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Summary

Six experiments were conducted to determine the ability of both adult and immature dogs to utilize various byproduct feedstuffs (distillers dried grains with solubles, beet pulp, grape pomace and tomato pomace). Supplementation of diets with low levels (4 to 8%) of distillers dried grains with solubles (DDGS) had no effect on the apparent digestibility of dry matter (DMD) or starch by adult dogs. Moderate levels of DDGS (16.1%) depressed ($P<.05$) DMD and had no effect on starch or energy digestibility. High levels of DDGS (26.1%) decreased ($P<.05$) DMD and energy digestibility and had no effect on crude protein digestibility. Growing puppies fed a moderate level of DDGS (14.1%) digested less ($P<.01$) dry matter and energy but more ($P<.05$) ADF than puppies fed no DDGS. N intake and fecal N were reduced ($P<.01$) by DDGS supplementation. Urinary N, total N, absorbed N and retained N were not affected by treatment. Each of two levels of beet pulp (6 and 12%) reduced ($P<.05$) dry matter digestibility by adult dogs, but energy and crude protein digestibilities were not affected. Acid detergent fiber digestibility was increased ($P<.05$) when 6% beet pulp was incorporated into the diet. Adult dogs fed 8% tomato pomace digested significantly less dry matter, energy and crude protein than dogs given no tomato pomace. Grape pomace addition depressed ($P<.01$) digestibilities of all nutrients tested.

(**Key Words:** Dogs, Distillers Dried Grains with Solubles, Beet Pulp, Pomaces, Nutrient Digestion, Nitrogen Balance.)

Introduction

Pet food sales have increased yearly for the past 25 years, reaching approximately \$3.288 billion from the sale of 4,246,000 metric tons annually (McCook, 1979). Therefore, efforts to find more economical nutrient sources less competitive with human foodstuffs have been intensified. Mowat (1980) indicated that the majority of human foods and beverages leave byproducts that are not consumed by humans. Frequently, these byproducts have a higher nonenergy nutritional value than the original products (e.g., soybean meal).

While many of these byproducts have been widely used in ruminant feedstuffs, their use in nonruminant nutrition, especially in pet feeding, has been limited, purportedly because of the relatively inefficient digestibility of fibrous feedstuffs by nonruminants. Although there has been little research on the digestibility of these feedstuffs by dogs, early work with corn distillers solubles was conducted by McCay *et al.* (1957), who found 7% distillers solubles 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% distillers dried solubles replaced a meat-scrap control.

Fiber is important in the control of intestinal activity in dogs (Corbin *et al.*, 1980). In addition, although fiber is not degraded by digestive enzymes, it can be fermented to VFA by gut microflora and possibly used as an energy source (Banta *et al.*, 1979).

With the increase in the availability of byproducts, especially with the recent emphasis on gasohol production, it is important that we maximize the use of these resources and determine the efficiency with which the companion animal can utilize them. The purpose of this work, then, was to evaluate the biological responses evoked by the feeding of various byproduct feedstuffs (distillers dried grains with solubles, beet pulp, tomato pomace and

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grape pomace) to both mature and young, actively growing dogs.

Materials and Methods

Four trials were conducted to evaluate the incorporation of distillers dried grains with solubles (DDGS) into dog diets. In each trial, 12 female English Pointers were used. The animals were kept in individual metabolism cages in a room maintained at temperatures ranging from 20 to 23 C. The dogs were placed in the cages 5 days before the start of the experiment so that they could become acclimated to the environment and to the diet. The animals were fed a corn-soybean meal-based diet with DDGS replacing corn and soybean meal in varied amounts.

In trial 1, dogs with an average initial weight of 19.4 kg and an average age of 2 years were assigned to each of the four diets outlined in table 1. A completely randomized design was used, with three dogs assigned to each treatment. The trial consisted of two periods, each comprising a 5-day preliminary period and a 5-day excreta collection period. In each period, a 10% aliquot of feces was retained and oven-dried at 50 C for subsequent analyses. Each dog was fed once daily 600 g of feed moistened with equal parts water. Refusals of wet feed were recorded. Water was provided *ad libitum.*

In trial 2, higher levels of DDGS (table 1) were included in diets calculated to be isonitrogenous and isocaloric on the basis of the following values: corn, 8.5% crude protein (CP), 3.2 kcal metabolizable energy (ME)/g; soybean meal (SBM), 50% CP, 3.11 kcal ME/g; DDGS, 24% CP, 3.57 kcal ME/g; fat, 8.65 kcal ME/g. A Latin square design was used, with three periods (each including 5-day preliminary, 5-day collection), three treatments and four replications per treatment. Dogs (average weight, 19.2 kg; average age, 2 years) were randomly assigned to treatments, and all dogs received all treatments. All other conditions were the same as in trial 1.

In both trials 1 and 2, percentage dry matter digestibility (DMD), percentage starch digestibility, percentage DM in the feces and fecal wet weights were measured. Starch was measured by the procedure of Macrae and Armstrong (1968).

In trial 3, high levels of DDGS were incorporated into diets, and the effects on digestibilities of various dietary constituents were evaluated. The ingredients and chemical composition of the diets are presented in table 2. Dogs with an average intial weight of 17.8 kg and an average age of 1.5 years were randomly allotted to treatments in a Latin square design consisting of three periods, three treatments and four replications per treatment. Each dog was fed

TABLE 1. INGREDIENT IN DIETS FED TO DOGS IN TRIALS 1 AND 2

Dietary ingredients	Level of DDGS, %						
	0	4.0	6.0	8.0	0	8.9	15.7
	Trial 1				Trial 2		
Extruded corn (IFN 4-02-935)	54.5	50.5	48.5	46.5	53.6	48.6	45.0
Extruded soybean meal (IFN 5-04-612)	30	30	30	30	30.9	27.6	25.0
DDGS (IFN 5-02-843)[a]	0	4	6	8	0	8.9	15.7
Tallow[b]	10	10	10	10	10	9.4	8.8
Vitamin premix[c]	.5	.5	.5	.5	.5	.5	.5
Mineral mix[d]	5	5	5	5	5	5	5

[a]DDGS (distillers dried grains with solubles) was obtained from the Distillers Feed Research Council, Cincinnati, OH.

[b]Bleachable fancy tallow for these diets was obtained from National Rendering, Peoria, IL.

[c]Composed of the following vitamins (per kilogram of premix): vitamin A, 500,000 USP units; vitamin D_3, 100,000 ICU; vitamin E, 4,000 IU; menadione sodium bilsulfite, 150 mg; thiamine mononitrate, 200 mg; riboflavin, 150 mg; pantothenic acid, 600 mg; niacin, 1 g; choline chloride, 30 g; vitamin B_{12}, 2 milligrams.

[d]Composed of the following minerals (percentage of mineral mix): $CaHPO_4$, 65%; NaCl, 15.4%; K_2CO_3, 14%; $MgCO_3$, 3.3%; $FeSO_4 \cdot H_2O$, 1%; $MnSO_4 \cdot H_2O$, .05%; $CoCl_2 \cdot 6H_2O$, .02%; $CuSO_4$, 1%; NaF, .02%; $ZnCO_3$, .2%; KI, .01%; $NaSeO_3$, .0001%.

once daily 540 g of feed moistened with an equal quantity of water. This quantity of feed met the normal maintenance requirements of the adult dog. The preliminary and excreta collection periods were 5 days each. Digestibilities of DM, energy and CP were evaluated. Dietary energy was measured by bomb calorimetry (in a Parr adiabatic bomb calorimeter) and N by the macro-Kjeldahl technique (AOAC, 1975).

In trial 4, a moderate level of DDGS was fed to growing puppies, and the effect on nutrient digestion and N balance was determined. Twelve female puppies with an average intial weight of 7.1 kg and an average age of 5 months were randomly assigned to treatments in a switchback design, with two periods, two treatments and six replications per treatment. The dogs were fed twice daily and water was available *ad libitum*. During the preliminary period, dogs were allowed to adjust to their individual *ad libitum* intakes. The dogs were then offered 90% of the *ad libitum* intake of the dog with the lowest consumption. Daily urine samples were collected in buckets containing 10 ml of 30% HCl and diluted to 2 liters. A 50-ml aliquot was removed each day and pooled for the 5-day period. Feed and fecal samples were analyzed for DM, acid detergent fiber (ADF; Goering and Van Soest, 1970), energy and N.

In trials 5 and 6, the use of fruit and vegetable byproducts in dog diets was evaluated. In trial 5, conducted with 12 adult female dogs (average weight, 18.2 kg; average age, 1.5 years), a Latin square design was used to test the incorporation of 6 and 12% beet pulp into a corn-soybean meal basal diet. Ingredients and chemical composition of the diets used in this trial (and also in trial 6) are presented in table 3. In all cases, beet pulp was substituted on a percentage basis for extruded corn, yet all diets were approximately isonitrogenous and isocaloric. All other procedures were as outlined for trial 1.

In trial 6, a Latin square design was used to compare the substitution of 8% tomato pomace and 8% grape pomace for extruded corn. Once again, the diets were approximately isocaloric and isonitrogenous, although the diets containing grape pomace had somewhat less CP than did the control diet or the diet containing

TABLE 2. INGREDIENT AND CHEMICAL COMPOSITIONS OF DIETS FED IN TRIALS 3 AND 4

Dietary ingredients	Level of DDGS, %				
	0	13.1	26.1	0	14.1
	Trial 3			Trial 4	
Extruded corn (IFN 4-02-935)	53.6	46.4	40.2	64.9	56.3
Extruded soybean meal (IFN 5-04-612)	30.9	25.0	19.2	19.6	14.1
DDGS (IFN 5-02-843)[a]	0	13.1	26.1	0	14.1
Tallow[b]	10	10	9	10	10
Vitamin premix[c]	.5	.5	.5	.5	.5
Mineral mix[d]	5	5	5	5	5
	Chemical composition				
Dry matter, %	91.0	91.0	90.2	91.1	91.1
Acid detergent fiber, %	...	...	...	3.3	8.6
Gross energy, kcal/g	4.9	5.0	5.0	4.8	4.9
Crude proetin, %	24.4	24.3	24.0	15.6	16.3

[a]DDGS (distillers dried grains with solubles) was obtained from the Distillers Feed Research Council, Cincinnati, OH.

[b]Bleachable fancy tallow for these diets was obtained from National Rendering, Peoria, IL.

[c]Composed of the following vitamins (per kilogram of premix): vitamin A, 500,000 USP units; vitamin D_3, 100,000 ICU; vitamin E, 4,000 IU; menadione sodium bilsulfite, 150 mg; thiamine mononitrate, 200 mg; riboflavin, 150 mg; pantothenic acid, 600 mg; niacin, 1 g; choline chloride, 30 g; vitamin B_{12}, 2 milligrams.

[d]Composed of the following minerals (percentage of mineral mix): $CaHPO_4$, 65%; NaCl, 15.4%; K_2CO_3, 14%; $MgCO_3$, 3.3%; $FeSO_4 \cdot H_2O$, 1%; $MnSO_4 \cdot H_2O$, .05%; $CoCl_2 \cdot 6H_2O$, .02%; $CuSO_4$, 1%; NaF, .02%; $ZnCO_3$, .2%; KI, .01%; $NaSeO_3$, .0001%.

TABLE 3. INGREDIENT AND CHEMICAL COMPOSITIONS OF DIETS FED TO DOGS IN TRIALS 5 AND 6

Dietary ingredients	Treatment					
	1	2	3	1	2	3
	Trial 5			Trial 6		
Extruded corn (IFN 4-02-935)	54.5	48.5	42.5	54.5	46.5	46.5
Extruded soybean meal (IFN 5-04-612)	30	30	30	30	30	30
Ground beet pulp (IFN 4-00-669)	0	6	12	...	...	...
Tomato pomace (IFN 5-05-041)[a]	...	...	...	...	8	...
Grape pomace[a]	...	...	...	...	...	8
Tallow[b]	10	10	10	10	10	10
Vitamin mix[c]	.5	.5	.5	.5	.5	.5
Mineral mix[d]	5	5	5	5	5	5
	Chemical composition					
Dry matter, %	89.7	89.9	89.6	90.3	90.6	90.5
Acid detergent fiber, %	4.2	5.1	7.1	7.1	13.4	12.2
Gross energy, kcal/g	4.9	4.9	4.9	5.0	5.1	5.1
Crude protein, %	24.7	23.8	24.1	23.9	24.1	21.9

[a]Pomaces were obtained from Bell Grain and Milling Co., Riverside, CA.

[b]Bleachable fancy tallow for these diets was obtained from National Rendering, Peoria, IL.

[c]Composed of the following vitamins (per kilogram of premix): vitamin A, 500,000 USP units; vitamin D_3, 100,000 ICU; vitamin E, 4,000 IU; menadione sodium bilsulfite, 150 mg; thiamine mononitrate, 200 mg; riboflavin, 150 mg; pantothenic acid, 600 mg; niacin, 1 g; choline chloride, 30 g; vitamin B_{12}, 2 milligrams.

[d]Composed of the following minerals (percentage of mineral mix): $CaHPO_4$, 65%; NaCl, 15.4%; K_2CO_3, 14%; $MgCO_3$, 3.3%; $FeSO_4 \cdot H_2O$, 1%; $MnSO_4 \cdot H_2O$, .05%; $CoCl_2 \cdot 6H_2O$, .02%; $CuSO_4$, 1%; NaF, .02%; $ZnCO_3$, .2%; KI, .01%; $NaSeO_3$, .0001%.

tomato pomace. All other procedures were as described for trial 1.

Data from all trials were analyzed by the General Linear Models Procedure of the Statistical Analysis System (Barr *et al.*, 1976).

Results and Discussion

Results of trial 1 are summarized in table 4. There were no differences ($P>.05$) due to treatment in any of the measurements tested. Low levels of DDGS substituted into corn-soybean meal diets apparently 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.

Data from trial 2 are also presented in table 4. Starch digestibility was not significantly affected by either level of DDGS supplementation. DMD was lowest ($P<.05$) at the 15.7% level of DDGS supplementation and tended to decrease as the level of dietary DDGS increased. Fecal DM was highest ($P<.05$) 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. Significant portions of traditional dietary energy and protein sources could apparently be conserved through DDGS substitution.

In trial 3, we determined whether high levels of DDGS were detrimental to the dog, considering the greater increase in the level of dietary fiber consumed. Data are summarized in table 5. CP digestibility was not significantly affected at either level of dietary DDGS, although digestion tended to be reduced at the higher level (26.1%). DMD and energy digestibility were significantly reduced only at the 26.1% level of DDGS supplementation. This decrease in digestion was not severe, and it appears that the inclusion of DDGS in traditional diets, even at high levels, could be a practical feeding alternative.

In trial 4, we tested the response of puppies

TABLE 4. DIGESTIBILITY DATA AND FECAL WEIGHTS FOR DOGS IN TRIALS 1 AND 2

	% digestibility		Fecal analyses	
Level of DDGS[a], %	Dry matter	Starch	Dry matter, %	Wet weight, g/5 days
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

[a]DDGS = distillers dried grains with solubles.

[b,c]Means in the same column with different superscripts differ ($P<.05$).

to an intermediate dietary level of DDGS (14.1%) which had no effect on nutrient digestibilities by adult dogs in a previous experiment. Results of this experiment are presented in table 6. DDGS affected ($P<.01$) digestibilities of all nutrients tested. ADF digestibility was significantly increased by DDGS. The growing dog apparently has the capacity to establish, at an early age, the intestinal population of bacteria necessary to ferment the fiber in DDGS. As a result of DDGS ingestion, pH of digesta could ostensibly increase, perhaps allowing promotion of fiber fermentation. In addition, DDGS contains a high concentration of hemicellulose, a polysaccharide that is more readily digested by nonruminants (Keys *et al.*, 1970) than other fiber sources are. Also, Cunningham *et al.* (1962) found that pigs digested nearly the same amount of fiber after 1 week of exposure as they did at 15 weeks, indicating that any capacity to ferment fiber manifests itself early after initial exposure to fiber-containing diets. While DMD and energy digestibility were significantly decreased by DDGS addition, they were not severely depressed. N intake and fecal N were both significantly increased when DDGS was incorporated into the diet. However, this increase was due to differences in total feed intakes between dogs instead of any inherent difference between diets. Urinary N and total N excretion were not significantly affected. N absorption and N retention were slightly increased with 14.1% DDGS supplementation, but neither was significantly different from the control value.

In this experiment, a period effect was noted even when no diet effect was detected. Feed intake by dogs was depressed during the preliminary phase of the second period. Consequently, the animals were removed from the

TABLE 5. DIGESTION COEFFICIENTS FOR DOGS FED 13.1 AND 26.1% DISTILLERS DRIED GRAINS WITH SOLUBLES (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,b]Means in the same row with different superscripts differ ($P<.05$).

TABLE 6. DIGESTION AND NITROGEN BALANCE DATA FOR PUPPIES FED CONTROL DIETS AND DIETS SUPPLEMENTED WITH DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS)

Item	Level of DDGS, %		
	0	14.1	SEM
Digestibility, %			
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
N balance, g/day			
Intake	4.7[a]	5.2[b]	.1
Excretion			
Feces	.9[a]	1.2[b]	.1
Urine	2.5	2.4	.1
Total	3.4	3.7	.1
N absorption, g/day	3.8	3.9	.1
N retention, g/day	1.3	1.5	.1

[a,b]Means in the same row with different superscripts differ (P<.01).

trial and wormed. When all dogs returned to their original level of intake (220 g/day), period 2 was started again. This period effect would be expected with growing dogs, as their metabolism is changing rapidly. However, no period × diet interactions were noted, indicating that the nature of the responses was similar in both periods.

Results from trials 5 and 6 are presented in table 7. In trial 5, DMD decreased linearly as level of beet pulp supplementation increased. A 6.1 percentage unit decrease (P<.01) in DMD occurred between the 0 and 12% levels of beet pulp supplementation. No significant differences in energy or CP digestibilities were observed between treatments. Digestion of ADF was greater (P<.05) for dogs fed the 6% beet pulp diet than for those on the control and 12% beet pulp treatments, which did not differ from each other.

In trial 6, both tomato and grape pomace additions decreased (P<.01) DMD, energy and CP digestibilities. Tomato pomace did not cause a reduction in ADF digestibility, but grape pomace severely lowered this value. Because pomace supplementation reduced digestibility of most nutrients tested, it could be concluded that pomaces at the levels used may not be suitable ingredients in diets for dogs. Pomaces contain pectins and many types of gums that generally are known for their adverse effects on fat and CP digestibilities (Viola *et al.*, 1970). It may be inferred from this that digestibilities of other nutrients are similarly affected.

ADF digestion coefficients for the dogs in trials 5 and 6 were similar to those for the young puppies in trial 4. It is important to be aware of the analytical problems that can result in the evaluation of fiber content of high concentrate type diets because misleading digestion coefficients can result from such problems (S. E. Allen, *unpublished data*). In our studies in which dietary ADF content and digestibilities were determined, filtration problems were minimal, but even then, some variation in ADF

TABLE 7. DIGESTION DATA FOR DOGS IN TRIALS 5 AND 6

Diet treatment	% digestibility			
	Dry matter	Acid detergent fiber	Energy	Crude protein
Trial 5				
Basal	77.7[a]	28.6[a]	75.8	73.2
Basal + 6% beet pulp	74.8[b]	39.2[b]	78.2	74.9
Basal + 12% beet pulp	71.6[c]	28.9[a]	70.8	73.1
SEM	.1	.8	1.6	1.4
Trial 6				
Basal	80.1[a]	34[a]	84.7[a]	82.3[a]
Basal + 8% tomato pomace	74.3[b]	34.1[a]	78.6[b]	78.2[b]
Basal + 8% grape pomace	74.9[b]	19.4[b]	79.3[b]	77.1[b]
SEM	.4	1.9	.3	.3

[a,b]Means in the same column and within a given data set bearing different superscripts differ (P<.01).

content occurred (ADF content of the control diets was 3.3, 4.2 and 7.1% in trials 4, 5 and 6, respectively). Other, possibly more sophisticated measurements should be taken when the incorporation of fibrous feedstuffs into nonruminant diets is being evaluated.

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