FEEDING VALUE OF WHOLE FUZZY COTTONSEED WITH ELEVATED CONCENTRATIONS OF FREE FATTY ACIDS

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Introduction

Several criteria are used for determining the acceptability of whole cottonseed (WCS) for crushing including concentrations of moisture, oil, free fatty acids in the oil (FFA), and ammonia. Whole cottonseed that does not meet the minimum standard is typically sold as a feed ingredient. When tropical storms delay cotton harvest and the moisture remains elevated, concentrations of FFA increase. Feeding supplemental fats with elevated concentrations of FFA to cattle has been reported to reduce dry matter intake (DMI), alter ruminal fermentation, fiber digestibility, and milk fatty acid concentrations.

Previous research at the University of Georgia has shown that feeding whole cottonseed (WCS) with up to 12% free fatty acids in the oil (FFA) does not negatively impact nutrient intake, milk yield or composition although minor changes in the fatty acid composition of milk were observed (Sullivan, 2002). When cannulated Holstein steers were fed similar diets containing WCS with up to 18% FFA, minor changes in ruminal fermentation occurred resulting in a slight increase in molar proportions of propionate and a corresponding decrease in acetate (Sullivan, 2002). The results of these trials indicate that feeding WCS with up to 18% FFA does not alter intake or performance of lactating dairy cattle, but the effects of feeding WCS with even higher concentrations of FFA have not been examined. These trials were conducted to determine the effects of feeding diets containing whole cottonseed varying in concentrations of FFA on DMI, milk yield, milk composition, ruminal fermentation, and blood metabolites.

Materials and Methods

Production Trial. Twenty-four lactating Holstein cows were used in an 8 wk randomized block trial at the Dairy Research Center in Tifton, GA. Treatments included a control WCS with normal concentrations of FFA and two lots of WCS with elevated FFA; HFFA1 and HFFA2. The HFFA1 averaged 24% FFA and look normal whereas HFFA2 averaged 22% FFA and were visibly discolored. Cows were trained to eat behind Calan doors and individually fed. All cows received the control diet (Table 1) for the first two weeks which was used as a standardization period. At the end of the standardization period, cows were assigned randomly to one of the three treatments outlined. Amount of feed offered and refused were recorded daily. Milk yield was recorded at each milking (2X). Milk samples were collected from two consecutive milkings each week for analysis of composition (Dairy Farmers of America, Knoxville, TN).

Samples of WCS and experimental diets were collected three times each week, composited, and shipped to Cumberland Valley Laboratory for chemical analysis. A sub-sample of each WCS sample was analyzed for free fatty acid in the oil.

Ruminal Fermentation Trial. Six lactating ruminally cannulated Holstein cows were used in a 6 wk replicated 3 X 3 Latin square design trial with 2 wk periods at the Dairy Research Center in Tifton, GA. Treatments were the same as in the production trial; control WCS with normal concentrations of FFA and two lots of WCS with elevated FFA; HFFA1 and HFFA2. Cows were trained to eat behind Calan doors and individually fed once daily. Amounts offered and refusals were recorded daily. Milk yield was recorded at each milking (2X). Milk samples were collected from two consecutive milkings each week for analysis of composition (Dairy Farmers of America, Knoxville, TN).

Approximately 200 ml of ruminal fluid samples were collected at 0, 2, 4, 6, and 8 hours post feeding during week 2 of each period. Ruminal fluid was strained through four layers of cheesecloth and two 50 ml samples collected. One 50 ml sample was immediately frozen for analysis of pH and ammonia while the second 50 ml sample was prepared by mixing 50 ml of ruminal fluid with 5 ml of 25% metaphosphoric acid to be used for VFA analysis.

At the end of each period, cows were switched to another treatment and the protocol repeated.

Results and Discussion

The FFA of the WCS averaged 6.8, 24.1, and 22.3% for control, HFFA1 and HFFA2 (Table 2). The WCS with elevated FFA tended to have higher concentrations of moisture and crude protein, but lower concentrations of oil and ADF. The experimental diets were similar in nutrient content (Table 3). Although the HFFA2 were discolored, concentrations of ADIN were similar to that of the control indicating that no heat damage had occurred.

The DMI was highest ($P = 0.06$) for cows fed the diet containing HFFA2 compared with control and HFFA1 (Table 4). No differences were observed among treatments in yield of milk, fat, protein, lactose, or SNF, ECM or efficiency of milk production. Milk fat percent was lower ($P = 0.007$) for diets containing WCS with elevated FFA. The decline in milk fat percentage is in contrast to previous research in which milk fat percent was similar for cows fed diets containing 12.5% WCS with concentration of FFA up to 12% (Sullivan, 2002). Typically reduced milk fat concentrations are associated with altered ruminal fermentation and reduced fiber digestion (Coppock and Wilks, 1991). While molar proportions of butyrate and isobutyrate were higher for HFFA1 and HFFA2 compared with control cottonseed ($P = 0.08$ and $P = 0.0004$, respectively), no differences were observed in concentrations of acetate or propionate. One reason for decreased milk fat percentages is a shift in VFA production from acetate to propionate. The fatty acid profile of the oil in WCS with 3 and 12% FFA was similar in our previous research (Sullivan, 2002), so reduced milk fat percent is not likely related to changes in dietary fatty acids that would alter transfer of fatty acids into the mammary gland. The FFA content of WCS used in this trial was higher than that used previously. The higher FFA did not limit total protein or energy availability in support of milk and milk protein synthesis.

No differences were observed in concentrations of MUN although values were numerically higher (*P* = 0.15) for diets containing WCS with elevated FFA. This suggests that a greater proportion of the protein in WCS with elevated FFA was degraded or that the amino acid profile absorbed from the small intestine was less desirable resulting in greater deamination of amino acids. This is consistent with the observations from our previous research in which Holstein steers fed diets containing WCS with 18% FFA had greater amounts of dietary protein passing to the duodenum and less microbial protein (Sullivan, 2002).

Results of this trial indicate that feeding WCS with high concentrations of FFA may slightly increase DMI but does not alter milk yield. The reduced concentration and yield of milk fat was not due to any change in ruminal fermentation, but may be a direct effect of specific fatty acids on milk fat synthesis when cows are fed WCS with high concentrations of FFA. The increase in MUN concentrations suggests greater degradation of protein provided by WCS or greater deamination of absorbed amino acids due to an imbalance in absorbed amino acids. However, these potential changes in fiber and protein digestion do not negatively impact intake or milk yield.

References

Coppock, C. E., and D. L. Wilks. 1991. Supplemental fat in high-energy rations for lactating cows: Effects on intake, digestion, milk yield, and composition. J. Anim. Sci. 69:3826-3837.

Sullivan, H. M. 2002. Effect of high free fatty acid cottonseed on production in Holstein cattle. Ph.D.Diss., Univ Georgia, Athens.

Table 1. Ingredient composition of experimental diets.

Ingredient	% of DM
Corn silage	39.87
Alfalfa hay	5.48
Wet brewers grains	12.38
Steam-flaked corn	12.96
Whole cottonseed	13.96
Concentrate[1]	15.35

[1]Concentrate contained (DM basis) 52.8% soybean meal, 48% CP; 13.2% calcium salts of long chain fatty acids; 13.2% Prolak (H. J. Baker & Bro., Inc., Stamford, CT); 4.8% limestone; 2.6% dicalcium phosphate; 1.1% magnesium oxide; 1.8% salt; 4.0% sodium bicarbonate; 0.8% potassium-magnesium-sulfate; 1.6 % yeast culture; and 1.6% trace mineral-vitamin premix.

Table 2. Composition of whole cottonseed (WCS) differing in concentrations of free fatty acids in the oil (FFA)[1].

Item	Control	HFFA1[2]	HFFA2[2]
Moisture, %	9.4 ± 0.4	10.6 ± 0.5	11.9 ± 0.7
Oil, %	18.4 ± 0.6	17.1 ± 0.3	15.9 ± 0.8
FFA, % of oil	6.8 ± 1.0	24.1 ±2.0	22.3 ± 3.9
Protein, %	19.6 ± 0.4	20.7 ± 0.3	21.0 ± 0.4
	----------------------------	%	----------------------------
DM	90.7 ± 0.7	89.4 ± 0.4	88.6 ± 0.9
	------------------------	% of DM	------------------------
CP	20.2 ± 0.6	21.9 ± 0.4	22.5 ± 0.8
NDF	51.3 ± 2.4	50.1 ± 1.4	50.1 ± 1.9
ADF	42.1 ± 1.6	39.8 ± 0.6	39.6 ± 1.2
Ash	4.0 ± 0.4	4.2 ± 0.2	4.1 ± 0.4
NFC[3]	23.6 ± 2.8	22.3 ± 2.4	22.3 ± 2.8
Ca	0.14 ± 0.01	0.15 ± 0.01	0.15 ± 0.01
P	0.57 ± 0.03	0.56 ± 0.01	0.57 ± 0.04
Mg	0.35 ± 0.01	0.36 ± 0.01	0.37 ± 0.02
K	1.14 ± 0.04	1.14 ± 0.04	1.16 ± 0.04
	------------------------	ppm of DM	------------------------
Mn	16.8 ± 1.0	19.0 ± 0.09	17.5 ± 1.8
Zn	28.0 ± 2.8	30.8 ± 1.2	36.5 ± 2.3
Cu	5.7 ± 2.0	6.7 ± 2.3	7.7 ± 2.0

[1]All data are presented as mean ?SD.
[2]HFFA1 = WCS with elevated concentrations of FFA, but look normal; HFFA2 = CS with elevated concentrations of FFA and discolored.
[3] Nonfibrous carbohydrate

Table 3. Chemical composition of experimental diets[1].

Item	Control	HFFA1[2]	HFFA2[2]
DM, %	44.6 ± 0.8	43.9 ± 0.9	44.4 ± 0.8
	------------------------	% of DM	------------------------
CP	17.2 ± 0.6	18.8 ± 1.0	17.7 ± 1.2
NDF	32.6 ± 3.3	31.2 ± 3.3	32.1 ± 4.1
ADF	22.6 ± 2.8	21.6 ± 2.5	22.4 ± 3.1
Ash	7.1 ± 0.7	7.0 ± 1.2	6.7 ± 0.8
NFC[3]	40.1 ± 2.4	40.5 ± 3.8	40.5 ± 3.2

[1]All data are presented as mean ?SD.
[2]HFFA1 = WCS with elevated concentrations of FFA, but look normal; HFFA2 = WCS with elevated concentrations of FFA and discolored.
[3]Non-fibrous carbohydrate

Table 4. Dry matter intake, milk yield and composition of cows fed diets containing off quality cottonseed.

Item	Control	HFFA1[1]	HFFA2[1]	SE	*P*
DMI, lb/d	47.5[b]	48.4[b]	51.7[a]	1.3	0.06
Milk, lb/d	77.0	74.9	77.3	2.1	0.68
Fat, %	4.22[a]	3.64[b]	3.58[b]	0.14	0.007
Fat, lb/d	3.03	2.76	2.84	0.11	0.19
Protein, %	3.15	3.08	3.06	0.05	0.44
Protein, lb/d	2.36	2.32	2.32	0.07	0.90
Lactose, %	4.71	4.80	4.73	0.04	0.35
Lactose, lb/d	3.68	3.61	3.63	0.10	0.89
SNF	8.74	8.67	8.64	0.07	0.62
SNF, lb/d	6.70	6.54	6.61	0.18	0.82
ECM, lb/d[2]	80.4	75.9	78.5	2.2	0.36
MUN, mg/dl	8.86	11.11	9.39	0.78	0.15
Efficiency					
Milk/DMI	1.58	1.58	1.50	0.08	0.76
ECM/DMI	1.66	1.57	1.52	0.07	0.36

[ab]Means in the same row with superscripts differ ($P < 0.01$).
[1]HFFA1 = WCS with elevated concentrations of FFA, but look normal; HFFA2 = WCS with elevated concentrations of FFA and discolored.
[2]ECM= Energy corrected milk

Table 5. Effect of increasing levels of free fatty acids (FFA) in the oil of whole cottonseed (WCS) on rumen VFA concentrations

Item	Control	HFFA1[1]	HFFA2[1]	SE	*P*
pH	6.07	6.14	6.21	0.06	0.28
Ammonia, mg/dl	28.84	25.54	26.54	1.75	0.40
Total VFA, mM	84.77	85.88	89.13	1.44	0.09
	------------------------- % Molar proportions -----------------------------				
Acetate (A)	60.51	59.82	59.56	0.50	0.38
Propionate (P)	24.82	24.96	24.62	0.50	0.89
Butyrate	10.16	10.06	10.60	0.17	0.08
Isobutyrate	0.47	0.52	1.08	0.11	0.0004
Isovalerate	2.06	2.16	2.05	0.05	0.22
Valerate	1.99	1.89	2.10	0.07	0.14
A:P	2.49	2.44	2.46	0.07	0.87

[1]HFFA1 = WCS with elevated concentrations of FFA, but look normal; HFFA2 = WCS with elevated concentrations of FFA and discolored.