CORN GLUTEN FEED IN BEEF CATTLE DIETS

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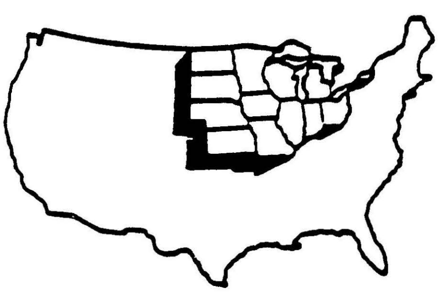

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Introduction

Corn is the most widely grown crop in the United States with almost nine billion bushels produced in 1985. Soil and other environmental conditions, producer expertise and preference, and government subsidy programs encourage over-production of corn. Carryover stocks of corn averaged about 20 percent of production during the past five years. This vast supply has increased the feasibility of using corn to produce products such as starch, sweeteners, and fuel alcohol. Production of these products consumed about one billion bushels of the 1985 corn crop, resulting in the production of approximately six million tons of byproducts (predominantly corn gluten feed and distiller's grains). This review will discuss only corn gluten feed (CGF).

Most of the CGF produced in the U.S. is exported to Europe; therefore, many U.S. beef producers, nutritionists, and consultants are unfamiliar with the nutritional value of CGF. The economic and political climate concerning CGF export may change, which could make CGF a less marketable product in Europe. This would enlarge the domestic supply and necessitate a better understanding of the feeding value of CGF when fed under a variety of conditions. The use of CGF in beef diets has been reviewed previously (Green et al., 1987b); however, a substantial amount of research has been published more recently. Our review will discuss both dry and wet CGF as protein and energy sources for growing and finishing beef cattle. Data generated at experiment stations in the North Central Region will be emphasized.

Production and Characteristics of CGF

Corn gluten feed is a byproduct of the wet milling industry. Wet milling separates the corn kernel into its components: starch, oil, protein, and bran (fiber). First, the corn is soaked in a weak solution of sulfurous acid for about two days. The steep liquor contains soluble proteins, amino acids, peptides, minerals, vitamins, and simple sugars. The swollen kernel is then coarsely ground and the germ is separated from the rest of the kernel by centrifugation. The starch and fiber residue is processed through another grinder that preferentially reduces the particle size of starch relative to bran. The slurry then is filtered; the bran is retained on the filter, and the starch passes through. The oil and starch are used primarily for human food products. The bran is mixed with the steep liquor (condensed via centrifugation) in a ratio of about 2 parts bran plus 1 part condensed liquor. This product contains about 40 percent dry matter (wet CGF, WCGF) and is usually flash-dried to about 90 percent dry matter (dry CGF, DCGF).

Wet CGF has a nutritional advantage over DCGF (discussed below), but DCGF is easier to handle. Wet CGF has a shelf life of a few days in the summer and one to two weeks in the winter; therefore, cattle feeders using WCGF must be near a wet milling plant, or have a suitable storage system. Furthermore, due to the high water content of WCGF, transportation cost per unit of dry matter (DM) is more than twice as high for WCGF as it is for DCGF. Wet CGF is usually less expensive (at the plant) per unit DM because there are no drying costs. Usually it is more economical for producers that are distant from a wet milling plant to use DCGF instead of WCGF; whereas, for producers in the vicinity of a corn processing plant, WCGF usually is more economical.

Chemical Composition of CGF

Typical nutrient composition values for WCGF, DCGF, soybean meal, and shelled corn are in Table 1. Nutrient composition of DCGF varies greatly among batches. Crude protein values ranged from 17 percent (DiCostanzo et al., 1986a) to 26 percent (Macleod et al., 1985); neutral detergent fiber (NDF) concentrations ranged from 26 percent (Krishnamoorthy et al., 1982) to 54 percent (DiCostanzo et al., 1986a); ether extract content ranged from 1 to 7 percent (Phelps, 1988). These wide variations in nutrient composition of CGF must be considered in diet formulation and make it necessary to either conduct chemical analyses on each batch purchased or buy CGF that has a guaranteed analysis so that balanced diets can be formulated.

Wet milling removes most of the starch and oil from corn, thereby concentrating the remaining components. The concentration of crude protein is about twice as high in CGF as it is in corn grain, and concentration of NDF is four to five times higher in CGF than in corn grain. The amino acid content of CGF is about two times higher than corn, but relative concentrations of the amino acids are similar. Therefore, the quantities of amino acids are greater in CGF, but the quality of the protein is about the same as in corn grain, which is poor. Corn gluten feed is a poor source of calcium, but contains a significant amount of phosphorus. The Ca to P ratio of CGF can be as low as 1:10; however, growing-finishing cattle should be fed diets with a Ca to P ratio of approximately 1.5:1. The high concentration of phosphorus relative to calcium could result in imbalances of these two minerals and cause urinary calculi when large amounts of CGF are fed. It is recommended that diets containing CGF be supplemented with adequate calcium to offset the high concentration of phosphorus. Concentrations of trace minerals and vitamins in CGF are too variable for average concentrations to have much meaning.

Studies comparing the nutrient composition of wet versus dry CGF from the same batch are lacking. Batch to batch variation precludes comparing WCGF from one

Table 1. Typical nutrient composition of wet (WCGF) and dry (DCGF) corn gluten feed, corn grain, and soybean meal (SBM).[1]

Item[2]	WCGF	DCGF	Corn	SBM
Dry matter, %	44	92	89	89
ME, Mcal/kg	3.35	3.25	3.42	3.29
Starch, %	26	18	70	NA
NDF, %	38	42	9	14
ADF, %	14	10	3	10
Lignin, %	3	NA	1	1
Crude protein, %	22	22	10	49
Soluble N (% of N)[3]	71	34	11	21
ADIN (% of N)	3	3	5	5
Ether extract, %	5	2	7	2
Ash, %	9	7	2	7
Calcium, %	.1	.2	.03	.3
Phosphorous, %	.6	.8	.3	.7
Potassium, %	1.50	1.50	.4	2.0
Sulfur, %	.4	.3	.12	.47
Lysine, %	.7	.5	.3	3.0
Methionine, %	.3	.3	.2	.6

[1]These data were compiled from feeding experiments cited in this review and NRC U.S.-Canadian Tables of Feed Composition, 1982.
[2]NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble N; ME, metabolizable energy; NA, not available. All values except dry matter and nitrogen fractions are on a dry matter basis.
[3]N soluble in bicarbonate-phosphate buffer solution.

batch to DCGF from another batch even within an experiment. For example, Cordes et al. (1988) fed DCGF that had an NDF concentration of 43 percent and WCGF that had 57 percent NDF. Crude protein of DCGF was 20 percent, and the WCGF had 17 percent crude protein. The higher NDF and lower CP of the WCGF as compared to DCGF are interpreted to suggest that more corn bran relative to condensed steep liquor was used in the batch from which the WCGF was produced. In general, however, average concentrations of crude fractions do not appear to be greatly different between DCGF and WCGF.

Macleod et al. (1985) conducted an extensive study of the crude protein fraction of WCGF and DCGF. About 30 and 70 percent of the total N in DCGF and WCGF, respectively, was soluble in bicarbonate-phosphate buffer. Heating usually reduces the N solubility of feeds; however, the changes in the N fraction of CGF induced by drying are not typical. Heating forages usually increases the amount of acid detergent insoluble N (ADIN) substantially (Van Soest, 1965); whereas, DCGF usually has values of ADIN similar to WCGF (Firkins et al., 1984). Heating (drying) CGF also did not appreciably change the amount of insoluble true protein, but reduced greatly the amount of soluble nonprotein amino acid N from 40 percent of total soluble N in WCGF to 14 percent in DCGF (Macleod et al., 1985). Bowman and Paterson (1988) reported no substantial differences in the amino acid composition of WCGF and DCGF.

An important physical characteristic that differs between WCGF and DCGF is particle size. Firkins et al. (1985) reported that mean particle size of WCGF was 2 mm and that of DCGF was .9 mm. This may have important analytical and nutritional ramifications. Detergent fiber determinations are somewhat dependent upon particle size. Ehle (1984) reported that alfalfa ground through a 2 mm screen had 54 percent NDF, but alfalfa from the same sample ground through a .5 mm screen had only 48 percent NDF. This could mean that, due to particle size differences, the detergent fiber fraction of WCGF could be overestimated relative to DCGF or vice versa. If this was true, then digestibility measurements of NDF and ADF of WCGF would be biased upward, or DCGF biased downward. For example, if particle size artifactually increased the NDF in WCGF, then intake of NDF from WCGF would be overestimated. Fecal particle size is nearer that of DCGF, so fecal output would not be overestimated. This would result in higher apparent digestibilities ([Intake—fecal output]/intake) of NDF from WCGF than from DCGF. The nutritional significance of particle size differences is discussed below.

Definitive studies comparing the true chemical composition of WCGF and DCGF are lacking. Correctly designed experiments must use wet and dry CGF from the same initial mix, and differences in particle size must be considered during chemical analysis of the feedstuffs.

Corn Gluten Feed in Beef Diets

The data base of cattle performance used in this review is in Table 2. More than 2,700 growing-finishing beef animals were used in 31 different experiments to evaluate the feeding value of CGF. Experiments were conducted to determine the value of CGF as a protein source and as an energy and fiber source.

CGF as a Protein Source

The apparent digestibility of crude protein (CP) by lambs fed diets containing essentially 100 percent WCGF or DCGF was about 70 percent (Firkins et al., 1985). The CP in soybean meal has an apparent digestibility of 80-90 percent (Schneider, 1947). It would be expected that metabolic fecal nitrogen would be higher when CGF is fed than when soybean meal is fed due to differences in fiber content (Swanson, 1982); therefore, comparison of apparent CP digestibilities of CGF and soybean meal may not accurately reflect differences in true digestibilities.Information on the true digestibility of CP from CGF is not available.

In typical corn silage-corn grain diets, about 10 percent CGF would need to be fed to meet the CP requirements of most classes of growing-finishing cattle. No experiments using this low amount of CGF were found in the literature, so performance data are lacking. Protein efficiency experiments conducted at Nebraska (DeHaan et al., 1983) reported that the protein in DCGF was only about 70 percent as efficient as soybean meal protein in supporting growth. The diets fed during these experiments consisted of a basal diet of 50 percent corn silage and 50 percent ammoniated corn cobs (dry matter basis), plus various amounts of the protein supplement. These diets are not typical of normal feedlot diets; therefore, extrapolation of this protein efficiency data to other feeding systems may not be appropriate.

Iowa research (Trenkle, 1986a; 1987b) has shown that CGF protein is superior to urea for growing calves when fed in isonitrogenous diets. It was reported (Trenkle, 1986a) also that calves receiving all their supplemental CP from soybean meal grew faster than calves receiving most of their supplemental CP from DCGF (urea provided 10 percent of supplemental CP). However, interpretation of the protein effect is confounded with varying energy values of the diets. The soybean meal diet contained 25 percent corn and 14 percent soybean meal, whereas the CGF diet contained no corn or soybean meal and 39 percent DCGF. As discussed below, a mixture of corn and soybean meal can have more energy than does DCGF. In the other experiment (Trenkle, 1987b), the sum of soybean meal and corn was kept constant, but the ratio varied along with the amount of urea so that diets were isonitrogenous (11 percent CP) and approximately isocaloric. No differences were observed among diets containing 30 percent DCGF plus 0, 2.5 percent, or 5 percent soybean meal. An experiment (Fleck et al., 1987) with growing heifers grazing native range plus supplemental protein from soybean meal (1lb/day), a 50/50 mix of soybean meal and DCGF (1.4 lbs/day) or DCGF (2.1 lbs/day) showed that growth rate was higher for animals fed some CGF than for animals fed just soybean meal. Cattle receiving supplemental CP grew faster than cattle receiving no supplemental CP. The data from the above experiments indicate that if diets are formulated to meet the NRC protein requirement of cattle, and if diets are approximately isocaloric, then CGF is approximately equal to soybean meal as a protein source. Therefore, if soybean meal (44 percent CP) is worth $200/ton, then DCGF would be worth about $84/ton as a protein source.

CGF as an Energy/Fiber Source

Initially, the data in Table 2 were broken down by type of roughage in the diet. Diets containing corn silage or corn cobs made up the largest subsets, and data from those experiments will be discussed in more detail. Fewer data are available when other roughages were fed in diets containing CGF. When diets containing alfalfa hay and either corn or DCGF were fed at two concentrations (20 and 60 percent of DM), no differences were found in rate or efficiency of gain (Hannah et al., 1987). Corn has a higher energy value than DCGF, but fermentation of corn in the rumen greatly reduces the digestibility of the fiber fraction of the diet. Corn gluten feed does not depress digestibility of fiber (Staples et al., 1984; Firkins et al., 1985; Hannah et al., 1987; Kampman and Loerch, 1988). This caused digestibility of total diet dry matter to be similar (Hannah et al., 1987). Similar results were found when steers were fed diets with about 50 percent low quality forage (grass hay, straw, and corn stover) plus DCGF (Oliveros et al., 1987).

Seven experiments used corn cobs as the roughage source, but due to the many different variables in the experiments (type of CGF, amount of CGF, and amount of cobs), it is difficult to reach specific conclusions. In general, however, cattle fed diets containing approximately 50 percent cobs and combinations of corn and CGF grew about 10 percent faster than did cattle that were fed diets with 50 percent cobs and corn grain. This is probably due to the non depressing effect of CGF on fiber digestibility as compared to corn. Feed efficiencies were similar among diets. Cattle fed low amounts of corn cobs plus corn grew about 10 percent faster and more efficiently than did cattle fed low amounts of cobs plus CGF.

Data from the experiments where corn silage was fed were grouped by amount of corn silage, energy source, and amount of CGF fed (Tables 3, 4). Based on these data, in low silage diets (10 percent corn silage), WCGF has an energy value of 95 percent of corn and DCGF has an energy value of about 86 percent of corn. In medium silage diets (40 percent corn silage) DCGF is worth 92 percent of corn and WCGF has an energy value of 95 percent of corn. In high silage diets (70 percent corn silage), WCGF and DCGF have energy values about 102 percent of corn.

Table 2. Diet composition and cattle performance in experiments evaluating corn gluten feed.[1]

Start Weight	CGF Type[2]	CGF %	Roughage Type[3]	Roughage %	Corn %	Suppl CP[4]	ADG lbs	DMI lbs	g DMI/ kg $W^{.75}$	F/G	N[5]	REF[6]
850		0	CS	15	85	U	3.0	20.5	107	6.90	14	5
850	D	30	CS	15	55	NONE	2.9	23.0	120	7.85	14	5
850	D	50	CS	0	50	NONE	3.1	21.5	112	7.00	14	5
850	D	75	CS	0	25	NONE	2.9	22.8	119	7.97	14	5
770		0	CS	15	85	U	3.0	19.9	112	6.70	17	5
770	D	30	CS	15	55	NONE	2.8	20.6	116	7.33	17	5
770	D	50	CS	0	50	NONE	3.2	20.7	117	6.45	17	5
770	D	75	CS	0	25	NONE	2.9	21.0	118	7.17	17	5
550		0	CS	80	20	SBM/U	2.7	14.9	108	5.60	14	4
550	D	20	CS	80	0	SBM/U	2.6	14.8	107	5.69	14	4
550	D	50	CS	50	0	SBM/U	3.1	17.4	126	5.65	14	4
550	D	80	CS	20	0	NONE	3.0	18.0	130	6.04	14	4
600		0	CS	80	20	SBM/U	2.1	14.3	97	6.98	7	4
600	D	20	CS	80	0	SBM/U	2.1	14.8	100	7.01	7	4
600	D	50	CS	50	0	SBM/U	2.3	15.6	105	6.84	7	4
600	D	80	CS	20	0	NONE	2.3	17.1	116	7.40	7	4
580		0	CS	80	10	SBM	2.4	15.4	107	6.42	30	16
580	D	40	CS	50	10	NONE	2.6	16.7	116	6.42	30	16
580	D	60	CS	30	8	NONE	2.7	19.4	135	7.19	30	16
580	D	80	CS	10	8	NONE	2.4	18.7	130	7.79	30	16
820		0	CS	15	75	SBM	3.3	18.5	99	5.61	30	16
820	D	40	CS	15	40	NONE	2.6	20.4	109	7.85	30	16
820	D	60	CS	15	20	NONE	2.5	21.6	116	8.64	30	16
820	D	80	CS	15	0	NONE	2.6	20.2	108	7.77	30	16
790		0	CS	30	60	SBM	2.8	18.7	103	6.68	11	16
790		0	CS	10	80	SBM	3.0	17.8	98	5.93	12	16
790	D	60	CS	30	0	NONE	2.6	20.2	111	7.77	11	16
790	D	80	CS	10	0	NONE	2.7	17.8	98	6.59	12	16

(Continued)

Table 2. Diet composition and cattle performance in experiments evaluating corn gluten feed[1] (continued).

Start Weight	CGF Type[2]	CGF %	Roughage Type[3]	Roughage %	Corn %	Suppl CP[4]	ADG lbs	DMI lbs	g DMI/kg $W^{.75}$	F/G	N[5]	REF[6]
600		0	CS	70	20	SBM	2.5	15.0	102	6.00	30	16
600		0	CS	45	40	SBM/U	2.9	16.3	110	5.62	30	16
600	D	20	CS	70	10	SBM	2.3	14.7	99	6.39	30	16
600	D	40	CS	45	15	NONE	2.8	17.4	118	6.21	30	16
760		0	CS	10	80	SBM	2.7	17.3	98	6.41	34	10
760	W	50	CS	10	35	NONE	2.9	19.4	110	6.69	34	10
760	W	50	NONE	0	45	NONE	2.9	19.4	104	6.34	34	10
760	W	70	CS	10	20	NONE	2.8	19.5	110	6.96	34	10
760	W	70	NONE	0	30	NONE	2.9	18.8	107	6.48	34	10
760	W	90	NONE	0	10	NONE	2.7	17.7	100	6.56	34	10
780		0	CS	10	85	SBM	3.0	17.2	95	5.86	6	22
780	W	45	CS	10	40	NONE	3.4	20.2	113	5.98	7	22
780	W	100	NONE	0	0	NONE	3.2	18.6	103	5.86	7	22
630		0	NONE	0	95	SBM	2.6	17.8	117	6.92	39	22
630	W	45	NONE	0	45	NONE	2.6	17.8	117	6.83	38	22
630	W	100	NONE	0	0	NONE	2.5	17.1	112	6.84	38	22
900		0	CS	20	80	NONE	3.2	20.1	100	6.28	18	32
900	W	40	NONE	0	60	NONE	3.0	19.9	99	6.63	18	32
900	W	50	NONE	0	50	NONE	3.1	20.6	103	6.65	18	32
900	W	60	NONE	0	40	NONE	3.1	21.2	106	6.84	18	32
700		0	CS	20	75	U	2.9	18.8	114	6.48	20	35
700	W	40	NONE	0	60	NONE	3.1	19.0	114	6.13	20	35
700	W	65	NONE	0	30	NONE	3.0	19.4	117	6.47	20	35
700	W	90	NONE	0	5	NONE	2.9	19.6	118	6.76	20	35
800		0	CS	20	75	U	3.3	19.3	105	5.85	54	34
800	W	45	NONE	0	50	NONE	3.4	20.0	109	5.88	54	34
600	D	35	CS	30	20	NONE	3.3	22.9	155	6.86	28	10
600	W	35	CS	30	20	NONE	3.2	20.9	141	6.51	28	10
600		0	CS	60	20	SBM	2.7	21.1	143	7.70	28	10

(Continued)

Table 2. Diet composition and cattle performance in experiments evaluating corn gluten feed[1] (continued).

Start Weight	CGF Type[2]	CGF %	Roughage Type[3]	Roughage %	Corn %	Suppl CP[4]	ADG lbs	DMI lbs	g DMI/ kg W$^{.75}$	F/G	N[5]	REF[6]
700		0	CS	65	30	U	2.8	16.9	102	6.04	10	33
700	W	30	CS	65	0	NONE	3.1	17.1	103	5.52	10	33
700	D	30	CS	65	0	NONE	3.0	17.3	104	5.77	10	33
700	W	50	NONE	0	50	NONE	3.1	16.7	100	5.39	10	33
700	D	50	NONE	0	50	NONE	3.1	16.5	99	5.32	10	33
900		0	CS	65	30	U	3.2	20.1	100	6.28	10	33
900	W	30	CS	65	0	NONE	2.9	19.5	97	6.72	10	33
900	D	30	CS	65	0	NONE	3.0	20.0	100	6.67	10	33
900	W	50	NONE	0	50	NONE	2.9	19.3	96	6.66	10	33
900	D	50	NONE	0	50	NONE	3.0	18.7	94	6.23	10	33
800		0	CS	70	30	U	2.7	19.5	106	7.22	13	33
800	W	30	CS	70	0	NONE	2.6	19.8	108	7.62	13	33
800	D	30	CS	70	0	NONE	2.8	20.3	111	7.25	13	33
740		0	CS	10	85	U	3.1	18.6	108	6.00	18	30
740		0	CS	20	75	U	3.3	20.4	118	6.18	18	30
740	D	30	CS	10	60	NONE	3.5	22.2	129	6.34	18	30
740	D	45	CS	5	50	NONE	3.2	21.5	124	6.72	18	30
740	D	60	NONE	0	40	NONE	3.2	21.1	122	6.59	18	30
740	W	30	CS	10	60	NONE	3.5	21.2	123	6.06	18	30
740	W	45	CS	5	50	NONE	3.4	20.4	118	6.00	18	30
740	W	60	NONE	0	40	NONE	3.4	19.7	114	5.79	18	30
700		0	CS	10	70	NONE	3.2	19.1	115	5.97	10	12
700	W	35	CS	10	40	NONE	3.0	18.9	114	6.30	10	12
700	W	20	CS	10	60	NONE	3.3	20.4	123	6.18	10	12
700	D	35	CS	10	40	NONE	2.7	18.4	111	6.81	10	12
700	D	20	CS	10	60	NONE	3.0	18.7	113	6.23	10	12
670		0	CS	10	70	CGM	3.4	22.1	138	6.50	31	13
670	D	20	CS	10	60	CGM	3.4	21.7	135	6.38	31	13
670	D	40	CS	10	40	CGM	3.3	22.2	139	6.73	31	13
670		0	CS	85	0	CGM	2.5	22.4	139	8.96	31	13
670	D	20	CS	60	20	CGM	2.9	24.2	151	8.34	31	13
670	D	40	CS	40	20	CGM	2.9	25.3	158	8.72	31	13

(Continued)

Table 2. Diet composition and cattle performance in experiments evaluating corn gluten feed[1] (continued).

Start Weight	CGF Type[2]	CGF %	Roughage Type[3]	Roughage %	Corn %	Suppl CP[4]	ADG lbs	DMI lbs	g DMI/ kg $W^{.75}$	F/G	N[5]	REF[6]
860		0	COB	15	80	U	2.0	16.9	87	8.45	16	28
860	D	30	COB	15	50	NONE	2.3	19.4	100	8.43	15	28
860	D	60	COB	15	20	NONE	1.8	20.8	107	11.56	15	28
860	W	30	COB	15	50	NONE	2.4	19.8	102	8.25	15	28
860	W	60	COB	15	20	NONE	2.0	19.7	102	9.85	15	28
400		0	COB	40	40	SBM	3.4	12.9	119	3.75	53	18
400	D	60	COB	30	0	NONE	2.8	12.7	116	4.47	53	18
400	D	50	COB	30	0	SBM	3.0	13.0	119	4.33	53	18
400	D	45	COB	30	0	SBM	2.9	13.1	120	4.56	53	18
470		0	COB	40	40	SBM	2.3	14.3	116	6.11	47	18
470	D	60	COB	30	0	NONE	1.5	13.1	106	8.51	47	18
470	D	50	COB	30	0	SBM	1.7	13.5	110	8.04	47	18
470	D	45	COB	30	0	SBM	1.5	14.3	116	9.53	47	18
640		0	COB	45	40	U	2.4	17.1	110	7.13	27	31
640	D	30	COB	45	10	U	2.9	19.5	126	6.72	26	31
640	D	30	COB	45	10	SBM/U	2.9	19.3	124	6.66	27	31
715		0	COB	50	25	SBM/U	2.5	18.2	108	7.28	21	27
715		0	COB	50	40	U	1.7	16.3	97	9.59	21	27
715	D	40	COB	50	0	NONE	2.1	17.3	103	8.24	21	27
740		0	COB	25	70	SBM/U	2.9	20.4	118	7.03	18	29
740	W	30	COB	10	55	NONE	3.4	21.5	124	6.32	18	29
740	W	50	COB	10	40	NONE	3.3	21.9	127	6.64	18	29
740	W	70	NONE	0	30	NONE	3.1	19.4	112	6.26	18	29
780		0	COB	20	70	SBM/U	3.5	21.2	118	6.06	29	36
780	W	30	COB	10	55	NONE	3.4	20.7	115	6.09	29	36
780	W	50	COB	10	40	NONE	3.7	21.7	121	5.86	29	36
780	W	90	NONE	0	5	NONE	3.5	20.5	114	5.86	29	36
600		0	GRAS	50	40	BM	2.2	18.0	122	8.18	34	21
600	D	40	GRAS	50	0	BM	2.1	16.4	111	7.81	33	21
600	W	40	GRAS	50	0	BM	2.4	16.2	109	6.75	34	21

(Continued)

Table 2. Diet composition and cattle performance in experiments evaluating corn gluten feed[1] (continued).

Start Weight	CGF Type[2]	CGF %	Roughage Type[3]	Roughage %	Corn %	Suppl CP[4]	ADG lbs	DMI lbs	g DMI/kg $W^{.75}$	F/G	N[5]	REF[6]
780		0	ALF	100	0	NONE	2.5	23.5	131	9.40	16	15
780		0	ALF	80	20	NONE	2.9	23.9	133	8.24	16	15
780		0	ALF	40	60	NONE	4.0	27.7	154	6.93	16	15
780	D	20	ALF	80	0	NONE	3.1	24.4	136	7.87	16	15
780	D	60	ALF	40	0	NONE	3.7	26.6	148	7.19	16	15
720	D	50	SGS	10	40	NONE	3.0	20.8	123	6.93	44	10
720	W	50	SGS	10	40	NONE	3.0	19.4	114	6.47	44	10
720		0	SGS	10	80	SBM	2.9	18.8	111	6.48	44	10
720		0	SGS	10	90	U	2.8	17.1	101	6.13	44	10

[1]Abbreviations: ADG, Average Daily Gain, lb/day; DMI, dry matter intake, lb/day; g DMI/kg $W^{.75}$, grams dry matter intake/kg metabolic body weight; F/G, DMI/ADG. All % on dry matter basis.
[2]Type of CGF; W=wet, D=dry.
[3]Type of roughage; CS=corn silage, COB=corn cob; GRAS=grass hay; ALF=alfalfa silage; SGS=small grain silage.
[4]Type of supplemental crude protein; SBM=soybean meal; U=urea; CGM=corn gluten meal; BM=blood meal.
[5]N=number of cattle/treatment.
[6]REF=reference number.

Table 3. Means and ranges of cattle performance and diet composition from experiments evaluating corn gluten feed (only experiments using corn silage as the roughage).

Item	0% Corn Silage		10% Corn Silage			40% Corn Silage			70% Corn Silage		
	WCGF	DCGF	Corn	WCGF	DCGF	Corn	WCGF	DCGF	Corn	WCGF	DCGF
Number of classes	17	7	12	8	13	2	2	8	9	3	6
Initial body weight, lbs											
mean	720	800	664	785	730	800	700	610	713	780	690
range	600-900	700-900	400-780	740-900	580-820	700-900	700	550-790	580-800	780	550-900
Corn silage, % of DM											
range	0	0	10-20	5-20	5-20	33-45	32-50	30-50	67-80	56-80	60-80
CGF, % of DM											
mean	61	59	0	51	53	0	40	46	0	30	25
range	40-90	50-75	0	30-90	20-80	0	35-50	35-60	0	30	20-30
Corn, % of DM											
mean	36	41	79	33	29	50	14	9	22	0	1
range	5-56	25-50	70-90	0-60	0-55	40-60	0-21	0-20	10-30	0	0-10
Average daily gain, lbs											
mean	3.1	3.1	3.1	3.0	2.8	2.8	3.1	2.8	2.6	2.9	2.6
range	2.7-3.4	2.9-3.2	2.7-3.3	2.7-3.5	2.3-3.2	2.8-2.9	3.0-3.2	2.3-3.1	2.1-3.2	2.6-3.1	2.1-3.0
DM intake, lbs/day											
mean	19.3	20.3	19	19.6	19.9	17.5	20.4	19.1	17.6	18.8	17
range	16.7-21.2	16.5-22.8	17.3-20.4	17.8-21.2	17.1-23.0	16.3-18.7	19.4-20.9	15.6-23.0	14.3-21.2	17.1-19.8	14.8-20.3
DM intake, g/kg $W^{.75}$											
mean	114	111	119	109	116	95	121	127	104	104	103
range	94-140	94-122	99-182	92-118	98-130	81-113	117-123	105-156	84-146	95-110	100-111
Feed/gain											
mean	6.3	6.7	6.2	6.5	7.2	6.2	6.5	6.7	6.7	6.6	6.5
range	5.8-6.8	6.2-8.0	5.6-6.9	6.0-7.0	6.0-8.6	5.6-6.7	6.5-6.6	5.6-7.8	5.6-7.8	5.5-7.6	5.7-7.3

Table 4. Average performance of beef cattle fed diets containing different amounts of corn silage and wet or dry corn gluten feed[1].

Item	% CGF[2]	DCGF Amount of Corn Silage[2] 0	10	40	70	WCGF Amount of Corn Silage[2] 0	10	40	70
ADG, lbs/d									
	0	—	3.1	2.8	2.6	—	3.1	2.8	2.6
	30	—	2.9	3.0	2.6	3.0	3.3	3.2	2.9
	50	3.1	3.2	2.7	—	3.0	3.2	3.0	—
	75	3.0	2.6	—	—	3.1	2.8	—	—
DM Intake g/kg $W^{.75}$									
	0	—	123	97	106	—	120	97	106
	30	—	116	136	104	123	117	125	104
	50	105	124	116	—	112	100	118	—
	75	119	117	—	—	113	118	—	—
Feed/gain									
	0	—	6.2	6.2	6.7	—	6.2	6.2	6.7
	30	—	7.1	6.6	6.5	6.4	6.2	6.5	6.6
	50	6.2	6.2	6.7	—	6.3	6.3	6.6	—
	75	7.3	7.2	—	—	6.4	7.0	—	—
Number of Observations									
	0	0	11	2	9	0	11	2	9
	30	0	6	4	6	2	3	2	3
	50	4	1	2	0	6	2	1	0
	75	3	6	0	0	6	2	0	0

[1]Remainder of diet was corn grain and supplement.
[2]Amounts on a dry matter basis.

These data indicate that the energy value of CGF is not constant but dependent upon the amount of silage in the diet. As silage content of the diet increases, the energy value of CGF relative to corn increases. Probably, this is because of the negative associative effects corn has on fiber utilization. General relationships between amount of corn silage in the diet and energy value of WCGF and DCGF relative to corn were developed by regressing percent dietary corn silage (dry matter basis) on feed to gain ratio expressed as a percent of the control. The resulting equations were:

For DCGF: Y=83+ .3 (% CS)
For WCGF: Y= 93+ .15 (% CS)
Y=energy value of CGF relative to corn
(100=no difference between corn and CGF).

Wet versus Dry CGF

The largest set of data are from experiments where corn silage was the roughage (19 experiments involving 1700 animals). For purposes of this review, the data from the corn silage subset were divided into groups fed low silage diets (5-20 percent of DM, designated 10 percent), medium silage diets (30-50 percent of DM, designated 40 percent), and high silage diets (60-80 percent of DM, designated 70 percent). Within each corn silage level, diets were grouped into animals fed WCGF, DCGF, and corn. Means and ranges of diet composition and performance data for this breakdown are in Table 3. Based on this categorization scheme, cattle fed WCGF usually grew faster than did cattle fed DCGF. Furthermore, cattle fed WCGF in high silage diets grew faster than cattle fed corn in high silage diets. Cattle fed DCGF generally grew slower or at similar rates than did cattle fed corn grain over all silage levels. For low and medium silage levels, feed efficiency was generally higher for cattle fed corn grain than for cattle fed CGF. At the high silage level (70 percent), feed to gain ratios were similar among all energy sources. Cattle fed WCGF gained weight 14 percent more efficiently than did cattle fed DCGF in diets containing no forage, but differences became much smaller as amount of forage in the diet increased (Table 4).

Dry matter intake per unit of metabolic body weight was similar between DCGF and WCGF over all silage levels. Both followed a quadratic response with a maximum intake at about 40 percent silage. A possible explanation for this is that at low silage levels (high concentrations of CGF), dietary factors such as excessive moisture content or molds for WCGF, or dustiness, and small particle size for DCGF might restrict intake, and at high silage concentrations, fiber content of the total diet may be high enough to limit intake. At intermediate silage levels, the problems with palatability might be masked, and due to associative effects of CGF, fiber digestion would be high. Dry matter intake of cattle fed corn grain generally declined as silage concentration increased.

A consistent finding was that WCGF was generally superior to DCGF when diets containing less than 70 percent silage were fed. Digestibility of DM and NDF is usually 5-10 percent higher in diets containing WCGF as compared to DCGF. There are at least three reasons for this. First, particle size differences between WCGF and DCGF could bias fiber digestion data as discussed earlier. This, however, would have no effect on DM digestibility. A second possibility is the influence of particle size on fiber digestion in the rumen. Particle size of WCGF is larger than DCGF (Firkins et al., 1985). Generally, particles smaller than about 1 mm are not retained in the rumen. Since extent of ruminal fiber digestion is dependent on time spent in the rumen, digestibility of small fibrous particles may be less than the digestibility of larger fibrous particles. However, most of the research examining particle size effects on fibrous feeds have compared small particles (mm) to large particles (cm). It is unknown whether changes in digestibility of fibrous feeds would be caused by a difference in mean particle size of about 1 mm. Reducing mean particle size of corn, a low fiber feed, from 4.7 mm to 1.2 mm had virtually no effect on passage rate out of the rumen (Ewing et al., 1986). Performance of feedlot steers also was similar when fed cracked or finely ground corn (mean particlesize not given) in high grain diets (Turgeon et al., 1983). Another possibility is that heating changes the chemical make-up of the CGF. In certain batches, dry matter digestibility of CGF was influenced by drying temperature, but this was not consistent among batches (Oliveros et al., 1987). Heating forages reduces the digestibility of all fiber constituents, but hemicellulose (NDF-ADF) is especially susceptible (Weiss et al., 1986). Corn gluten feed is high in hemicellulose and, therefore, may be highly susceptible to heat damage. More research is needed to determine the cause of the lower nutrient value of DCGF as compared to WCGF.

Effects of Concentration of CGF in Diet

The corn silage data set was broken down further by corn silage level, type of CGF, and amount of CGF. For simplification, amount of CGF fed was grouped into 0, 30 percent (10-35 percent of DM), 50 percent (40-60 percent of DM), and 75 percent (>60 percent of DM). Performance data are in Table 4. Due to the partitioning of the data, many cells contain means based on only a few experiments. In general, replacement of WCGF and DCGF for corn grain resulted in the same general trends. Increasing amount of WCGF or DCGF in diets with no silage had no effect on average daily gain (ADG) or feed efficiency. When about 10 percent silage was fed, ADG and feed efficiency decreased when high amounts of CGF were fed (low amounts of corn). In high silage diets, adding WCGF to the diet improved ADG, but did not affect feed efficiency. With DCGF in high silage diets, ADG and feed efficiency tended to decrease as the amount of DCGF in the diet increased.

Carcass Characteristics and Health

In most finishing trials, including CGF in the diet did not consistently influence dressing percent, yield, or quality grade. In an extensive study, Trenkle (1988c) found that feeding CGF did not affect carcass characteristics or chemical composition of the carcass.

Diets containing CGF instead of corn have lower concentrations of starch. There has been speculation that cattle fed CGF may have reduced incidences of acute and subacute acidosis and liver abscesses compared to cattle fed corn-based diets. Ruminal pH tends to be higher in animals fed CGF instead of corn (Firkins et al., 1985; Kampman and Loerch, 1988); however, no consistent trend of reduced liver abscesses in cattle fed CGF instead of corn has been found. An unconfirmed case of polioencephalomalacia (polio) was reported when large amounts of freshly made WCGF were fed; however, no reports of WCGF causing increased incidence of polio were found in the scientific literature. Some researchers recommend that cattle be supplemented with thiamin when large amounts of WCGF are being fed. Thiamin supplementation can reduce the incidence of polio.

Summary

Corn gluten feed is a diverse and flexible feedstuff that can be used successfully as a source of protein and energy in the diets of growing-finishing beef cattle. The value of CGF protein is similar or slightly less than that of soybean meal protein. As an energy source, WCGF is usually nutritionally superior to DCGF. However, problems with storage and high transportation cost will limit the use of WCGF to those producers that are close to manufacturing sites. In high forage diets, DCGF is equivalent to corn with respect to ADG and slightly superior to corn with respect to feed efficiency. In high grain diets, corn produces faster and more efficient gains than does DCGF. Cattle fed WCGF gained faster than cattle fed corn in medium to high silage diets, but in low silage diets, gains were similar. Feed efficiency was improved for cattle fed corn as compared to cattle fed WCGF under most conditions except in high silage diets where feed efficiencies were similar. A potential problem with using CGF in diets is the great variability in nutrient composition of the feedstuff. To obtain max-

imum performance when feeding CGF, diets must be balanced; therefore, the composition of the CGF must be known. Published values for composition of CGF should only be used as a guide.

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