Feeding Value of Cottonseed Meal for Feedlot Cattle

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ABSTRACT: One hundred twenty crossbred steers (294 kg, initially) were used in a 141-d finishing trial. Four concentrations (8, 16, 24, and 32% of diet DM) of cottonseed meal (**CSM**, prepressed solvent extracted) replaced steam-flaked corn in a corn-based finishing diet. Increasing level of CSM decreased ADG (linear component, $P < .10$), feed efficiency (linear component, $P < .01$), and dietary NE (linear component, $P < .01$). Observed dietary NE was 99% of expected at 8 and 16% CSM, but 95% of expected at higher levels of inclusion (linear component, $P < .05$). Level of CSM did not influence ($P > .10$) dressing percentage, longissimus area, fat thickness, or retail yield. Eight Holstein steers (285 kg) were used in a replicated 4 X 4 Latin square design to evaluate treatment effects on characteristics of digestion. Ruminal digestibility of OM decreased (linear component, $P < .05$) as CSM increased, although ruminal digestibility of starch and feed N were not affected ($P > .10$). Ruminal escape protein from CSM was 58%. Total tract starch digestion was not altered ($P > .10$), but total tract digestibility of OM and GE decreased (linear component, $P < .05$), and digestion of N increased (linear component, $P < .01$) as CSM replaced steam-flaked corn. The ratio of observed vs expected DE value of the diets were similar across CSM levels averaging .99. Thus, comparative DE value of CSM was not affected by level of inclusion, averaging 3.32 Mcal/kg. We conclude that the NE_m and NE_g values of CSM are 1.88 and 1.24 Mcal/kg, respectively (in close agreement with tabular values). However, CSM should not exceed 16% of DMI, as higher levels may depress cattle performance and replacement value of CSM.

Introduction

Cottonseed meal is a co-product from oil extraction of the seed kernel (after removal of the hull). Due to its high protein content (45% crude protein), the value of CSM has been largely ascribed to its value as a protein supplement. Nevertheless, availability and price can make it attractive as an energy source. Based on nutrient composition, the NEm and NEg value of CSM has been set at 1.82 and 1.19 Mcal/kg, respectively (NRC, 1984). These values have not been confirmed in growing-finishing diets for feedlot cattle. At higher rates of inclusion, questions remain about effects on diet acceptability and carcass characteristics. The objective of this study was to evaluate the influence of level of CSM supplementation on its feeding value in finishing diets for feedlot cattle.

Experimental Procedure

Trial 1. One hundred twenty crossbred steers (294 kg, initially) were blocked by weight and randomly assigned within weight group to 20 pens (six steers per pen). Pens were 43 m^2 with 22 m^2 overhead shade, automatic waterers and 2.4 m fence-line feed bunks. The trial was initiated June 22, 1995. Average daily minimum and maximum air temperature during the trial was 17.2 and 35.8°C, respectively. There was no precipitation, and average daily relative humidity was 35%. Four levels of CSM (8, 16, 24, and 32% of diet DM) were substituted for steam-flaked corn in a corn-based finishing diet (Table 1). Diets were prepared at approximately weekly intervals and stored in plywood boxes located in front of each pen. Steers had ad libitum access to their diet. Fresh feed was added twice daily. Steers were implanted with Synovex-S® (Syntex, Des Moines, IA) on d 1 and 56 of the trial. Hot carcass weights were obtained from all steers at time of slaughter. After the carcasses were chilled for 48 h, the following measurements were obtained: 1) longissimus muscle area (ribeye area), by direct grid reading of the eye muscle at the twelfth rib; 2) subcutaneous fat over the eye muscle at the twelfth rib taken at a location 3/4 the lateral length from the chine bone end; 3) kidney, pelvic and heart fat (KPH) as a percentage of carcass weight; and 4) marbling score (USDA, 1965). Energy gain (EG) was calculated by the equation: $EG = ADG^{1.095}\ .0557W^{.75}$, where EG is the daily energy deposited (Mcal/d), ADG is weight gain (kg/d) and W is the mean shrunk body weight (kg; NRC, 1984). Maintenance energy (EM) was calculated by the equation: $EM = .077\ W^{.75}$ (Lofgreen and Garrett, 1968). From the derived estimates for energy required for maintenance and gain, the NE_m and NE_g values for the diet were estimated by process of iteration to fit the relationship: $NE_g = .877NE_m + .410$ (derived from NRC, 1984). The basic language algorism for performing this iteration is given in Zinn and Plascencia (1996). For calculating steer performance, initial and final full weights were reduced 4% to account for digestive tract fill. Pens were used as experimental units. The trial was analyzed as a randomized complete block design experiment. Treatment effects were tested for linear, quadratic, and cubic components by means of orthogonal polynomials (Hicks, 1973).

Trial 2. Eight Holstein steers (285 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a replicated 4 X 4 Latin square design experiment to study treatment effects on characteristics of digestion. Treatments were the same as those used in trial 1 (Table 1), with .32% chromic oxide added as a digesta marker. Steers were maintained in individual pens with access to water at all times. Diets were fed at 0800 and 2000 daily. Dry matter intake was restricted to 2% of body weight. Experimental periods were 2 wk, with 10 d for diet adjustment and 4 d for collection. During collection, duodenal and fecal samples were taken twice daily as follows: d 1, 0750 and

1350; d 2, 0900 and 1500; d 3, 1050 and 1650, and d 4, 1200 and 1800. Upon completion of the trial, approximately 500 ml of ruminal fluid were obtained from each steer, composited across diets; bacteria were isolated via differential centrifugation (Bergen et al., 1968). The microbial isolates were prepared for analysis by oven drying at 70^{o}C and grinding with mortar and pestle. Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70^{o}C and grinding in a lab mill (Micro-Mill, Bel-Arts Products, Pequannock, NJ). Samples were oven dried at 105^{o}C until no further weight was lost and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analyses: ash, ammonia N, Kjeldahl N (AOAC, 1984); chromic oxide (Hill and Anderson, 1958); GE (adiabatic bomb calorimeter); purines (Zinn and Owens, 1986); and starch (Zinn, 1990). Microbial organic matter (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N and MN and, thus, includes any endogenous additions. This trial was analyzed as a replicated 4X4 Latin square according to the following statistical model: $Y_{ijkl}=\mu + B_i + A_{j(i)} + P_k + T_l + E_{ijkl}$, where B_i is block, $A_{j(i)}$ is steer within block, P_k is period, T_l is treatment and E_{ijkl} is residual error. Treatment effects were tested for linear, quadratic, and cubic components by means of orthogonal polynomials (Hicks, 1973).

Implications

The net energy value of prepress solvent extracted cottonseed meal is 1.88 and 1.24 megacalories per kilogram, respectively, when included at less than 16% of diet dry matter. These estimates based on feedlot cattle growth performance are in close agreement with tabular values and estimates based on nutrient composition of cottonseed meal. Cottonseed meal should not exceed 16% of the dry matter intake of growing-finishing feedlot cattle. Higher levels of cottonseed meal inclusion may depress daily weight gain, feed efficiency, and the net energy value of cottonseed meal. The lower feeding value of the diet with high levels of cottonseed meal inclusion is due largely to energetic cost of elimination of excess nitrogen.

Table 1. Composition of experimental diets (Trials 1 and 2[a])

Item	Cottonseed meal level, %			
	8	16	24	32
Ingredient composition, % (DM basis)				
Alfalfa hay	6.00	6.00	6.00	6.00
Sundangrass hay	6.00	6.00	6.00	6.00
Steam-flaked corn	65.85	57.85	49.85	41.85
Yellow grease	4.00	4.00	4.00	4.00
Molasses cane	8.00	8.00	8.00	8.00
Magnesium oxide	.15	.15	.15	.15
Cottonseed meal	8.00	16.00	24.00	32.00
Limestone	1.50	1.50	1.50	1.50
Trace mineral salt[b]	.50	.50	.50	.50
Nutrient composition (DM basis)[c]				
DE, Mcal/kg	3.97	3.91	3.87	3.82
NE, Mcal/kg				
Maintenance	2.26	2.22	2.19	2.15
Gain	1.57	1.54	1.51	1.48
Crude protein, %	11.93	14.82	17.70	20.59
Ether extract, %	7.13	6.89	6.66	6.43
ADF, %	7.88	9.16	10.44	11.72
Calcium, %	.80	.81	.83	.84
Phosphorus, %	.37	.44	.50	.57
Potassium, %	.94	1.03	1.12	1.21
Magnesium, %	.31	.34	.38	.42
Sulfur, %	.17	.18	.20	.21

[a]Chromic oxide (.4%) was added as a digesta marker in Trial 2.

[b]Trace mineral salt contained: $CoSO_4$, .068%; $CuSO_4$,1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052%; and NaCl, 92.96%.

[c]Based on tabular net energy (**NE**) values for individual

feed ingredients (**NRC**, 1984) with the exception of supplemental fat, which was assigned $\mathbf{NE_m}$ and $\mathbf{NE_g}$ values of 6.03 and 4.79, respectively.

Table 2. Composition of cottonseed meal (Trials 1 and 2)

Item	Cottonseed meal Test[a]	Cottonseed meal NRC[b]
Composition, % (DM basis)		
DM	91.2	91.0
Gossypol		
Free	.06	
Total	1.41	
Crude protein	42.4	45.2
Soluble N[c]	5.7	
Pepsin insoluble N	1.7	
ADF	16.8	17.0
Lipid	4.4	1.6
Ash	7.4	7.1
Arginine	4.14	4.51
Histidine	1.74	1.74
Isoleucine	1.25	1.56
Leucine	2.43	2.50
Lysine	2.25	1.73
Methionine	.59	.62
Phenylalanine	2.31	2.35
Threonine	1.29	1.44
Valine	2.04	2.05
DE, Mcal/kg[d]	3.51	3.53
NE, Mcal/kg[d]		
Maintenance	1.92	1.94
Gain	1.28	1.30

[a]Expander-solvent extracted cottonseed meal.
[b]Tabular values for pre press solvent extracted cottonseed

meal(NRC, 1984).

[c]Nitrogen soluble in .15 N NaCl following 6 h incubation at 39°C (Waldo and Goering, 1979).

[d]Based on chemical composition according to the following equations (adapted from NRC, 1984; Zinn and Plascencia, 1993): NE_m = .0255ADF% + .0325CP% + .0704EE% + .0340NFE% - 1.18, NE_g = .877NE_m - .41, DE = (NE_m -.661)/.736, where NFE is 100 - (ADF% + CP% + EE% + ash%).

Table 3. Influence of cottonseed meal level on growth performance of feedlot steers and net energy (NE) value of the diet (Trial 1)

	Level of cottonseed meal, %				
Item	8	16	24	32	SE
Days on test	141	141	141	141	
Pen replicates	5	5	5	5	
Live weight, kg[a]					
Initial	288.0	297.1	296.2	294.7	5.2
Final[b]	496.7	496.6	485.5	479.9	6.5
Weight gain, kg/d[b]	1.47	1.41	1.34	1.32	.05
DM intake, kg/d	7.85	7.89	8.08	8.06	.18
DM intake/gain[c]	5.38	5.60	6.03	6.13	.15
Diet net energy, Mcal/kg					
Maintenance[c]	2.24	2.20	2.07	2.04	.03
Gain[c]	1.55	1.52	1.41	1.38	.03
Observed/expected diet NE					
Maintenance[d]	.99	.99	.95	.95	.01
Gain[d]	.99	.99	.93	.94	.01

Cottonseed meal NE, Mcal/kg			
Maintenance	1.88	1.32	1.55
Gain	1.24	.75	.95

[a]Initial and final live weights reduced 4% to account for fill.
[b]Linear effect (P < .10).
[c]Linear effect (P < .01).
[d]Linear effect (P < .05).

Table 4. Influence of cottonseed meal on carcass characteristics (Trial 1)

	Level of cottonseed meal, %				
Item	8	16	24	32	SE
Carcass wt, kg[a]	312.3	315.3	306.8	302.1	4.4
Dressing percentage	62.9	63.5	63.2	63.0	.3
Longissimus area, cm^2	78.2	79.6	78.6	77.8	1.0
Fat thickness, cm	1.08	1.18	1.03	1.17	.09
KPH, %[bc]	2.32	2.35	2.18	2.38	.06
Marbling score, degree[de]	3.66	3.84	3.46	3.62	.10
Retail yield, %	50.4	50.3	50.7	50.3	.3
Liver abscess, %	16.7	30.0	25.3	20.0	8.4

[a]Linear effect (P < .10).
[b]Kidney, pelvic, and heart fat as a percentage of carcass weight.
[c]Cubic effect (P < .10).
[d]Cubic effect (P < .05).
[e]Coded: minimum slight = 3, minimum small = 4, etc.

Table 5. Influence of cottonseed meal on characteristics of ruminal and total tract digestion in steers (Trial 2)

	Level of cottonseed meal, %				
Item	8	16	24	32	SE
Steer weight, kg	285	285	285	285	
Animal replicates	8	8	8	8	
Intake, g/d					
DM	5589	5593	5612	5623	
OM	5237	5224	5229	5227	
N	104	128	148	173	
Starch	2593	2374	2031	1836	
GE, Mcal/kg	25.2	25.2	25.3	25.4	
Flow to the duodenum, g/d					

OM[a]	2886	3132	3306	3291	106
Starch[a]	475	446	401	309	43
Nonammonia N[bc]	126.3	149.9	157.1	163.4	4.3
Microbial N	65.9	69.5	70.4	69.6	2.9
Feed N[b]	60.4	80.4	86.7	93.8	3.7
Ruminal digestion, %					
OM[a]	57.0	53.4	51.1	50.9	1.7
Feed N	42.4	38.0	42.3	46.3	2.7
Starch	81.6	81.6	80.9	83.6	1.9
MN efficiency[ad]	22.1	26.2	28.4	28.1	1.8
N efficiency[be]	1.20	1.16	1.05	.94	.03
Fecal excretion, g/d					
OM[b]	1107	1229	1311	1312	37
N[b]	38.9	44.7	49.3	52.0	1.4
Starch[f]	39.0	26.0	25.5	17.5	7.3
GE, Mcal/d[b]	6.33	6.64	7.26	7.30	.24
Postruminal digestion, %					
OM	61.5	60.4	59.3	58.7	1.3
N	70.0	71.2	69.9	69.4	.64
Starch	92.3	93.2	91.8	91.8	1.69
Total-tract digestion, %					
OM[b]	78.6	76.5	75.0	74.8	.74
N[b]	62.8	65.4	66.9	70.0	1.0
Starch	98.3	98.8	98.7	99.0	.3
Digestible energy					
%[a]	74.8	74.0	71.7	71.2	1.0
Mcal/kg[a]	3.37	3.34	3.23	3.21	.05

[a]Linear effect ($P < .05$)
[b]Linear effect ($P < .01$)
[c]Quadratic effect ($P < .10$).
[d]Grams microbial N/kg OM fermented.
[e]Nonammonia N leaving the abomasum/N intake.
[f]Linear effect ($P < .10$).