Performance of Lactating Dairy Cows Fed Whole Cottonseed Coated with Gelatinized Cornstarch[1]

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ABSTRACT

The handling characteristics of whole cottonseed are improved by coating with gelatinized cornstarch, but limited information is available on the effects of feeding the coated cottonseed to lactating dairy cows. Thirty-six lactating Jersey cows were used in a crossover design trial with 4-wk experimental periods to evaluate the influence of coating whole cottonseed with 2.5% gelatinized cornstarch on dry matter intake, milk yield, and composition. Cows were fed diets containing 10.2% alfalfa-orchardgrass hay, 45.2% corn silage, 15.0% coated or uncoated whole cottonseed, and 29.6% concentrate for ad libitum consumption. Coating whole cottonseed with gelatinized cornstarch tended to reduce dry matter intake, which averaged 16.2 and 15.9 kg/d for uncoated and coated cottonseed, respectively. Milk yield and composition were similar for uncoated and coated cottonseed. The yield of energy-corrected milk per unit of dry matter consumed was greater with coated cottonseed. Cows fed coated cottonseed gained body weight, but cows fed uncoated cottonseed lost weight. Concentrations of plasma urea were similar among treatments; however, NEFA concentrations were lower for cows fed coated whole cottonseed. Results of this trial indicate that coating whole cottonseed with 2.5% gelatinized cornstarch does not alter its feeding value for lactating dairy cows.
(**Key words**: cottonseed, starch, milk yield)

Abbreviation key: **ECM** = energy-corrected milk, **WCS** = whole cottonseed; **WCS + 2S** = WCS coated with 2.5% gelatinized cornstarch.

INTRODUCTION

Whole cottonseed (**WCS**) is a unique feedstuff that contains high concentrations of energy and fiber and moderate concentrations of protein. The fiber provided by the lint and the hull of WCS has been shown to be a good source of effective fiber (6). It is commonly used in diets for high producing dairy cows to increase the energy density and maintain acceptable fiber concentrations (7). The high fiber concentrations are desirable for maintaining effective fiber levels in the diet, but the lint on the WCS causes handling problems in mechanized feed handling systems. Consequently, use of WCS is limited in many commercial feed mills and dairy farms.

Processing methods that have been used on WCS to improve handling characteristics include pelleting (2), extruding (3, 17, 20), or acid delinting (8). Mechanical processes that rupture the seed increase the amount of free oil in the rumen, and this has been shown to reduce ruminal fiber digestion (13, 14, 18). Acid-delinted and Pima cottonseed have lower fat digestibility and higher passage rates of intact seed (8, 21) compared with WCS.

Recent research has focused on coating WCS with starch to bind the lint and create a free flowing product (10, 11, 12). Results of a previous trial (4) indicated that WCS coated with 5% gelatinized cornstarch was readily consumed and supported similar levels of milk production compared with WCS, but milk fat concentrations were numerically lower. This was apparently due to a shift in the ruminal fermentation that favored higher concentrations of total VFA and propionate and reduced the acetate:propionate ratio and reduced digestibility of ADF and NDF (4). The critical cost in preparing coated WCS is energy for drying; consequently, coatings that require less water would be desirable. The objective of this trial was to evaluate the effect of coating WCS with 2.5% gelatinized cornstarch on DMI, milk production and composition, and blood metabolite concentrations.

MATERIALS AND METHODS

One load of WCS was divided into two equal batches. One batch served as a control and the second batch was coated with a solution of 2.5% gelatinized cornstarch (**WCS + 2S**) at the USDA-ARS Cotton Ginning Laboratory (Lubbock, TX) as described by

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Laird et al. (10, 11, 12). Samples were collected from each treatment after coating for grade analysis (15) by A & L Plains Agricultural Laboratory, Inc. (Lubbock, TX). Treated cottonseed was packed in tote bags and shipped by commercial carrier to the Dairy Experiment Station (Lewisburg, TN) for use in the production trial.

Thirty-six lactating Jersey cows were assigned to one of two groups by DIM, age, and pretrial energy-corrected milk yield (**ECM**). Cows averaged 160 ± 39 DIM and were producing 25.6 ± 4.6 kg of milk/d containing 5.3 ± 0.9% fat, and 3.6 ± 0.3% protein at the beginning of the trial (July 15, 1997). Treatments in the cross-over design trial were WCS or WCS + 2S. Each 4-wk experimental period consisted of 2 wk for ration adjustment; the samples were collected during the last 2 wk of the experimental period. Experimental diets were formulated to meet NRC (16) requirements based on pretrial production and contained (DM basis) 10.2% alfalfa-orchardgrass hay, 45.2% corn silage, 15.0% WCS or WCS + 2S, and 29.6% concentrate. The ingredient composition of the concentrate is given in Table 1. Cows were individually fed twice daily behind Calan doors (American Calan Inc., Northwood, NH). The amounts of feed offered and orts were recorded daily. Milk yield was recorded electronically at each milking. Milk samples were collected from two consecutive milkings each week and shipped to Tennessee DHI Lab Services (Powell, TN) for analysis of percentage of fat, protein, lactose, and solids-not-fat using a Bentley 2000 equipped with an A filter (Bentley Instrument, Chaska, MN) (1). Cows were weighed on two consecutive days at the beginning and end of each period. The change in BW was calculated as the difference between the beginning and ending BW divided by the number of days in each period. Body condition scores (23) were assigned at the beginning and end of each period.

Samples of ingredients, diets, and orts were collected daily, and DM was content determined by drying in a forced-air oven at 55°C for 48 h. During each collection period, ingredient samples were composited by week and ground to pass through a 1-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Composite samples were shipped to a commercial laboratory (Cumberland Valley Analytical Services, Maugansville, MD) for analysis of DM, CP, ash, minerals, ether extract, ADF (1), and NDF (9, without sodium sulfite). Whole blood samples were collected by venipuncture 4 h after the a.m. milking into tubes containing sodium heparin during wk 4 of each period. Plasma was harvested by centrifugation at 3,000 × g for 15 min and frozen. Samples were analyzed for concentrations of plasma urea nitrogen (kit number 535; Sigma Chemical Co., St. Louis, MO) and NEFA (NEFA-C kit; Wako Chemical USA, Inc., Richmond, VA).

Analysis of variance was conducted using SAS (19). Sums of squares were partitioned to cow, period, treatment, and block × treatment. Significance was declared at $P < 0.05$.

TABLE 1. Composition of experimental concentrate.

Ingredient	% of DM
Ground corn	38.35
Wheat middlings	15.85
Soybean meal, 48% CP	24.72
Molasses, dehydrated	3.72
Blood meal	2.54
Fish meal, Menhaden	2.54
Urea, 45% N	1.11
Limestone	5.29
Sodium bicarbonate	2.38
Dicalcium phosphate	1.27
Dynamate®,[1]	0.79
Salt, white	0.55
Trace mineral-vitamin premix[2]	0.40
Magnesium oxide	0.32
Zinpro-40®,[3]	0.08

[1]IMC-Agrico Co. (Bannockburn, IL).

[2]Premix provided 44,092 ppm of Fe; 20,944 ppm of Cu; 441 ppm of Co; 66,139 ppm of Mn; 71,650 ppm of Zn; 728 ppm of I; 178.5 ppm of Se; 1,451,496 IU/kg of Vitamin A; 430,912 IU/kg of vitamin D; and 2,744 IU/kg of vitamin E.

[3]ZinPro Corp. (Eden Prairie, MN).

TABLE 2. Grade certificate analysis of whole cottonseed (WCS) and WCS coated with 2.5% gelatinized corn starch (WCS + 2S).

Item	WCS		WCS + 2S	
	$\bar{X}$	SD	$\bar{X}$	SD
Moisture, %	8.0	0.6	9.6	0.7
Total foreign matter, %	0.9	0.2	0.6	0.2
Free fatty acids in oil, % of DM	2.2	0.5	2.8	0.7
Oil,[1] % of DM	19.3	0.7	19.2	0.9
Ammonia, % of DM	4.4	0.1	4.3	0.1
Crude protein,[2] % of DM	22.5	0.4	21.9	0.7
Grade[3]	99.1	3.6	94.7	5.0

[1]Oil content was determined using petroleum ether (15).

[2]Crude protein was calculated from ammonia (% ammonia × 5.14).

[3]Cottonseed grade was calculated according to the trading rules of the National Cottonseed Products Association (15). The calculation considers both quantitative (oil and ammonia) and qualitative factors (moisture, foreign matter, and free fatty acids in oil).

TABLE 3. Chemical analysis of dietary components.[1]

Item	WCS[2]		WCS + 2S		Alfalfa-orchardgrass hay		Corn silage		Concentrate	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
	(% of DM)									
CP	17.1	1.1	18.5	4.9	13.9	0.9	8.3	0.3	28.2	0.7
ADF	54.8	0.7	51.8	1.2	36.9	1.1	21.9	2.0	5.0	0.7
NDF	66.6	0.6	64.7	0.8	63.5	0.2	41.0	2.1	15.8	0.6
EE[3]	14.3	1.2	15.5	0.8	2.9	0.2	3.7	0.1	2.5	0.2
Ash	3.5	0.3	3.5	0.2	9.8	0.3	3.8	0.1	13.4	1.2
Ca	0.12	0.02	0.12	0.00	0.66	0.04	0.34	0.03	2.71	0.28
P	0.39	0.04	0.44	0.03	0.43	0.01	0.29	0.03	0.77	0.04
Mg	0.30	0.02	0.32	0.01	0.21	0.01	0.14	0.01	0.47	0.02
	1.47	0.82	1.68	0.53	3.04	0.09	0.94	0.06	1.81	0.93

[1]Average of four composite samples (2 samples per period).

[2]WCS = whole fuzzy cottonseed; WCS + 2S = WCS coated with 2.5% gelatinized corn starch.

[3]Ether extract.

RESULTS AND DISCUSSION

Chemical Analyses

The cottonseed grade analysis is presented in Table 2. Cottonseed in this trial had smaller amounts of foreign matter, higher concentrations of free fatty acids in oil, and lower total oil (extracted with petroleum ether) concentrations than the cottonseed used in the previous trial (4). The values obtained for protein and oil are in good agreement with those reported for whole cottonseed by Calhoun et al. (5). The chemical analysis (Table 3) of WCS and WCS + 2S were similar, but concentrations of ether extract and CP were lower than that observed from the grade analysis. Similar differences were observed in our previous trial (4) and reflect the difficulty in analyzing cottonseed.

Chemical analysis of alfalfa-orchardgrass hay, corn silage, and concentrate is also presented in Table 3. Experimental diets contained similar concentrations of nutrients (Table 4). Concentrations of CP were higher than planned due to higher concentrations of CP in alfalfa-orchardgrass hay compared with preliminary chemical analysis.

Milk Yield and Composition

The DMI of cows fed WCS tended to be greater ($P < 0.10$) than with WCS + 2S (Table 5). In our previous trial (4), cows fed the coated WCS consumed approximately 1 kg of DM/d more than cows fed WCS, but this difference was not significant. The results of this trial and our previous trial (4) show that coating WCS with gelatinized cornstarch does not alter the palatability of WCS.

Milk yield and concentration and yield of milk components were similar for both cottonseed products (Table 5). Feeding WCS coated with 5% gelatinized cornstarch and 10% maltodextrin sugar depressed the percentage of milk fat in our previous trial (4), presumably because of changes in ruminal fermentation, which favored greater production of VFA, especially propionate, and L-lactate. The percentage of milk fat was numerically, but not significantly lower,

TABLE 4. Calculated nutrient composition of experimental diets containing whole cottonseed (WCS) or WCS coated with 2.5% gelatinized corn starch (WCS + 2S).

Item	Experimental diets	
	WCS	WCS + 2S
	(% of DM)	
CP	16.1	16.3
ADF	23.4	22.9
NDF	39.7	39.4
Fat	4.9	5.0
Ash	7.2	7.2
NFC[1]	32.1	32.1
Ca	1.04	1.04
P	0.46	0.47
Mg	0.27	0.27
K	1.49	1.52
	(mg/kg of DM)	
Fe	312	313
Mn	101	100
Zn	96	95
Cu	23	23
	(Mcal/kg)	
NE_L[2]	1.72	1.72

[1]Nonfibrous carbohydrate = (100 – (CP + NDF + Fat + Ash)).

[2]Calculated using NRC NE_L values (16).

TABLE 5. Production response of lactating Jersey cows fed diets containing whole fuzzy cottonseed (WCS) or WCS coated with 2.5% gelatinized corn starch (WCS + 2S).

	Experimental diet			
Item	WCS	WCS + 2S	SE	*P*
DMI, kg/d	16.2	15.9	0.1	0.08
Milk, kg/d	19.3	19.4	0.1	0.67
Fat, %	4.62	4.70	0.05	0.31
Fat, kg/d	1.00	1.02	0.01	0.30
Protein, %	3.66	3.65	0.02	0.62
Protein, kg/d	0.79	0.78	0.00	0.61
Lactose, %	4.36	4.34	0.03	0.56
Lactose, kg/d	0.94	0.93	0.00	0.58
SNF, %	8.73	8.66	0.05	0.37
SNF, kg/d	1.88	1.87	0.01	0.38
ECM,[1] kg/d	24.6	24.9	0.2	0.34
ECM/DMI, kg/kg	1.52	1.57	0.01	0.04
BW, kg	412.5	417.2	1.3	0.02
Change in BW, kg/d	–0.27	0.15	0.09	0.01
BCS[2]	3.46	3.43	0.01	0.15

[1]Energy-corrected milk (22).

[2]Body condition score based on five-point scale where 1 = thin to 5 = fat (23).

in the previous trial (4) when WCS coated with 5% gelatinized cornstarch was fed. Coating WCS with 5% gelatinized cornstarch increased the total dietary starch content by <1%. However, reducing the amount of starch in the coating to 2.5% appears to have alleviated any potential for milk fat depression (Table 5).

The production of ECM per unit of DMI was highest ($P < 0.05$) when cows were fed WCS + 2S. The BW of cows on WCS + 2S was higher ($P < 0.02$) than cows on WCS. Cows consuming WCS lost ($P < 0.01$) BW compared with cows consuming WCS + 2S. Body condition score was not different among treatments and averaged 3.44. The small differences in ECM/DMI and BW gain with WCS + 2S suggest that energy utilization was improved, but data are not available to confirm this.

Plasma Metabolites

Concentrations of urea were similar for WCS (20.6 mg/dl) and WCS + 2S (20.7 mg/dl), respectively. However, NEFA concentrations were lower ($P < 0.05$) with WCS + 2S (239.3 μEq/ml) compared with WCS (272.1 μEq/ml). The differences in plasma NEFA concentrations reflect changes in BW. In our previous trial (4), the concentrations of NEFA were lower when WCS coated with 5% gelatinized cornstarch plus 10% maltodextrin sugar was fed, but were unchanged when WCS was coated with 5% gelatinized cornstarch.

CONCLUSIONS

Coating WCS with 2.5% gelatinized cornstarch to improve their handling characteristics does not alter their feeding value for lactating dairy cows. The coated cottonseed are readily consumed and support equal levels of milk production containing similar concentrations of components. Feeding WCS + 2S starch resulted in small improvements in energy balance based on the greater yield of ECM per unit of DMI, positive BW gains, and decreased NEFA concentrations. Additional research is needed to measure the long-term effects of feeding coated WCS on ruminal fermentation and energy balance.

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