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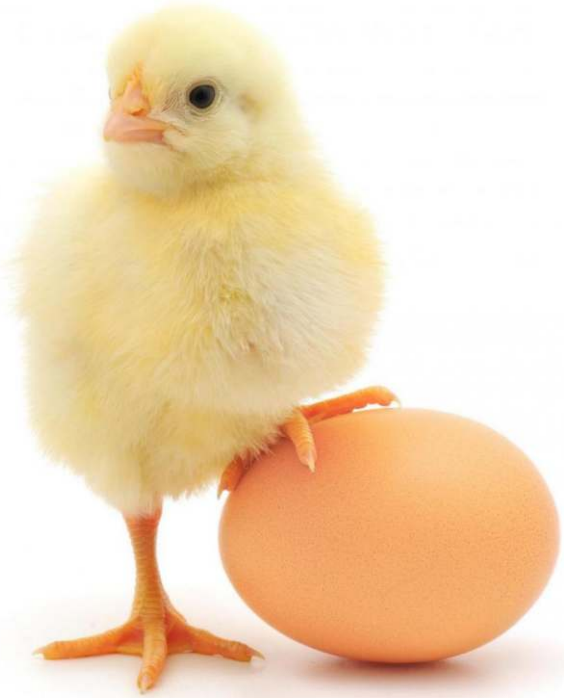

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Reduction in Dietary Nutrient Density Aids in Utilization of High Protein Cottonseed Meal in Broiler Diets[1]

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Abstract: This trial was conducted to determine if the reduction in weight gains and feed intake observed for broilers fed 30% cottonseed meal diets was associated with the high fat level of the diets necessary to maintain the diets isocaloric compared to corn-soybean meal control diets. Three series of energy levels were formulated to contain 2950/3000, 3000/3050, 3050/3100 ME Kcal/kg with values representing the starter/grower (S/G) dietary energy values, respectively. Within each energy series, diets were formulated to contain either soybean meal as the primary protein source (0% CSM) or 30 % cottonseed meal (30 % CSM). Male broilers were fed starter diets 0 to 21 days followed by grower diets to 42 days. At the end of the trial, six birds per pen were processed to determine carcass and parts yield. Results showed that 21 and 42 days body weights, feed consumption and mortality of the birds receiving the 30 % CSM diets were comparable to the performance of birds receiving the 0% CSM diet for the similar energy series. There was an interaction effect for 21 days feed conversion with the feed conversion of the 0% CSM 3000/3050 series significantly lower than all of the other conversion rates. Feed conversion rates at 21 and 42 days were significantly depressed for the birds receiving the 30 % CSM diets. Although the dressing percentage was lower for the 30 % CSM birds, abdominal fat was also lower and breast meat yield equaled the 0 % CSM birds. Increasing the dietary energy level increased abdominal fat. The results indicated that the high dietary fat levels used in previous experiments could to be interfering with optimum usage of a 30 % CSM diet for growth but not for feed conversion.

Key Words: Broilers, cottonseed meal, nutrient density, pelleting, protein sources

Introduction

Cottonseed meal (CSM) incorporated into broilers diets at levels of up to 20 percent has been shown to support body weights and feed conversion similar to that observed in broilers fed isocaloric corn-soybean meal diets (Watkins *et al.*, 1994; Watkins *et al.*, 1995; Fernandez *et al.*,1995) . However, when 30% CSM was fed, performance (weight, feed conversion) was depressed. One reason for these adverse results may be the high level of fat necessary to make the CSM diets isocaloric to the corn-soy diets. In a previous study (Watkins *et al.*, 1995), level of supplemental fat in the 30% CSM diet was 9.52 % as compared to the 4.50 % supplemental fat in the corn-soybean meal diet. Due to the high fat level in diets with 30 % CSM, pellet quality was decidedly inferior not only to the control diet but also to diets with 20 % CSM diet. The pellet quality of the high fat 30% CSM diets had a consistency more similar to a greasy mash.

Both pellet quality and dietary fat level can impact weight gain and feed conversion (Dudley-Cash and William, 1992; Bearse *et al.*, 1952; Wenk and Van Es, 1979; McNaughton and Reece, 1984; Dale and Fuller, 1979; Pesti *et al.*, 1983; Jensen and Falen, 1973; Proudfoot and Hulan *et al.*, 1982; Skinner *et al.*, 1992; Leclercq and Escartin, 1987). The beneficial effects of pelleting diets versus feeding mash feeds are well documented (Hussar and Robblee, 1962; Blakely *et al.*, 1963; Turner, 1995). Increasing the percentage of fines also has a negative effect on performance (Proudfoot and Hulan, 1982; Leclercq and Escartin, 1987; Mercier and Guilbot, 1974). The pre-conditioning phase of the pelleting process, which involves steam and pressure, enhances the nutritional value of many of the starches in the ingredients (Mercier and Guilbot, 1974; Moran, 1989). Pelleting experts agree that high-fat diets do not condition well, resulting in an even greater loss of nutritional enhancement, particularly for young poultry (Blakely *et al.*, 1963, Moran, 1989; Rodriguez, 1996). Therefore, the following experiment was conducted to determine if the poor performance supported by 30 % CSM diets in previous experiments could be attributed to the high dietary fat and/or poor conditioning and pellet quality. By reducing the dietary nutrient density (metabolizable energy and associated nutrients), it was possible to formulate 30% CSM diets with lower fat levels and, consequently, diets that pelleted more effectively.

Table 1: Determined nutrient content of cottonseed meal

Nutrient	% of sample
Crude protein	44.96
Moisture	9.37
Ether extract	1.46
Crude fiber	10.03
Ash	6.53
Calcium	0.21
Chloride	0.05
Potassium	1.63
Sodium	0.21
Phosphorus	1.18
Methionine	0.72
Cystine	0.79
Lysine	1.97
Arginine	4.95
Tryptophan	0.45
Tyrosine	1.26
Threonine	1.31
Serine	1.57
Phenylalanine	2.31
Glutamic acid	8.03
Proline	1.54
Glycine	1.78
Alanine	1.67
Valine	1.90
Isoleucine	1.38
Leucine	2.55
Histidine	1.23
Free gossypol	0.13

[1] Published with the approval of the Director, Arkansas Agricultural Experiment Station, MS # 96041

Table 2: Composition and calculated nutrient content of broiler starter diets fed 0 to 21 days

Ingredient	CSM level and Assigned Dietary ME Value (Kcal/kg)					
	30 CSM			0 CSM		
	2950	3000	3050	2950	3000	3050
			g / kg			
g/kg Yellow corn	463.58	442.25	394.11	663.41	663.78	616.40
Cottonseed meal (45% CP)	300.40	300.00	300.00	0.00	0.00	0.00
Soybean meal (48% CP)	106.57	115.36	148.02	240.35	246.25	273.84
Poultry by-product meal	50.0	50.00	50.00	50.00	50.00	50.00
Poultry oil	47.08	59.34	75.85	0.00	4.16	21.06
Ground rice hulls	0.0	0.00	0.00	11.10	0.00	0.00
Limestone	13.69	13.85	13.94	12.93	13.13	13.81
Vitamin premix[A]	5.00	5.00	5.00	5.00	5.00	5.00
Dicalcium phosphate	5.79	6.15	6.35	8.21	8.52	9.92
Salt	2.23	2.32	2.40	3.66	3.74	4.06
Trace mineral premix[B]	1.00	1.00	1.00	1.00	1.00	1.00
DL Methionine (98%)	1.33	1.43	1.27	2.13	2.19	2.55
Lysine HCl (98%)	0.93	0.88	0.00	0.0	0.0	0.0
Threonine	0.40	0.42	0.06	0.21	0.23	0. 36
Stenerol	1.00	1.00	1.00	1.00	1.00	1.00
Bacitracin MD	1.00	1.00	1.00	1.00	1.00	1.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Nutrient						
ME Kcal/Kg	2950	3000	3050	2950	3000	3050
Crude Protein (%)	25.731	25.99	27.07	20.34	20.64	21.632
Arginine, %	1.862	1.885	1.985	1.30	1.321	1.402
Lysine, %	1.065	1.083	1.101	1.065	1.083	1.155
Glycine, %	1.067	1.078	1.131	1.007	1.019	1.062
Serine , %	0.893	0.908	0.974	0.951	0.966	1.020
Histidine, %	0.539	0.545	0.578	0.518	0.526	0.552
Isoleucine, %	0.774	0.788	0.845	0.812	0.825	0.872
Methionine, %	0.502	0.514	0.512	0.545	0.556	0.602
Met + Cys, %	0.871	0.886	0.901	0.871	0.886	0.945
Phenylalanine, %	1.053	1.067	1.128	0.929	0.943	0.992
Threonine, %	0.774	0.788	0.801	0.774	0.787	0.840
Tryptophan, %	0.232	0.238	0.26	0.243	0.248	0.266
Valine, %	0.980	0.991	1.047	0.935	0.949	0.994
Calcium,%	0.992	0.937	0.953	0.922	0.938	1.00
Total Phosphorus, %	0.753	0.759	0.769	0.581	0.591	0.621
Available Phosphorus, %	0.415	0.422	0.429	0.415	0.422	0.450

[A] Provides per kg of diet: Vitamin A, 9900 IU; cholecalciferol, 3300 ICU; vitamin E, 13 IU; vitamin B_{12}, 0013 mg; riboflavin, 6.6 mg; niacin, 66 mg; d-pantothenic acid, 16.5 mg; choline, 660 mg; menadione, 1.1 mg; folacin, 1.1 mg; thiamin, 1.1 mg, pyridoxine, 3.3 mg; d-biotin, 0.11 mg; Se, 0.20 mg; ethoxyquin, 125 mg.

[B] provides per kg of diet: Mn ($MnSO_4*H_2O$), 100mg; Zn ($ZnSO_4*7H_2O$), 100mg; Fe ($FeSO_4*7H_2O$), 50 mg; Cu ($CuSO_4*5H_2O$), 10 mg; I ($Ca(IO_3)_2*H_2O$), 1 mg.

Materials and Methods

The cottonseed meal utilized in this experiment was a 44.96% crude protein meal supplied by a major cottonseed producer. The meal had been subjected to mild expeller processing followed by solvent extraction. Amino acid and mineral analyses were conducted by a commercial laboratory, and these values were used in diet formulation (Table 1). These values are in agreement with those found in a commercial CSM (Leclercq and Escartin, 1987; Fernandez *et al.*, 1994). The free gossypol content of the meal was 0.13 %. Based on digestibility coefficients reported by 1994 NRC (National Research council, 1994), total amino acid values for the CSM were reduced by 25% for all essential amino acids except lysine, which was given a 35% reduction in availability. The assigned ME value for the cottonseed meal was 2000 kcal/kg in agreement with values previously reported by this laboratory and others (Watkins *et al.*, 1995; Fernandez *et al.*, 1995; Dale, 1995).

Utilizing linear programming, three dietary energy series were formulated for starter (0 to 21 days) and grower (21 to 42 days). Starter diets contained 2950, 3000, 3050 ME Kcal/kg while grower diets contained 3000, 3050 or 3100 ME kcal/kg. Within each energy series, diets were formulated to contain either soybean meal as the primary protein source (0% CSM) or 30 % CSM. Diets were formulated to contain similar calorie-to-available-amino acid ratios. All nutrients were formulated to meet recommend standards for males (Thomas *et al.*, 1992) adjusted to the dietary energy level. The composition and calculated nutrient contents for both the starter and grower diets are shown in Tables 2 and 3. Analyzed protein values were in close agreement to calculated values for all diets. The addition of supplemental iron to alleviate the effects of free gossypol found in this sample of cottonseed meal was previously shown to not be

Table 3: Composition and calculated nutrient content of broiler grower diets fed 21 to 42 days

Ingredient	CSM level and Assigned Dietary ME Value (Kcal/kg)					
	30 CSM			0 CSM		
	3000	3050	3100	3000	3050	3100
	g / kg					
Yellow corn	496.95	476.47	455.72	701.64	696.91	677.39
Cottonseed meal (45% CP)	299.40	299.40	299.41	0.0	0.0	0.0
Soybean meal (48% CP)	76.9	84.84	92.97	210.81	216.20	223.17
Poultry by-product meal	49.9	49.9	49.9	50.0	49.9	49.9
Poultry oil	49.41	61.39	73.45	0.0	6.46	18.32
Ground rice hulls	0.00	0.00	0.00	7.60	0.00	0.00
Limestone	14.26	14.42	14.58	13.54	13.70	13.87
Vitamin premix[A]	4.99	4.99	4.99	5.00	4.99	4.99
Dicalcium phosphate	1.31	1.60	1.89	3.71	3.95	4.25
Salt	2.32	2.41	2.49	3.70	3.82	3.90
Trace mineral premix[B]	1.00	1.00	1.00	1.00	1.00	1.00
DL Methionine (98%)	0.19	0.23	0.28	0.78	0.83	0.92
Lysine HCl (98%)	0.95	0.91	0.87	0.0	0.0	0.0
Threonine	0.42	0.44	0.47	0.22	0.24	0. 28
Monensin	1.00	1.00	1.00	1.00	1.00	1.00
Bacitracin MD	1.00	1.00	1.00	1.00	1 .00	1.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Nutrient						
ME Kcal/Kg	3054	3094	3133	3059	3098	3138
Crude Protein (%)	22.87	23.11	23.35	18.83	18.61	18.81
Arginine, %	1.92	1.94	1.96	1.22	1.22	1.26
Lysine, %	1.03	1.05	1.06	0.96	0.97	0.99
Glycine, %	1.12	1.13	1.14	1.03	1.04	1.05
Serine , %	1.05	1.06	1.08	1.06	1.07	1.09
Histidine, %	0.59	0.60	0.60	0.55	0.55	0.56
Isoleucine, %	0.75	0.76	0.78	0.76	0.77	0.79
Methionine, %	0.37	0.37	0.38	0.43	0.43	0.44
Met + Cys, %	0.75	0.75	0.76	0.75	0.76	0.77
Phenylalanine, %	1.10	1.11	1.13	0.95	0.96	0.98
Tyrosine, %	0.70	0.71	0.72	0.71	0.72	0.73
Threonine, %	0.74	0.76	0.77	0.71	0.72	0.72
Tryptophan, %	0.27	0.27	0.28	0.24	0.24	0.25
Valine, %	0.96	0.97	0.99	0.87	0.88	0.89
Calcium,%	0.80	0.81	0.82	0.81	0.83	0.84
Total Phosphorus, %	0.59	0.60	0.60	0.49	0.49	0.50
Available Phosphorus, %	0.27	0.28	0.28	0.27	0.27	0.28

[A] Provides per kg of diet: Vitamin A, 9900 IU; cholecalciferol, 3300 ICU; vitamin E, 13 IU; vitamin B_{12}, 0013 mg; riboflavin, 6.6 mg; niacin, 66 mg; d-pantothenic acid, 16.5 mg; choline, 660 mg; menadione, 1.1 mg; folacin, 1.1 mg; thiamin, 1.1 mg, pyridoxine, 3.3 mg; d-biotin, 0.11 mg; Se, 0.20 mg; ethoxyquin, 125 mg.

[B] Provides per kg of diet: Mn ($MnSO_4$*H_2O), 100mg; Zn ($ZnSO_4$*$7H_2O$), 100mg; Fe ($FeSO_4$*$7H_2O$), 50 mg; Cu ($CuSO_4$*$5H_2O$), 10 mg; I ($Ca(IO_3)_2$*H_2O), 1 mg.

beneficial in alleviating the effects of low free gossypol (Watkins *et al.*, 1995). Therefore, in this experiment CSM diets were not supplemented with additional iron above that found in the trace mineral premix (50 ppm). Each of the diets was fortified with complete vitamin and trace mineral supplements.

All diets were pelleted with steam (175 °F and 4-mm pellet die) with starter diets crumbled after cooling. The reduction in ME levels resulted in lower levels of supplemental fats for the cottonseed meal diets, resulting in improved pellet quality as compared to previous studies. Although no measurements were made of pellet quality or durability, visual observation supported the conclusion that lower dietary fat levels resulted in improved pellet quality for 30 % CSM diets formulated with lower ME Kcal/Kg levels.

Day-old male chicks of a commercial broiler strain (Ross Poultry Breeders Elkmont, AL 35620) were obtained from a local hatchery. Fifty birds were randomly assigned to each of thirty-six pens (50 ft^2) in a steel truss broiler house of commercial design. Each pen was equipped with two tube feeders and an automatic water font. Litter was used pine wood shavings over a concrete floor. Birds were brooded using whole house brooding beginning at 88 °F and reduced by 5 °F weekly. Due to hot weather rearing, a minimum of 70 °F was never achieved. Thermostatically controlled fans, and automatic sidewall curtains controlled temperature and ventilation rates.

Pen group body weights were obtained at 21 and 42 days of age. Feed consumed by pen was also determined for these time periods. Birds were checked twice daily for mortality, and dead bird weights were used for correction of feed utilization. At the end of the experiment, six birds per pen were randomly chosen for

Table 4:Twenty One Day Performance of Male Broilers Fed Different Dietary Energy Levels With or Without Cottonseed Meal in the Diet

CSM % of Diet	Dietary ME Kcal/Kg (S/G)	Body Weight (g)	Feed to Gain Ratio (g/g)	Feed Intake (g)	Mortality (%)
0		635	1.467[a]	937	1.11
30		629	1.515[b]	958	1.29
SEM		6	0.013	11	0.48
Pr > F		0.5484	0.0160	0.1865	0.7941
	2950/3000	623	1.495	940	1.67
	3000/3050	626	1.510	957	1.38
	3050/3100	646	1.468	947	0.55
	SEM	7	0.016	14	0.59
	Pr > F	0.0923	0.1885	0.6985	0.3962

[a-b] Means in a column with no common superscripts differ significantly (P<0.05)

Table 5: The Interaction Effect of Dietary Cottonseed Meal and Energy Levels on the 21 Day Feed to Gain Ratio of Male Broiler Chicks

Dietary ME kcal/Kg (S/G)	CSM (% of Diet)	
	0	30
2950/3000	1.503[b]	1.486[b]
3000/3050	1.487[b]	1.533[b]
3050/3100	1.410[a]	1.526[b]
Pooled SEM	0.02	

Pr>F=.024 [a-b] Means within column with no common superscripts differ significantly (P<0.05)

processing to determine carcass yield, abdominal fat (AF) content, and parts yield. Birds with visible signs of defects were not selected for processing. Live weights of individual birds were taken after a ten-hour fast. Birds were banded and transported less than one mile to the pilot processing plant, and all birds were killed within two hours of cooping. Birds were killed following electrical stunning, bled 120 seconds followed by scalding at 140 °F for two minutes in a dunking scalder. They were picked for 45 seconds in a rotary drum picker and manually eviscerated. The dressed carcass and AF were weighed prior to a hot cutup. Abdominal fat is defined as the fat surrounding the gizzard extending within the ischium and surrounding the Bursa of Fabricius, cloaca, and adjacent abdominal muscles. Dressing percentage was calculated as prechill carcass weight (including the AF but excluding neck and giblets) as a percentage of fasted live weight. Abdominal fat weights were analyzed on a weight basis and as a percentage of the carcass weight. Wings were removed so that minimal breast meat was taken and leg quarters were removed as a thigh-drum piece. Breast skin was removed, followed by the breast (combining pectoralis major and minor). Breast, leg quarter, and wing were calculated as a percentage of carcass yield. Data was analyzed by the General Linear Model of SAS (SAS, 1982). Pen means served as the experimental unit. Means which were found to be significantly different at the P<0.05 level were separated using the least square procedure. All percentage data were converted to arc sine and morality data were transformed to square root of n + 1 prior to analysis. All results are presented as natural numbers.

Results and Discussion

The effects of level of CSM and dietary energy level on performance of broilers at 21 d are shown in Tables 4 and 5. Body weight did not differ between birds fed diets with 0 or 30% CSM. Body weight tended to increase as the dietary energy level increased (P=0.09); however, there was no significant interaction of dietary energy level and CSM level of the diet. Feed conversion was poorer on diets with 30% CSM; however, there was a significant interaction of level of CSM and dietary energy. In diets with no CSM, feed conversion improved as dietary energy levels increased while in diets with 30% CSM, no improvement in feed conversion was noted as dietary energy level increased. These diets were fed as crumbles; therefore, they may not have attained the full benefits of pelleting. Mortality did not differ among treatments.

The effects of level of CSM and dietary energy level on performance of broilers at 42 d are shown in Table 6. There were no significant differences in body weight associated with level of CSM or dietary energy level, nor was there any significant interaction of CSM level and dietary energy. Feed conversion was significantly poorer for birds fed 30% CSM as compared to those fed the corn-soybean meal control. This may have been associated with the higher (P=0.08) mortality in birds fed the diet with 30% CSM. Although adjustments were made for the weight of birds that died, this is at best an imperfect correction. Overall, there were no significant effects of dietary energy on feed conversion or mortality, nor was there an interaction of level of CSM and dietary energy on feed conversion or mortality. Inclusion of 30% CSM in the diet had a significant negative effect on dressing percentage (Table 7); however, the birds fed the 30% CSM diets also had significantly lower abdominal fat content. Breast meat yield (% of carcass or actual weight) was virtually identical for birds fed diets with 0 or 30% CSM.

As dietary energy level increased, a significant increase in percent and weight of abdominal fat occurred. There is considerable disagreement in the literature regardingo the effects of increasing dietary energy on abdominal fat. Increasing dietary energy has been shown to increase abdominal fat (Sohn and Han, 1983; Deaton and Lott, 1985) while others have found that increasing energy reduces abdominal fat (Skinner *et al.*, 1992; Bartov *et al.*, 1974; Sizemore and Siegel, 1993). Dietary nutrient density appears to have a very important role in the formation of abdominal fat (Sizemore and Siegel, 1993; Saleh *et al.*, 1994; Griffiths *et al.*, 1977). Several researchers have shown that maintaining a narrow calorie to amino acid ratio reduces abdominal fat, resulting in a leaner carcass (Turner,1995; Bartov *et al.*, 1974; Sizemore and Siegel, 1993; Mabray and Waldroup, 1981). The reduction in abdominal fat on diets containing 30% CSM indicates that the assigned energy value for the cottonseed meal (2000 ME Kcal/Kg) reflects a good estimation of the energy content. However, the results of low AF and equal breast meat yield may also be a reflection of an underestimation of the available amino acid content of the high protein CSM with particular attention to an underestimation of lysine availability. Although there were significant differences due to dietary energy in the dressing percentage, these differences followed no apparent trend.

The results of this experiment indicate that an improvement in the

Table 6: Forty-Two Day Performance of Male Broilers Fed Different Dietary Energy Levels With or Without Cottonseed Meal

CSM	Dietary Energy Level (S/G)	Body Weight (g)	Feed to Gain Ratio (g/g)	Feed Intake (g)	Mortality (%)
0		2127	1.819[a]	3927	3.28
30		2122	1.830[b]	3882	5.91
SEM		22	0.013	11	1.03
Pr > F		0.8807	0.0160	0.1865	0.0835
	2950/3000	2105	1.825	3839	4.17
	3000/3050	2113	1.842	3982	4.34
	3050/3100	2156	1.808	3892	5.28
	SEM	28	0.017	52	1.26
	Pr > F	0.3989	0.4511	0.1634	0.8005

[a-b] Means in a column with no common superscripts differ significantly (P<0.05)

Table 7: Forty-Two Day Carcass Yield of Male Broilers Fed Different Dietary Energy Levels With or Without Cottonseed Meal

CSM	Dietary Energy Level	Dressing (%)	Fat (grams)	Abdominal Fat (%)[1]	Breast (grams)	Breast (%)[1]	Leg Quarter (%)[1]	Wing (%)[1]
0		65.32[a]	46.72[a]	2.81[a]	409	24.57	36.05	11.44
30		63.97[b]	34.80[b]	2.12[b]	408	25.02	35.77	11.59
SEM		0.19	0.999	0.056	6	0.21	0.14	0.058
Pr > F		0.0001	0.0001	0.0001	0.8902	0.1371	0.1510	0.0777
	2950	65.45[a]	38.70[b]	2.33[b]	409	24.61	36.03	11.51
	3000	63.79[c]	40.09[b]	2.44[ab]	403	24.77	35.93	11.48
	3050	64.69[b]	43.49[a]	2.63[a]	414	25.01	35.77	11.55
		0.25	1.22	0.068	8	0.25	0.17	0.07
		0.0004	0.0298	0.0164	0.6272	0.5503	0.5619	0.7972

[a-b] Means in a column with no common superscripts differ significantly (P<0.05)

[1] Pe rcents of cutup yields are calculated as a percentage of carcass without giblets.

pellet quality of diets containing 30% CSM by reducing dietary nutrient density with a concomitant reduction in levels of supplemental fat resulted in 21 and 42 day weights similar to that of birds fed corn-soybean meal control diets. However even with the improved pellet quality, feed-to-gain ratios were poorer for the CSM birds, perhaps related to the elevated mortality. Fernandez and Parsons (Fernandez and Parsons, 1996) also reported less than optimal feed conversion in broilers consuming high CSM diets. They demonstrated that essential amino acid availability was not the reason for this poor performance. The diets containing 30% CSM supported lower dressing percentages as well as lower abdominal fat. Breast meat for the 30% cottonseed meal birds was equivalent to that of the 0% CSM birds. Improving pelleting quality of the high cottonseed meal diets improved but did not totally alleviate the problem of reduced feed conversion associated with feeding 30% CSM diets.

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