ILLINOIS RESEARCH ON DISTILLERS GRAINS: BEEF CATTLE AND COMPANION ANIMAL STUDIES

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SUMMARY

During the past 10 years, our laboratory has been involved in research on the nutritional value of distillers grains with solubles (DGS). In our ruminant research, we compared both wet and dry forms of DGS to wet and dry forms of corn gluten feed (CGF). In situ, N of wet vs dry DGS and N of wet vs dry CGF disappeared at similar rates. However, N disappearance rates were greater for wet and dry DGS. In a ruminal escape trial, percentage protein apparently escaping ruminal fermentation was greater for steers fed wet DGS (47%) or dried DGS (54%) than for those fed wet CGF (26%) or dry CGF (14%). Under feedlot conditions, steers fed dry DGS performed better than steers fed soybean meal-corn silage growing diets. Wet DGS can be fed at levels of at least 50% of diet dry matter (DM) in finishing diets and maintain performance comparable with that of steers fed corn-based diets. In mature dogs, nutrients in DGS-containing diets are well digested up to DGS levels approximating 25% of DM. In puppies, a five percentage unit decrease in DM and energy digestion occurred when the level of dietary DGS was approximately 14%.

Key Words: Distillers dried grains with solubles, Beef cattle, Dogs, Digestibility, Ruminal fermentation.

INTRODUCTION

The fermentation of carbohydrates to produce ethyl alcohol is among the oldest biological phenomena known to mankind. Production of beverage spirits is the main result of this process but fuel shortages, which occur occasionally, stimulate interest in the substitution of alcohol for petroleum™ based fuels. When grains are fermented to alcohol, approximately 33% of the original DM may be recovered. The four main products resulting from the fermentation process are condensed distillers solubles (CDS), distillers dried solubles (DDS), distillers dried grains (DDG) and distillers dried grains with solubles (DDGS). Approximately 40% of the DM recovered is solubles and 60% is dried grains.

The main effect of grain fermentation is starch removal, resulting in a three-fold increase in the concentration of remaining nutrients. Corn, for example, is converted from a high energy feed to a protein supplement relatively high in fiber. The nutrient composition of corn vs DDG and

DDGS resulting from the fermentation of the corn indicates that the crude protein content is increased from approximately 9% for the corn to 28% for the DDG and DDGS. Neutral detergent fiber (NDF) increases from approximately 10% in corn to approximately 43% in DDG and DDGS. The total digestible nutrient (TDN) content is reasonably similar for the three products. Comparing the nutrient composition of DDGS with soybean meal, the major difference is that DDGS are lower in crude protein (27 vs 49%) and higher in fiber (43 vs 10%). The DDGS are also higher in fat than is soybean meal (8 vs .9%) with calcium, phosphorus and TDN being reasonably similar. The energy value of corn DDGS per unit of DM is approximately 91, 85 and 71% for cattle, swine and poultry, respectively. The differences among species reflect the ruminant's ability to digest more of the fiber as compared to nonruminants.

BEEF CATTLE RESEARCH

Beef cattle have two unique capabilities as food-producing animals. First, because their ruminal microbial population produces the enzyme, cellulase, cellulose and other fibrous materials can be fermented. Thus, the fiber in by-product feeds such as DDG can be used as an energy source. Secondly, because the microbes produce the enzyme, urease, and can assimilate ammonia and carbon skeletons to form amino acids, nonprotein nitrogen can be converted to animal protein. However, these ruminal microbes also degrade dietary proteins to ammonia and then use this ammonia to synthesize microbial protein. Depending on the quality of the feed protein digested and the amount of energy available to synthesize microbial protein, this may be a very inefficient process. Consequently, in most cattle diets requiring supplemental protein, a plant protein source which escapes microbial digestion in the rumen and then is digested in the small intestine will result in the greatest weight gain per unit of supplemental protein. This assumes that there is adequate ruminal ammonia from the basal ingredients in the diet or from supplemental urea. Distillers dried grains with solubles has proven to be a protein source which is resistant to ruminal digestion. Satter et al. (1977) and Waller et al. (1980) both estimated that approximately 60% of the DDGS protein passed out of the rumen intact. By comparison, most research suggests that only 30 to 40% of soybean meal protein escapes ruminal digestion.

We conducted a number of experiments examining the ruminal N degradability and escape value of wet and dry DGS vs wet and dry CGF (Firkins et al., 1984). Corn gluten feed is lower in crude protein content compared to DGS because much of the gluten protein is separated from CGF during wet™ milling. Corn gluten is a relatively insoluble protein, so CGF protein would be expected to be more soluble than protein of DGS. Because solubility may influence extent of ruminal protein degradation, CGF protein may be degraded more rapidly than protein of other corn by-products. While ruminal escape characteristics of dry distillers grains (DDG) had been researched (Satter et al., 1977; Waller et al., 1980), little was known about ruminal degradation of protein in wet distillers grains (WDG). Consequently, N solubilities and ruminal degradability of DDG and WDG vs dry CGF (DCGF) and wet CGF (WCGF) were compared.

Nitrogen solubility and in situ N disappearance results are presented in table 1. Acid detergent insoluble N (ADIN) as a percentage of N was determined for WDG (15.6), DDG (12.3), WCGF (3.0), DCGF (3.2) and soybean meal (6.5). Nitrogen of WDG was more insoluble in modified Burrough's mineral mix (artificial saliva) than was N of DDG. Wet corn gluten feed N was more insoluble than was DCGF N, but both were less insoluble in the mineral mix than was N from soybean meal, WDG or DDG. No effect of pH on N solubility was noted for WDG, DDG, WCGF or DCGF at pH 5, 6 or 7 (data not shown). Rate and extent of disappearance of N from dacron bags was not affected by form (wet vs dry) of DGS. Less N remained in dacron bags containing WCGF or DCGF than in those containing soybean meal at 8 h. Rates of N disappearance of WCGF and DCGF were similar to those of soybean meal.

TABLE 1. NITROGEN SOLUBILITY AND IN SITU NITROGEN DISAPPEARANCE DATA

Feed Source	N	ADIN[a]	N insolubility[b]	In situ residual N 8 h	In situ residual N 96 h	Rate of in situ N disappearance between 2 and 8 h
	% DM	--------% N	--------% N--------	--% of original N--	--% of original N--	%/h
WDG	4.93	15.6	99.5^{c}	77.7^{c}	.38^{c}	3.90^{d}
DDG	5.43	12.3	94.4^{d}	73.4^{c}	.68^{c}	4.27^{d}
WCGF	3.34	3.0	58.7^{f}	15.6^{e}	.08^{d}	9.46^{e}
DCGF	3.44	3.2	46.3^{g}	17.5^{e}	.09^{d}	8.93^{e}
Soybean meal	8.29	6.5	77.9^{e}	29.2^{d}	.04^{d}	9.97^{e}
SEM	-----	-----	.4	1.9	.11	.97

aAcid detergent insoluble N expressed as a percentage of N.
bAmount not solubilized after 1 hincubation in modified Burrough's mix expressed as a percentage of total N.
c,d,e,f,gMeans in the same column with different superscripts differ (P<.05).

Higher ADIN of WDG and DDG than of WCGF and DCGF may indicate greater heat damage of DGS during processing. Differences in N solubility between DGS and CGF probably were due to differences in processing techniques. In the wet-milling steeping process, dilute acid may cause some hydrolysis of CGF protein. The more insoluble corn gluten is removed during wet-milling which explains the greater N insolubility of DGS, which contain gluten protein. Processing techniques had a dramatic effect on in situ disappearance of these by-product feeds. The WCGF contained more insoluble N than did DCGF, but it disappeared from dacron bags more rapidly so that by 8 h, only 15.6 and 17.5% of the original N in WCGF and DCGF remained in the bags. This is in comparison with 29.2% of the original soybean meal N and 77.7 and 73.4% of the original WDG and DDG N that remained after 8 h of incubation.

Amount of protein of WDG, DDG, WCGF and DCGF escaping ruminal fermentation was determined using five Angus-Hereford steers (550 kg) fitted with ruminal t-type duodenal cannulae. A 5 X 5 Latin square design was used with diets, periods and animals as factors. The basal diet contained chopped hay, cracked corn and corn cobs as the major ingredients and was supplemented daily with the by-product feeds due to storage problems of wet feeds. Diets were balanced to contain 70% TDN and 13.5% crude protein. Because postruminal N flow is subject to large variations other than those from diet, this concentration of protein was used to increase the probability of detecting treatment differences. Results are presented in table 2. Duodenal N flow tended to be greater for wet and dry DGS treatments compared with wet and dry CGF treatments, reflecting greater ruminal escape of the DGS protein. Ruminal escape of DDG protein measured in this study (54%) is similar to that in other reports. Satter et al. (1977) estimated that approximately 60% of the protein in DDG and DDGS escaped degradation in the rumen. Using lactating dairy cows, Santos et al. (1983) determined that 54% of the DDGS-containing diet escaped ruminal fermentation compared to 30% for a soybean meal-containing diet. Forty-seven percent of WDG protein escaped ruminal fermentation in our trial. Ruminal escape of WDG and DDG protein is higher than soybean meal escape values (15 to 28%; Loerch et al., 1983). Also, ruminants should derive similar benefits from ruminal escape of WDG to those described for protein in DDG (Klopfenstein et al., 1982).

TABLE 2. EFFECTS OF FEEDING CORN BY-PRODUCT FEEDS ON NITROGEN FLOW AT THE DUODENUM OF STEERS

Item	Treatment					
	Urea	WDG	DDG	WCGF	DCGF	SEM
N intake, g/d[b]		163.2	170.2	165.2	161.4	3.8
N intake from protein source, g/d[c,d]		86.6	93.6	84.6	84.7	1.1
Total duodenal N flow, g/d		202.8	210.6	165.6	192.6	13.4
Duodenal N flow, % of intake		124.5	123.7	100.0	119.4	9.3
Protein source N escaping ruminal degradation, %[c]		47	54	26	14	8.5

aWDG = wet distillers grains; DDG = dry distillers grains; WCGF = wet corn gluten feed; DCGF = dry corn gluten feed.
bComparison of urea vs WDG, DDG, WCGF and DCGF (P<.05). cComparison of WDG and DDG vs WCGF and DCGF (P<.05).

Neutral detergent fiber intake and apparent ruminal digestion were higher for steers fed WDG and DDG vs WCGF and DCGF (table 3). Because corn is steeped in dilute acid in the wet-milling process, some of the hemicellulosic sugars may be solubilized. This could reduce NDF content of CGF and leave a residual NDF fraction that is more resistant to digestion than is NDF in DGS. Apparent ruminal NDF digestibility was lowest for steers fed the urea diet, reflecting the relatively higher intake of corn cob fiber as a proportion of total fiber intake.

TABLE 3. DRY MATTER AND NEUTRAL DETERGENT FIBER (NDF) INTAKE AND RUMINAL DIGESTION BY STEERS FED CORN BY-PRODUCT FEEDS

Item	Treatment[a]					
	Urea	WDG	DDG	WCGF	DCGF	SEM
Dry matter intake, g/d	6,800	6,800	6,800	6,800	6,800	
Apparent ruminal dry matter digestion, %[b]	44.7	57.7	57.3	57.4	49.2	4.2
NDF intake, g/d[b,c]	3,140	3,899	3,876	3,447	3,433	48
Apparent ruminal NDF digestion, %[b,c]	33.9	62.6	63.5	53.8	47.2	4.1

aWDG = wet distillers grains; DDG = dry distillers grains, WCGF = wet corn gluten feed; DCGF = dry corn gluten feed.
bComparison of urea vs WDG, DDG, WCGF and DCGF (P<.05).
cComparison of WDG and DDG vs WCGF and DCGF (P<.05).

Performance of feedlot cattle fed DDG (Waller et al., 1980) or WDG (DeHaan et al., 1982) has been comparable with performance of cattle fed soybean meal. Firkins et al. (1985) conducted a finishing trial with 132 crossbred steers (avg. initial BW, 310 kg) to determine the efficacy of WDG as an energy source. Wet distillers grains were fed at 0, 25 and 50% of diet DM. The basal diet consisted of 13% chopped hay, 72% high moisture corn and 14.8% supplement. Wet distillers grains were added at 25 or 50% (DM basis), replacing soybean meal and high moisture corn. The WDG fed in this experiment contained an average of 38% DM and 28.8% crude protein. Results are presented in table 4.

TABLE 4. GROWTH PERFORMANCE OF STEERS FED INCREASING LEVELS OF WET DISTILLERS GRAINS (WDG)

Item	% WDG			
	0	25	50	SEM
Initial weight, kg	310	309	309	
Final weight, kg	424	431	437	
Daily gain, kg[a]	1.08	1.15	1.20	.04
Daily feed, kg	6.99	7.43	7.02	.13
Feed gain[b]	6.57	6.50	5.92	.21

aLinear treatment effect (P<.08).
bLinear treatment effect (P<.07).

A linear increase in daily gain due to level of WDG in the diet was observed. Feed/gain was also improved linearly due to the presence of WDG in the diets. Steers fed 50% WDG consumed as much DM as those fed the control diet. There were no significant differences in carcass characteristics due to dietary treatment (data not shown).

In this study, crude protein levels ranged from 12% for the control diet to 18.8% for the 50% WDG diet. However, performance responses to protein levels above 12% are seldom noted for heavier feedlot cattle (Fox et al., 1977). Because the net energy value for gain is higher for corn than for DDG (1.43 vs 1.33 Mcal/kg DM; NRC 1976), it is difficult to explain the improved feedlot performance noted in this trial. The most plausible explanation is that WDG contain more digestible energy than NRC (1976) lists for DDG. Because nearly all of the original cornstarch is removed during the distilling process, it is also possible that ruminal pH may not have been decreased to the same extent as with higher corn diets. Therefore, fiber digestibility may have increased due to inclusion of WDG in the diets. These results suggest that WDG can be utilized effectively as an energy source in feedlot cattle diets at levels as high as 50% of dietary DM.

In another feedlot study, 84 Charolais steers (avg. initial BW, 274 kg) were used. Corn silage and soybean meal (7.8% of dietary DM) in the control diet were replaced with DCGF (34.9%), WCGF (34.9%) or DDG (17.4%) to balance all diets at 11.5% crude protein. Results are presented in table 5.

TABLE 5. PERFORMANCE OF GROWING STEERS

Item	Treatment[a]				
	DCGF	WCGF	SBM	DDG	SEM
Initial weight, kg	275	276	274	273	
Final weight, kg	422	418	394	426	
Daily gain, kg	1.52[b,c]	1.46[c]	1.24[d]	1.57[b]	.02
Daily feed, kg	10.42[b]	9.52[c]	9.61[c]	8.99[c]	.18
Feed gain	6.86[c]	6.52[c]	7.73[b]	5.71[d]	.10

aDCGF = dry corn gluten feed; WCGF = wet corn gluten feed; SBM = soybean meal; DDG = dry distillers grains.
b,c,dMeans in the same row with different superscripts differ (P<.05).

Steers fed all diets had excellent rates of gain and F/G, probably due to compensatory gain and the growth potential of these Charolais steers. Steers fed DDG gained faster and more efficiently than did those fed the other diets. This may be due to lower ruminal degradability of DDG protein (Satter et al.,1977; Waller et al., 1980; Firkins et al., 1984), resulting in a higher escape of amino acids to the small intestine. These results may have been magnified by the relatively higher protein requirements of these large-framed, rapidly growing steers (Fox et al., 1977).

No direct comparisons can be made between WDG and DDG because they were not fed under the same experimental conditions. However, feeding both WDG and DDG-containing diets resulted in improved feedlot performance compared with their respective controls. Furthermore, N, DM and NDF digestibilities were similar for lambs fed WDG or DDG (data not shown). These results agree with those of DeHaan et al. (1981) and Abrams et al. (1983), suggesting that WDG are at least equal to DDG as protein sources for growing cattle and lambs.

COMPANION ANIMAL RESEARCH

The dog has successfully adapted over time to a wide variety of feeding regimens and this characteristic has permitted the feeding of diets which differ markedly in chemical composition and physical characteristics. Use of by-product feeds in pet diets has been limited, purportedly because of the relatively inefficient digestibility of the fibrous components of these by™ products. Early work with CDS was conducted by McCay et al. (1957) who found 7% CDS in dog diets to be satisfactory on the basis of weight gain and blood measurements. Wanner et al. (1958) found conception to be excellent and litter size and weaning rate satisfactory when 7% CDS replaced a portion of a meat scrap control.

Allen et al. (1981) conducted four trials to evaluate the utilization of DDGS by dogs. In each trial, 12 female English Pointers were used. The dogs were fed an extruded corn-extruded soybean meal-based diet with DDGS replacing corn and soybean meal in varying amounts. Tallow, a vitamin premix and a mineral mix made up the remaining components of the diet.

In trials 1 and 2 (table 6), 600 g of diet moistened with equal parts of water were fed. Dogs averaged 19.3 kg in BW and were approximately 2 years old. In trial 1, there were no differences among treatments in any of the measurements taken. Low levels of DDGS substituted into corn-soybean meal diets appear to have no effect on apparent digestibility of DM or starch. The amount of DM in the feces was lower with DDGS additions, but this difference was not significant. In trial 2, starch digestibility was not affected by either level of DDGS supplementation. Apparent DM digestibility was lowest at the 15.7% level of DDGS supplementation and tended to decrease as the level of dietary DDGS increased. Fecal DM was highest at the 15.7% level of DDGS supplementation. These trials indicate that moderate levels of DDGS can be successfully incorporated into the diet of the mature dog. While digestibility coefficients tended to decline with DDGS supplementation, none of the values were abnormally low. Rather significant portions of traditional dietary energy and protein sources apparently could be conserved through DDGS substitution.

TABLE 6. DIGESTIBILITY DATA AND FECAL WEIGHTS FOR DOGS IN TRIALS 1 AND 2

	Digestability, %		Fecal Analyses	
Level of DDGS[a], %	Dry matter	Starch	Dry matter, %	Wet weight, g/5d
Trial 1				
0%	83.6	97.8	17.7	2,513
4%	83.4	99.2	16.4	2,500
6%	82.3	98.2	16.4	2,813
8%	82.1	95.3	16.5	2,299
SEM	.4	.6	.4	80
Trial 2				
0%	84.8[b]	98.1	16.2[b]	2,300[b]
8.9%	83.6[b]	99.0	15.6[b]	2,632[b]
15.7%	79.9[c]	97.5	17.9[c]	3,021[c]
SEM	.3	.6	.2	73

aDDGS = distillers dried grains with solubles.
b,cMeans in the same column with different superscripts differ (P<.05).

In trial 3, we determined whether high levels of DDGS were detrimental to the dog, considering the increase in the level of dietary fiber consumed. Dogs with an average initial BW of 17.8 kg and an average age of 1.5 years were fed 540 g of each diet moistened with an equal quantity of water. Results are presented in table 7. Crude protein digestibility was not affected at either level of dietary DDGS, although digestion tended to be reduced at the 26.1% level. Apparent DM digestibility and energy digestibility were reduced at the 26.1% level of DDGS supplementation. This decrease was not severe and it appears that inclusion of DDGS in traditional dog diets, even at levels approximating 25% of diet DM, could be a practical feeding alternative.

TABLE 7. DIGESTION COEFFICIENTS FOR DOGS FED 13.1 AND 26.1% DISTILLERS DRIEDGRAINS WITH SOLUBLES (DDGS; TRIAL 3)

	Level of DDGS, %			
Item	0	13.1	26.1	SEM
Dry matter	74.9[a]	74.0[a]	69.6[b]	.2
Energy	79.8[a]	78.2[a]	74.0[b]	.2
Crude protein	75.5	75.4	72.4	.2

a,bMeans in the same row with different superscripts differ (P<.05).

In trial 4, we tested the response of puppies (avg. initial BW, 7.1 kg; average age, 5 mo) to an intermediate dietary level (14.1%) of DDGS; this level had no effect on nutrient digestibilities by the adult dog. Puppies were fed 220 g diet/d in two equal increments. Results are presented in table 8.

TABLE 8. DIGESTION DATA FOR PUPPIES FED A DIET SUPPLEMENTED WITH DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS)

Item	Level of DDGS, % 0	14.1	SEM
Digestability, %			
Dry matter	85.7[a]	81.2[b]	.5
Acid detergent fiber	39.3[a]	64.6[b]	1.5
Energy	86.9[a]	81.6[b]	.6

a,bMeans in the same row with different superscripts differ (P<.01).

Acid detergent fiber digestibility was increased by the addition of DDGS to the diet. The growing dog apparently has the capacity to establish, at an early age, the intestinal microbial population necessary to ferment the fiber in DDGS. Distillers dried grains with solubles contain a high concentration of hemicellulose, a plant cell wall component that is more readily digested by nonruminant animals than are other fibrous constituents such as cellulose. Another factor to consider is that the fiber in DDGS is more fermentable than the fiber in extruded corn and extruded soybean meal, the major constituents of these diets. Also, the extrusion process could negatively affect the digestibility of their fiber constituents.

While DM digestibility and energy digestibility were decreased by DDGS addition, neither were severely depressed, indicating the potential efficacy of including DDGS in diets for puppies. Nitrogen balance (data not shown) was not affected by DDGS supplementation.

Distillers dried grains with solubles can be utilized effectively by dogs in diets containing adequate or greater than adequate quantities of essential nutrients. As is the case for other species with the exception of ruminants, these fibrous materials will likely be incorporated, at least at the higher levels, into diets fed to dogs at maintenance or those in gestation. Growing, working and (or) lactating animals need to be provided with diets which will ensure positive N and energy balances. Inclusion of certain types of fibrous feeds into these diets may affect negatively both of these criteria.

GENERAL CONCLUSION

Feeding strategies have been established which allow for the use of distillers feeds in diets of both ruminant and nonruminant animals. Given our more precise knowledge of animal nutrient requirements, and given the wide variety of supplements which may be formulated to aid in proper utilization of the energy portion of animal diets, strategies can be developed where the feeding of by-product feeds such as DGS may be alternated with periods where possibly better quality feed ingredients are required. It is apparent that distillers feeds occupy a position of importance in animal nutrition.

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