM in the control to 38% of DM for the treatment diet (Kononoff et al., 2006).

It is possible to chemically balance a ration that includes large amounts of WCGF, but physical characteristics of the TMR must be accounted for. Although WCGF is relatively high in fiber, the small fiber particles provide little physically effective fiber; physically effective NDF of WCGF was reported as 11% of NDF based on rumination time and ruminal pH of lactating cows (Allen and Grant, 2000). Many investigators have shown that physically effective fiber is necessary for maintaining proper rumen function and preventing milk fat depression (Lammers et al., 1996; Mertens, 1997). In ruminants, physically effective fiber stimulates rumination, which facilitates the secretion of saliva that, in turn, buffers the rumen (Kay, 1966). Because of the mechanical stimulation provided by AH particles, feeding high levels of WCGF without AH could lead to milk fat depression. Therefore, the objective of this study was to evaluate the effects of varying AH inclusion rate, in diets containing 31% WCGF, on milk and milk fat yield and BW gain.

MATERIALS AND METHODS

Experimental procedures were approved by the Institutional Animal Care and Use Committee at Kansas State University.

Design and Treatments

Forty-one primiparous and 39 multiparous Holstein cows (178 ± 90 DIM; 1.8 ± 0.99 lactations; mean $\pm$ SD) from the Kansas State University Dairy Cattle Teaching and Research Facility were randomly assigned to 1 of 8 free-stall pens. After initial pen assignments, variation in pen means for DIM, milk yield, and parity were assessed, and the randomization was repeated until the coefficient of variation for all 3 variables declined below 25%. Each pen was assigned randomly to one of

Table 1. Composition of corn silage (CS) and alfalfa hay (AH)

Nutrient ¹	Ingredient	
	CS	AH
DM	34.6	86.1
NDF	42.6	40.3
CP	7.6	18.3
Starch	27.7	4.0
Ether extract	2.8	1.1
Ash	5.5	9.3

¹Nutrients other than DM expressed as a percentage of diet DM.

two 4×4 Latin squares balanced for carryover effects. Treatment periods were 28 d, with the final 9 d used to collect samples and data. Recombinant bST (Posilac, Monsanto, St. Louis, MO) was administered on d 1 and 15 of each period. At the beginning of the experiment, BW and BCS of cows were 674 ± 97 kg and 2.92 ± 0.36 , respectively.

Cows were offered 1 of 4 rations that differed in the amount of AH included. Alfalfa hay inclusion rates were 0, 7, 14, or 21%, primarily replacing CS of similar forage quality (Table 1). The strategy for formulating experimental diets was to develop diets with similar concentrations of CP, NDF, and NFC. Consequently, diets containing more AH had less CS and soybean meal but more corn grain (Table 2).

Data and Sample Collection

Throughout the experiment, cows were housed in free stalls and fed twice daily at 110% of the expected intake. Amounts of feed delivered and refused were recorded on d 19, 20, 21, 26, 27, and 28 of each period. The TMR and orts were analyzed for DM, and particle size was measured. Samples of all dietary ingredients were collected on d 19, 21, 26, and 28 and composited into 1 sample per period. Cows were milked twice daily in a milking parlor; milk was sampled and yield was recorded for every milking on d 21 and 28 of each period. Body weight and BCS were measured on d 1 of each period and d 28 of the last period. Body condition score was measured by 2 trained investigators according to procedures described by Wildman et al. (1982).

Sample Analysis

The Penn State Particle Separator was used to measure particle size for both TMR and orts (Lammers et al., 1996). Diet ingredients were dried in a 55°C forced-air oven for 72 h and analyzed for DM concentration. All samples were ground with a Wiley mill (1-mm screen, Arthur H. Thomas, Philadelphia, PA). Ash concentration was determined after 5 h of oxidation at 500°C in a muffle furnace. Concentration of NDF was determined

Table 2. Ingredient and nutrient composition of dietary treatments

Item	Treatment, ¹ %			
	0	7	14	21
Ingredient, % of DM				
Corn silage	41.0	33.9	26.7	19.4
Alfalfa hay	0.0	6.6	13.4	20.2
WCGF ²	30.9	31.1	31.4	31.6
Cottonseed	7.3	7.3	7.4	7.5
Corn grain	9.7	11.6	13.5	15.6
Soybean meal	4.9	3.4	1.7	0.0
Molasses	0.4	0.4	0.4	0.4
Expeller soybean meal	2.5	2.5	2.6	2.6
Limestone	1.9	1.7	1.5	1.2
Micronutrient premix ³	1.3	1.4	1.3	1.4
Nutrient ⁴				
DM, % (as fed)	52.5	55.8	59.5	63.9
CP	16.5	16.5	16.7	16.7
NDF	34.6	34.7	34.5	34.7
Starch	17.7	16.3	16.6	15.8
NFC ⁵	36.0	36.0	36.4	36.5
Ether extract	3.8	3.7	3.6	3.6
Ash	9.1	9.0	8.8	8.6

¹0% = 0% alfalfa hay (AH); 7% = 6.6% AH; 14% = 13.4% AH; 21% = 20.2% AH (DM basis).

²Wet corn gluten feed (SweetBran, Cargill Inc., Blair, NE).

³Premix consists of 48.85% sodium bicarbonate, 20.92% trace mineral salt, 10.77% magnesium oxide, 9.41% Bio-Mos (Alltech, Lexington, KY), 4.18% 4-Plex (Zinpro Corp., Eden Prairie, MN), 2.72% Se premix, 2.09% vitamin E, 0.84% vitamin A, and 0.21% vitamin D.

⁴Nutrients other than DM expressed as a percentage of diet DM.

⁵Calculated as DM – (CP + NDF + ether extract + ash).

(Van Soest et al., 1991; method A) by using an Ankom Fiber Analyzer (Ankom Technology, Fairport, NY). Crude protein was determined by oxidation and detection of elemental nitrogen (Leco Analyzer, Leco Corp, St. Joseph, MI). Crude fat was determined by ether extract (AOAC, 2000; method 920.9). Starch content was determined by glucoamylase digestion, followed by glucose quantification using the glucose oxidase method (Dairy One Forage Testing Laboratory, Ithaca, NY). Concentrations of all nutrients except DM were expressed as percentages of DM, as determined by drying at 105°C in a forced-air oven for more than 8 h.

Milk samples were composited by day and analyzed for fat, true protein, and lactose with a B2000 Infrared Analyzer (Bentley Instruments, Chaska, MN) by Heart of America DHIA (Manhattan, KS). Energy-corrected milk ($0.327 \times \text{milk yield} + 12.86 \times \text{fat yield} + 7.65 \times \text{protein yield}$; DHI glossary, Dairy Records Management Systems, 2007) and SCM yield were calculated (Tyrrell and Reid, 1965).

Economic Model Analysis

A break-even analysis was conducted to determine whether the added milk production from including AH

was sufficient to justify feeding it in this type of ration. Changes in milk income, feed consumed, and feed costs were incorporated in a model to determine the relative difference in AH compared with CS value (DM basis) at different milk:feed cost ratios. Diets compared were the 0 and 21% AH treatments, and production and intake means for these treatments were used in this model. The value of AH was fixed at \$250/ton of DM (\$0.27/kg), and milk value was fixed at \$0.20/lb (\$0.44/kg), whereas the value of CS and TMR costs varied with the AH price differential and the milk:feed cost ratio, respectively. Addition of 21% AH also allowed the exchange of 5% soybean meal for corn grain, and the cost differential between these commodities was set at \$120/ton of DM (soybean meal – corn grain, \$0.13/kg). Changes to the fixed values had little effect on the results as presented, although the model was somewhat sensitive to the corn grain-to-soybean meal price differential. To account for this effect of corn and soybean meal prices, we also ran the model using maximum and minimum price differentials for corn and soybean meal from 2003 to 2008 (National Agricultural Statistics Service, 2008); \$120/ton of DM was the mean differential for this period.

Statistical Analysis

Five cows were removed from the experiment before its completion for various reasons unrelated to treatments, and 2 replacement cows were added during periods 1 and 2. Dry matter intake was divided by the number of cows in each pen to account for missing animals.

Data were analyzed according to the following model by using the REML procedure of JMP (version 6.0, SAS Institute, Cary, NC):

$$Y_{ijk} = \mu + P_i + T_j + N_k + PT_{ij} + e_{ijk},$$

where μ is the overall mean, P_i is the fixed effect of period ($i = 1$ to 4), T_j is the fixed effect of treatment ($j = 1$ to 4), N_k is the random effect of pen ($k = 1$ to 8), PT_{ij} is the interaction of period and treatment, and e_{ijk} is the residual error. Linear and quadratic effects of treatment were tested. The interaction term was included primarily to determine if the treatment responses varied by stage of lactation. The model used to analyze milk yield responses also included the random effect of cow nested within pen, and all models were checked to ensure that no more than 18 denominator degrees of freedom were available for treatment contrasts. Treatment effects were declared significant at $P < 0.05$. Tendencies for treatment effects were declared at $P < 0.10$.

Table 3. Effects of treatments on intake and performance of lactating cows

Item	Treatment, ¹ %				SEM	SED	P-value	
	0	7	14	21			Linear	Quadratic
DMI, kg/d	26.7	27.3	27.4	27.5	1.16	0.38	0.05	0.33
NDF intake, kg/d	9.1	9.2	9.3	9.2	0.18	0.13	0.35	0.92
Milk, kg/d	30.9	31.1	31.7	31.3	1.48	0.26	0.03*	0.16*
SCM, kg/d	29.9	30.2	30.8	30.5	1.36	0.40	0.07	0.30
ECM, kg/d	32.9	33.3	33.8	33.6	1.45	0.43	0.09	0.32
ECM/DMI	1.16	1.14	1.16	1.15	0.03	0.02	0.75	0.88
BW change, kg/28 d	23.0	18.0	11.2	9.5	3.6	5.7	0.02	0.69
BCS change/28 d	0.014	0.031	-0.006	-0.013	0.041	0.065	0.57	0.80

¹0% = 0% alfalfa hay (AH); 7% = 6.6% AH; 14% = 13.4% AH; 21% = 20.2% AH (DM basis).

*Significant treatment × period interaction.

RESULTS AND DISCUSSION

Ration Composition, Feed Intake, and Milk Production

Final analyses showed that nutrient composition of diets remained similar across all 4 treatments, with DM increasing and starch decreasing slightly as more AH was added (Table 2). Adding more AH to the ration tended to linearly increase DMI as well as ECM and SCM yields (Table 3). Statistical analysis of milk yield showed a significant treatment × period interaction. Cows in this study averaged 290 DIM at the end of the study, and not surprisingly, milk yield declined during the study; however, this interaction suggested that greater AH inclusion may have supported improved persistence in late lactation. Cows receiving 14 and 21% AH maintained milk production better through period 4 (means of 28.4, 28.3, 31.1, and 30.9 kg/d for 0, 7, 14, and 21% AH, respectively). However, we are not aware of full-lactation studies demonstrating improved persistence with AH-based diets, and given that period × treatment interactions were not observed for ECM or FCM yields, this result should be interpreted with caution.

Feed efficiency, as measured as ECM/DMI, averaged 1.15 ± 0.03 and was similar across treatments. The low feed efficiency in this study was likely primarily because relatively late-lactation cows were used. Feed efficiency ratios have often exceeded 1.3 in other studies investigating diets with high inclusion rates of corn gluten feed (Ohajuruka and Palmquist, 1989; Schroeder, 2003; Kononoff et al., 2006).

Fat and protein percentages and yield were not affected by treatment ($P > 0.15$; Table 4). Concentrations of milk fat and protein averaged 3.78 ± 0.11 and $3.45 \pm 0.07\%$, respectively, and yield of these components averaged 1.17 ± 0.06 and 1.07 ± 0.03 kg/d, respectively (Table 4). We observed a significant linear effect of AH on lactose yield, which was consistent with the tendency for increased SCM yield with higher alfalfa inclusion rates. There was a quadratic effect of AH inclusion rate on MUN ($P = 0.05$); however, the range of means was very small and the response did not correspond with treatment effects on dietary CP or milk protein yield; therefore, there is no clear explanation for this observation.

Lack of a significant treatment effect on milk fat yield or concentration suggests that ruminal biohy-

Table 4. Effects of treatments on milk components

Item	Treatment, ¹ %				SEM	SED	P-value	
	0	7	14	21			Linear	Quadratic
Milk fat, %	3.75	3.81	3.75	3.79	0.11	0.08	0.79	0.83
Milk protein, %	3.47	3.46	3.44	3.44	0.07	0.03	0.38	0.84
Lactose, %	4.77	4.75	4.81	4.76	0.03	0.02	0.64	0.44
SCC, log	2.17	2.19	2.18	2.22	0.06	0.05	0.46	0.80
MUN, mg/dL	12.6	13.0	12.7	12.5	0.48	0.22	0.31	0.05
Yield, kg/d								
Milk fat	1.14	1.17	1.18	1.18	0.06	0.03	0.21	0.44
Milk protein	1.06	1.06	1.08	1.07	0.03	0.01	0.15	0.48
Milk lactose	1.48	1.48	1.54	1.51	0.08	0.02	0.02	0.18

¹0% = 0% alfalfa hay (AH); 7% = 6.6% AH; 14% = 13.2% AH; 21% = 20.2% AH (DM basis).

Table 5. Particle size separation (as-fed basis)¹

Item	Treatment, ² %			
	0	7	14	21
TMR				
>19 mm	2.2 ^a	4.5 ^a	9.5 ^b	14.1 ^c
19 > 8 mm	39.1 ^b	36.6 ^b	30.5 ^a	26.8 ^a
<8 mm	58.7	58.9	60.0	59.1
Orts ³				
>19 mm	2.7 ^a	10.5 ^b	20.5 ^c	24.5 ^c
19 > 8 mm	48.6 ^c	39.4 ^b	32.1 ^a	28.6 ^a
<8 mm	48.8	50.1	47.3	46.9

^{a-c}Means with different superscripts within a row are significantly different by Tukey's HSD ($P < 0.05$).

¹Measured with a 3-compartment Penn State Particle Size Separator (Lammers et al., 1996).

²0% = 0% alfalfa hay (AH); 7% = 6.6% AH; 14% = 13.2% AH; 21% = 20.2% AH (DM basis).

³Mean refusal amounts ranged from 3.5 to 4.2 kg/cow daily (approximately 15% of what was offered) and did not vary by treatment ($P > 0.30$).

drogenation was not inhibited in diets with lower AH inclusion rates, which agrees with the results reported by Kleinschmit et al. (2007). In our study, NDF intake was not altered by treatment ($P > 0.35$; Table 3), but diets with more AH offered greater proportions of particles longer than 19 mm, which would be expected to increase the physical effectiveness of NDF. However, cows sorted against longer particles in the diets with more AH (Table 5), which is consistent with previous research (Methu et al., 2001; Leonardi and Armentano, 2003). It is not possible to determine whether sorting occurred because of the difference in TMR moisture or because more long particles were offered. Regardless, the fact that cows sorted against large particles may help explain why milk fat production remained similar across treatments, despite large differences in the physical effectiveness of fiber in the diets as fed.

Production responses to replacement of CS with AH have been inconsistent. This is not surprising, given that different formulation strategies can dramatically influence factors such as particle size, protein degradability, and fiber digestibility when AH is added. Kleinschmit et al. (2007) reported a linear increase in milk yield when AH replaced CS in a diet including 15% (DM) distillers dried grains with solubles. In contrast, Kowsar et al. (2008) reported that when finely chopped AH partially replaced CS, DMI and milk, protein, and lactose yields all decreased. Diets based on WCGF may provide the ideal setting for removal of AH. Wet corn gluten feed is a source of highly degradable protein (Kononoff et al., 2007), making the loss of RDP from AH less detrimental. Additionally, despite concerns about the lack of physically effective fiber in such diets, they also tend to contain less starch than typical lactation rations,

which may help prevent acidosis-related problems associated with the loss of long-stem AH. Nevertheless, our findings generally agree with those of Kleinschmit et al. (2007), with higher AH inclusion rates tending to increase FCM production.

Energetics

Body condition score was not significantly affected by dietary treatment ($P > 0.57$; Table 3). However, cows fed TMR containing more AH gained less BW compared with cows fed less AH ($P = 0.02$). As AH was added to the ration, energy partitioning changed from BW gain to milk production, and total energy for production and gain tended to decrease linearly ($P = 0.06$; Figure 1). Diets with more AH and less CS were not as fermentable (Holden, 1999), which likely decreased ruminal production of propionate. Propionate stimulates insulin secretion both directly and through stimulation of gluconeogenesis, and lactating cows fed more fermentable diets often have higher plasma insulin concentrations (Grant et al., 1990). Decreased fermentability in the high-AH treatments may have decreased plasma insulin, resulting in decreased lipogenesis in adipose tissue (Oba and Allen, 2003). However, blood samples were not collected during this study, so this hypothesis cannot be confirmed.

Figure 1. Total energy partitioned to milk production and BW gain in cows fed varying levels of alfalfa hay (AH). As AH was added, total energy utilization tended ($P = 0.06$) to decrease linearly. Body weight gain was assigned an energetic value of 5.975 Mcal/kg (NRC, 2001), and milk energy was calculated according to Tyrrell and Reid (1965).

Figure 2. Break-even analysis of the alfalfa hay (AH)-to-corn silage (CS) cost differential. Break-even analysis was conducted to determine whether the added milk production from including AH was sufficient to justify feeding it in this type of ration. The line indicates the break-even additional cost that can be paid for alfalfa compared with CS (per ton of DM) at a given milk:feed cost ratio. Values were calculated by using milk production and DMI data from the 0 and 21% alfalfa diets. The 3 lines represent the minimum (\$80), mean (\$120), and maximum (\$188) corn-soybean meal price differential from 2003 to 2008.

Manure Production

Fecal output was not monitored in this study, but on the basis of previous findings (Weiss et al., 2007), we speculate that manure production was likely influenced. Figure 1 represents the total energy used for production and BW gain of cows consuming each TMR; the tendency for decreased energy yield in the face of increasing DMI strongly suggests that the diets containing more AH were less digestible, which is not surprising given that a dried hay replaced an ensiled forage in these diets (Holden, 1999). Because fecal production is highly dependent on DM digestibility, increased manure production is one likely result of incorporating AH in rations similar to those used in this study.

Economic Analysis

Although feeding greater levels of AH tended to increase ECM production, it also led to greater DMI. The potential economic effects of such a response were evaluated to determine the theoretical value of AH relative to CS. According to the break-even analysis presented in Figure 2, if the price differential between AH and CS falls below the line at a given milk:feed cost ratio, it is profitable to incorporate AH into this type of ration. However, on the basis of responses to

the 0 and 21% alfalfa treatments in this study, adding AH to diets with high WCGF inclusion rates may not be profitable, especially when milk:feed cost ratios are low. This analysis suggests that even with favorable milk:feed cost ratios and expensive soybean meal, AH should demand no more than a \$60 premium per ton of DM to be incorporated into similar rations. Additionally, this analysis ignores costs associated with predicted increases in manure output and costs (or benefits) of decreased BW gain when more AH is fed.

CONCLUSIONS

Feeding higher proportions of AH tended to increase ECM yield and decrease BW gain, suggesting that ME supply was repartitioned from BW gain to milk production as more AH was included. Nonetheless, decreasing the AH inclusion rate may improve farm profitability by reducing feed costs and expenses associated with manure handling, despite small losses in productivity.

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