Whole Cottonseeds or a Combination of Soybeans and Soybean Hulls in the Diets of Lactating Dairy Cows[1]

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ABSTRACT

Whole raw soybeans and soybean hulls were evaluated as a dietary replacement for whole cottonseed as determined by rumination and total chewing activity, milk fat percentage, and efficiency of 4% fat-corrected milk (FCM) production. Twenty-six Holstein dairy cows (14 multiparous; 35 ± 12 d of lactation) were assigned randomly to one of two total mixed rations (TMR) for 15 wk. The whole cottonseed TMR and the soybean plus soybean hull TMR contained 40% of a 45:55 mixture of alfalfa and corn silages (dry matter basis) and either 15% cottonseed or 15% soybeans, 8% soybean hulls, and 0.7% sodium bicarbonate. Both TMR provided 60% of dietary neutral detergent fiber from forage. The TMR, fed twice daily, were isonitrogenous (17.5% crude protein) and equal in neutral detergent fiber (30%). The TMR had no effect on dry matter intake (24.8 kg/d). The cottonseed TMR stimulated greater rumination and total chewing activity. Although milk production was greater for cows fed the cottonseed TMR (35.7 vs. 34.1 kg/d), milk fat production was unaffected by TMR (3.72%). The efficiency of 4% FCM production was similar for cows fed the cottonseed and soybean plus soybean hull TMR (1.33), and both TMR resulted in a positive net energy balance (10.9 Mcal/d). A combination of soybeans, soybean hulls, and sodium bicarbonate was an effective alternative to whole cottonseed as measured by the efficiency of FCM production.
(**Key words**: cottonseed, soybeans, soybean hulls)

Abbreviation key: **EE** = ether extract, **SB** = whole raw soybeans, **SH** = soybean hulls, **WCS** = whole linted cottonseed.

INTRODUCTION

Recently, Clark and Armentano (5) demonstrated that the effectiveness of NDF from whole linted cottonseed (**WCS**) was equivalent to that from alfalfa haylage, and WCS appeared to be an excellent source of effective fiber for maintaining milk fat percentage when substituted for dietary alfalfa. Whole cottonseed also contains approximately 20% ether extract (**EE**) and thus is an excellent source of supplemental fat to increase energy density of the diet of high producing dairy cows (13).

Whole raw soybeans (**SB**) contain nearly the same concentration of EE as does WCS (19 to 20%, DM basis), but SB contain very little NDF (<14%, DM basis). When fed in combination with the proper amount and particle size of forage NDF to prevent reduced DMI, SB are an acceptable source of fat for high producing dairy cows (10). In addition, diets with ≤19% SB have been fed to lactating dairy cows with no negative effect on milk production (11). Soybeans are typically the most economical fat source in Nebraska and other areas of the midwestern US where SB are grown (17).

Whole raw soybeans contain much less NDF than does WCS (14% vs. 45% NDF, DM basis). A coproduct of SB processing, soybean hulls (**SH**), contains 70% NDF, and, when fed with SB, the combination might create a feed mixture that provides concentrations of EE and NDF that are equivalent to those in WCS. However, the roughage value of SH is only 35% that of alfalfa or corn silages (12). Allshouse et al. (1) observed a 75% reduction in rumination time of Jersey steers fed SH versus hay. To compensate for reduced salivary buffering caused by fibrous coproducts, Firkins and Eastridge (9) evaluated the use of sodium bicarbonate in diets containing high SH in place of forage. However, the relative effectiveness of a combination of SB, SH, and sodium bicarbonate compared with WCS as a dietary source of fiber and supplemental fat has not been investigated. The objective of this study was to test whether a combination of SB, SH, and sodium bicarbonate that was added to compensate for decreased rumination would be an effective replacement for WCS as measured by milk fat percentage and production and by efficiency of 4% FCM production.

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MATERIALS AND METHODS

Cows and Treatments

Twenty-six Holstein cows (14 multiparous; 35 ± 12 d of lactation) were grouped by age and were assigned randomly to one of two experimental TMR following a 2-wk feeding period during which all cows were fed a common TMR. Each experimental TMR was fed to 7 multiparous cows and 6 primiparous cows. The 2nd wk of the covariable period was used to collect data on milk production and composition for subsequent covariable analyses. The covariable TMR contained 50% of the same forage mixture as did the experimental TMR but did not contain WCS, SB, or SH. Dietary treatments (Table 1) were 1) a WCS TMR that contained 40% of a 44:56 mixture of alfalfa and corn silages (DM basis) plus 15% WCS with 60% of dietary NDF from forage and 2) a TMR that contained 40% silage, 15% SB, 8% ground SH, and 0.7% sodium bicarbonate with 60% of dietary NDF from forage. The SB plus SH TMR resulted in concentrations of CP, EE, and NDF that were approximately equal to those of the WCS TMR. Sodium bicarbonate was added to compensate for the reduced chewing activity and subsequent saliva secretion expected for cows fed the SB plus SH TMR.

The experimental period lasted 15 wk. The TMR were fed once daily individually in amounts to ensure 10% orts. Amounts offered and orts were recorded daily. Body weight was measured weekly immediately after the a.m. milking. Cows were removed twice daily from the tie-stall barn for milking, estrus detection, and exercise in a dirt lot for a total of 4 to 5 h. Sand was used as bedding material to prevent consumption of any roughage that was not included in the TMR.

TABLE 1. Dietary ingredients and nutrient composition of experimental TMR.

Composition	WCS[1]	SB plus SH[2]
	(% of DM)	
Ingredient		
Alfalfa silage	17.5	17.5
Corn silage	22.5	22.5
Whole cottonseeds[3]	15.0	...
Whole raw soybeans[4]	...	15.0
Soybean hulls[5]	...	8.0
Sodium bicarbonate	...	0.7
Shelled corn	31.0	30.0
Soybean meal (44% CP)	10.6	2.9
Blood meal	0.6	1.4
Mineral and vitamin mix[6]	2.8	2.0
Nutrient		
DM, %	70.9	70.7
NDF	30.0	30.3
CP	17.6	17.3
RUP	6.5	5.8
NFC[7]	40.3	40.2
EE[8]	5.9	5.8
NDF From roughage, % of NDF	60.0	60.0
NE_L,[9] Mcal/kg of DM	1.76	1.76

[1]Whole linted cottonseed.

[2]Whole raw soybeans plus soybean hulls.

[3]Contained 23.0% CP, 20.0% EE, and 45.0% NDF (DM basis).

[4]Contained 42.0% CP, 19.5% EE, and 12.0% NDF (DM basis).

[5]Contained 11.3% CP, 2.0% EE, and 70.3% NDF (DM basis).

[6]Minerals and vitamins were formulated to meet or slightly exceed the requirements of the NRC (15); both TMR contained 0.95% Ca and 0.35% Mg (DM basis) as calculated from NRC (15) values.

[7]Nonfiber carbohydrate calculated from NRC (15) values.

[8]Ether extract.

[9]Calculated from NRC (15) values.

Sample Collection and Analysis

Samples of forages and TMR were composited weekly for analyses. Composited samples were oven-dried (60°C), ground through a Wiley mill (1-mm screen; Arthur H. Thomas Co., Philadelphia, PA), and analyzed for CP (2), amylase-modified NDF (22), and EE (2). The RUP and NE_L were calculated using NRC (15) values. A vertically oscillating sieve shaker (W. S. Tyler, Inc., Mentor, OH) was used to determine particle distributions of dried silages that were collected weekly. Geometric means of particle sizes were calculated (23).

Daily milk production was recorded electronically. Composite a.m. and p.m. milk samples were collected weekly and analyzed for fat, protein, and lactose percentages (Milko-Scan Fossomatic; Foss Food Technology Corp., Eden Prairie, MN). Calculation of milk composition was weighted according to a.m. and p.m. milk production.

Daily energy balance (megacalories per day) was calculated weekly as follows: NE_L intake – net energy required for maintenance – energy secreted in milk. Intake of NE_L was calculated as mean daily DMI multiplied by dietary NE_L concentration. Net energy for daily maintenance was calculated as 80 × kilograms of $BW^{0.75}/1000$ (15). Daily megacalories of milk energy were calculated according to the formula of Tyrrell and Reid (21): milk production (kilograms) × [92.239857 (percentage of milk fat) + 49.140211 (percentage of SNF) – 56.393297]/1000, where milk production was the mean daily production by week, and milk composition was based on weighted means of a.m. and p.m. samples. Energy balance was expressed as megacalories of NE_L per day for each week.

Total chewing, eating, and ruminating times were recorded during wk 5 and 10 of the experiment. The chewing action of individual cows was observed and recorded every 5 min during 24 h. Although not an absolute measurement, this method of scan sampling yielded reliable estimates because of the short interval between observations (24). Rumination activity (minutes per kilogram of NDF intake) was calculated.

Statistical Analysis

Data for milk production and composition were analyzed using analysis of covariance (16). Composite means for the entire 15-wk experimental period for each cow were adjusted by covariable analyses using the mean response during the last week of the 2-wk covariable period. Intake, BW, and chewing activity were analyzed using ANOVA (16). Differences among treatment means for significant main effects were determined using the Student-Newman-Keuls multiple range test (16). Significance was declared at $P < 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

TMR Composition

Both TMR were formulated to contain a 45:55 mixture of alfalfa and corn silages (DM basis), because Smith et al. (19) showed that replacing 25 to 50% of dietary corn silage DM with alfalfa overcame reductions in milk production or milk fat percentage caused by the inclusion of WCS in diets containing corn silage. Blood meal was added to all TMR to meet the minimum recommendations for RUP (15). Addition of 15% WCS or SB resulted in a dietary EE concentration of 5.8% (DM basis).

Both TMR contained approximately 30% NDF (DM basis). However, the NRC (15) recommends that 75% of dietary NDF come from forage. This recommendation recognizes the importance of adequate particle size as a component of the fiber requirement for lactating dairy cows. In contrast, the WCS and SB plus SH TMR contained only 60% of dietary NDF from silage, which theoretically could result in fiber deficiency symptoms, such as reduced rumination or milk fat percentage. The geometric mean particle size (± logarithmic SD) of both TMR was 1.46 (±0.06 mm). Therefore, a TMR that contained less NDF from forage than the NRC (15) recommendations (75%) could be used to test our hypothesis that a combination of SB, SH, and sodium bicarbonate could effectively replace WCS as measured by indexes that reflect adequacy of dietary NDF, such as milk fat production and efficiency of FCM production.

The SB plus SH TMR contained 15% SB, 8% SH, and 0.7% sodium bicarbonate (DM basis) to compensate for the expected reduction in rumination activity for cows fed this TMR. Using the roughage values that were given for our dietary ingredients by Mertens (12) and Sudweeks et al. (20), which were expressed as minutes of total chewing time per kilogram of DMI, we calculated that the WCS TMR would result in approximately 85 min/d more chewing activity than the SB plus SH TMR. This difference in chewing activity would result in approximately 23.5 L less saliva produced daily by cows fed the SB plus SH TMR (4). At an average salivary composition of 6000 mg/L of bicarbonate (3), approximately 140 g/d less bicarbonate would be available for ruminal buffering to cows fed the SB plus SH TMR. To compensate for this reduction, we added 0.7% sodium bicarbonate to the TMR and assumed cows would consume at least 20 kg/d of the TMR.

Nutrient Intake and Performance

The TMR had no effect on DM, CP, NDF, or EE intake (Table 2). Milk production was greatest for cows fed the WCS TMR (Table 3). After wk 2, milk production was consistently higher for cows fed the WCS TMR than for cows fed the SB plus SH TMR (Figure 1). However, milk fat percentage and production were unaffected by TMR. Similarly, milk protein and lactose percentages were unaffected by TMR, and daily production of milk protein and lactose reflected daily milk production (Table 3) and were unaffected

TABLE 2. Intake of DM components as influenced by TMR.

Intake	WCS[1]	SB plus SH[2]	SE
DM			
kg/d	24.9	24.7	0.1
% of BW	4.59	4.46	0.09
CP			
kg/d	4.4	4.3	<0.1
% of BW	0.80	0.78	0.01
NDF			
kg/d	7.5	7.4	<0.1
% of BW	1.37	1.34	0.02
EE[3]			
kg/d	1.46	1.43	0.02
% of BW	0.26	0.25	<0.01

[1]Whole linted cottonseed.

[2]Whole raw soybeans plus soybean hulls.

[3]Ether extract.

TABLE 3. Performance of dairy cows as influenced by TMR.

Item	WCS[1]	SB plus SH[2]	SE
Milk, kg/d	35.7[a]	34.1[b]	0.6
Milk fat			
%	3.69	3.75	0.04
kg/d	1.29	1.27	0.01
Milk protein			
%	3.09	3.15	0.04
kg/d	1.09	1.06	0.02
Milk lactose			
%	4.93	4.95	0.01
kg/d	1.72	1.67	0.04
4% FCM, kg/d	33.4	32.6	0.6
4% FCM/DMI, kg/kg	1.34	1.32	0.01
BW, kg	545	556	7
NEB,[3] Mcal/d	11.2	10.7	0.4

[a,b]Means within a row with no common superscripts differ ($P < 0.05$).

[1]Whole linted cottonseed.

[2]Whole raw soybeans plus soybean hulls.

[3]Net energy balance.

by TMR. Although milk production was greatest for cows fed the WCS TMR, production of 4% FCM and efficiency of FCM production (FCM/DMI) were similar for the WCS and SB plus SH TMR. Mean BW throughout the experiment and NE balance were not affected by TMR (Table 3).

The usefulness of WCS and SB as sources of dietary fat has been examined (6, 10, 13), but the effectiveness of these oilseeds in maintaining normal rumination activity and milk fat production is unclear. Research comparing diets with and without WCS and SB has shown increased milk production (6) or milk fat percentage (6, 10) when diets containing these oilseeds were fed, but results have been inconsistent (10). Sklan et al. (18) found that WCS stimulated milk fat and FCM production specifically when fed with low forage diets containing approximately 40% silage (32.7% wheat silage and 6.7% vetch hay, DM basis), as in our study. In contrast, Mohamed et al. (13) fed 55% forage diets containing either 20% WCS or 20% SB and observed no increase in milk production, relative to the control diet, even though the oilseed diets contained 4.3% more NE_L than did the control diet. More recent research (7, 8) suggests that WCS fed at 20% or more of ration DM may reduce milk production and protein percentage.

Chewing Activity

The primary objective of this research was to test the relative effectiveness of a combination of SB, SH, and sodium bicarbonate as a dietary replacement for WCS. Previous research (14) has shown that the inclusion of dietary SH minimized the effect of high concentrations of dietary starch that depressed milk fat percentage. However, SH had relatively little ability to stimulate chewing activity (1). In contrast, WCS was as effective as alfalfa haylage at maintaining normal milk fat and rumination activity when cows were fed low forage diets (5). The research model that was developed by Clark and Armentano (5) used 21-d periods to measure the effectiveness of WCS in maintaining rumination and normal milk fat percentage relative to a control diet with low and high concentrations of forage fiber.

In the present study, there was no significant difference ($P > 0.10$) in chewing activity between wk 5 and 10 of the experiment and no significant treatment × week interaction ($P > 0.10$); therefore, the data for each week were combined (Table 4). Eating activity was significantly greater for cows fed the SB plus SH TMR than for cows fed the WCS TMR (Table 4). However, the WCS TMR promoted the greatest rumination activity. As judged by rumination activity and total chewing time, the SB plus SH TMR did not effectively replace the WCS TMR. Whether rumination activity or total chewing activity is the most appropriate measure of fiber effectiveness is still debatable (12). Interestingly, the WCS TMR resulted in rumination activity that was 39% greater than that for the SB plus SH TMR, but the WCS TMR was only 17% greater in total chewing time.

The actual difference in total chewing times between the WCS and SB plus SH TMR was 137 min/d. We had predicted a difference of only 83 min, but the higher than predicted DMI (Table 2) allowed for greater intake of sodium bicarbonate for cows fed the

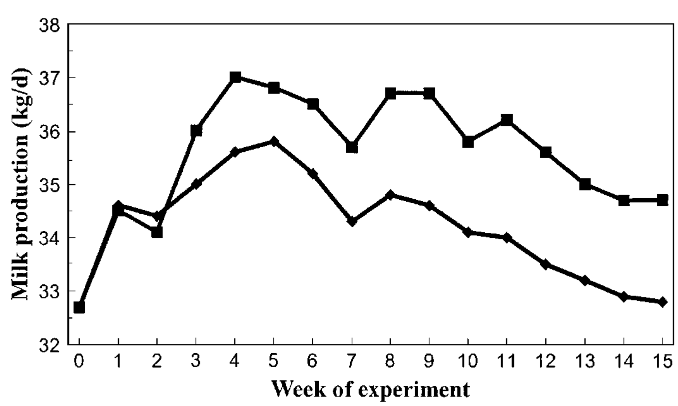

Figure 1. Milk production by week of experiment for cows fed TMR containing whole linted cottonseed (WCS; ■) or whole raw soybeans plus soybean hulls (SB plus SH; ♦). After wk 2, the WCS TMR consistently outperformed the and SB plus SH TMR. Pooled standard error for all treatments was 0.60 kg/d.

TABLE 4. Chewing activity as influenced by TMR.

Activity	WCS[1]	SB plus SH[2]	SE
Eating			
min/24 h	219[b]	268[a]	12
min/kg of NDF Intake	29[b]	36[a]	2
Ruminating			
min/24 h	638[a]	451[b]	13
min/kg of NDF Intake	85[a]	61[b]	9
Total chewing			
min/24 h	856[a]	719[b]	49
min/kg of NDF Intake	114[a]	97[b]	6

[a,b]Means within a row with no common superscripts differ ($P < 0.05$).

[1]Whole linted cottonseed.

[2]Whole raw soybeans plus soybean hulls.

SB plus SH TMR, which apparently compensated for the expected decline in saliva production. Data on milk fat percentage, milk fat production, and efficiency of FCM production support this conclusion.

CONCLUSIONS

As measured by milk fat percentage, 4% FCM production, and efficiency of FCM production, the SB, SH, and sodium bicarbonate combination effectively replaced dietary WCS. However, rumination activity and milk production were less for cows fed the SB plus SH TMR than for cows fed the WCS TMR. When fed as a component of a 40% forage diet, an economical combination of SB, SH, and sodium bicarbonate was an effective alternative to WCS as a dietary source of fiber and lipid for lactating dairy cows.

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