TB 1053 (1952) USDA TECHNICAL BULLETINS UPDATA
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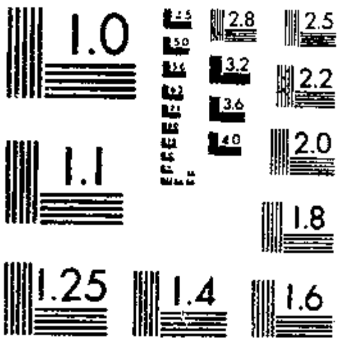

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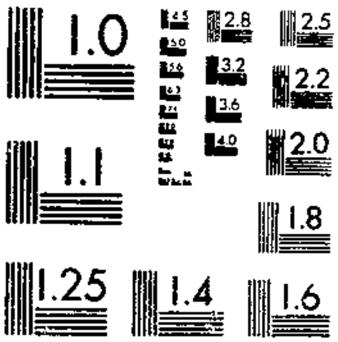

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Technical Bulletin No. 1053 • *1952*

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Feeding Qualities for Livestock of Distiller's Corn Byproducts From Fungal Amylase-Converted Mashes, Compared With Those From Malt Amylase-Converted Mashes[1,2]

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CONTENTS

DISTILLER'S BYPRODUCTS AND THEIR IMPORTANCE AS FEEDSTUFFS

About 300,000 tons of distiller's byproducts are fed annually to cattle, swine, sheep, and poultry. Since these feeds contain relatively large amounts of crude protein, B vitamins, and other nutrients (*4*),[4] they play an important role in livestock production.

Distiller's byproducts are made up of the residues after the production of alcohol from grain. During the process, grain starch is converted to sugars by enzymatic action, the sugars are converted into alcohol and carbon dioxide by the actions of yeast and other microorganisms, and the alcohol is removed by distillation. The remaining material—the whole stillage—contains the unfermentable part of the grain consisting mostly of protein, fats, and minerals, along with unfermentable carbohydrates. It also includes most of the vitamins present in the original grain, together with those added by the

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[1] Received for publication November 6, 1951.

[2] This investigation was carried out in cooperation with the Production and Marketing Administration of the United States Department of Agriculture and the Department's Bureau of Agricultural and Industrial Chemistry at the Northern Regional Research Laboratory, Peoria, Ill. It was conducted under the Research and Marketing Act of 1946.

[3] Resigned November 1, 1950.

[4] Numbers in parentheses refer to Literature Cited, p. 29.

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yeast and the fermentation process. At present, most of the whole stillage is screened to remove the grains, which are then pressed and dried to produce distiller's dried grains. The liquid remaining is known as distiller's thin slop. When this slop is evaporated under vacuum and then dried on rotary driers, the resulting product is called distiller's dried solubles. If the solubles are dried on the grain residue, the resulting product is distiller's dried grains with solubles.

Distiller's dried grains contain relatively high percentages of protein, fat, and fiber. Distiller's dried solubles contain less crude fiber and fat but include substantial amounts of water-soluble vitamins, proteins, minerals, and lactic acid. Since distiller's dried grains with solubles are a combination of distiller's dried grains and solubles, their composition is intermediate between the two depending on the amount of solubles recombined. When the latter is 50 to 55 percent, the distiller's grains with solubles are representative of whole stillage.

PURPOSE OF THE STUDY AND MATERIALS USED

In conventional distilling practice the enzymes required for the conversion of starch to sugars are supplied by barley malt. During periods of emergency, such as the present, when the demand for alcohol is greatly increased, barley malt becomes scarce and expensive. Consequently, cheaper sources of the converting enzymes are needed.

Investigations have shown that in the alcoholic fermentation of grain, fungal enzymes derived from common molds can supplement or replace barley malt. The yield of alcohol is comparable, and their use may result in considerable financial savings to the distilling industry (*6, 8, 16, 30, 31, 37, 38*).

The process of producing and using a fungal amylase agent has been studied on a pilot-plant scale by the Northern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry at Peoria, Ill. (*17*). A further step has consisted in tests, on a plant scale, of the methods and cost of using fungal amylase, produced by a special strain of *Aspergillus niger*, in comparison with the use of barley malt in grain fermentation for the production of alcohol. This investigation was carried out by the Production and Marketing Administration of the United States Department of Agriculture and the Grain Processing Corporation at Muscatine, Iowa, with the cooperation of the Northern Regional Research Laboratory (*28*). The studies proved that the use of fungal amylase is feasible in large-scale alcohol fermentation. In yield and quality, the alcohol produced during this study was equal to alcohol produced by the malt process, and the new method is definitely cheaper than the old one.

In view of the importance of distiller's byproducts as animal feed, it was considered highly desirable to determine whether those produced by the new process could replace, in the animal diet, the byproducts from malt-converted mashes. The purpose of the studies reported in this bulletin, therefore, was to compare the two byproducts for chemical composition, toxicity, palatability, digestibility, and their effect on the growth and fattening of animals. Comparisons were made during 1949 and 1950 by the Bureau of Animal Industry at the Agricultural Research Center, Beltsville, Md.

For use in the chemical analysis, samples of distiller's corn dried solubles and dried grains with solubles produced by the two processes were obtained from the Northern Regional Research Laboratory at

Peoria. All these samples were manufactured at the same plant. As corn was the principal ingredient used, the byproducts recovered were comparable to distiller's corn byproducts obtained commercially.

For use in determining the digestion coefficients and other nutritive properties of the byproducts produced by the two processes, additional samples of such materials originating from milo as well as corn were also obtained. In order that the samples used in nutrition studies might be as representative as possible of those obtained commercially, batches from several manufacturers were composited.

CHEMICAL COMPOSITION OF THE BYPRODUCTS

By Ivan L. Lindahl and L. J. Machlin

Analysis of the byproducts for percentage composition involved the following methods: For crude protein, ash, and crude fiber, the official and tentative methods of analysis of the Association of Official Agricultural Chemists (*1*); for moisture, a toluene distillation procedure; for ether extract, extraction with water preceding the usual extraction with ethyl ether; for niacin, the use of the cyanogen bromide reaction as employed by Powick and coworkers (*27*); for riboflavin, the fluorometric method (*21*); for thiamine, the thiochrome method (*1*); for pantothenic acid, a rat-growth method developed in the laboratories of the Bureau of Animal Industry; for glycine and tyrosine, the microbiological method of Steele and coworkers (*32*) using *Leuconostoc mesenteroides* P–60, except that the final volume was 10 ml., which was titrat d with 0.10 N NaOH; for the other amino acids, the method of Stokes and coworkers (*33*).

Data on the chemical composition, together with mineral and vitamin constituents, are shown in table 1. The amino acid composition of the byproducts is given in table 2. In all these respects, differences

TABLE 1.—*Chemical composition of distiller's byproducts made from corn mashes by the two processes*

Constituent	Dried solubles obtained by—		Dried grains with solubles obtained by—	
	Fungal amylase process	Malt amylase process	Fungal amylase process	Malt amylase process
Moisture.........percent..	4.42	4.63	6.62	7.31
Crude protein.........do....	28.30	32.40	24.92	25.69
Crude fiber.........do....	4.13	4.38	10.32	11.82
Ether extract.........do....	14.52	14.58	12.01	12.52
Nitrogen-free extract.........do....	48.63	44.01	42.67	39.17
Ash.........do....	5.96	7.29	3.46	3.49
Calcium.........do....	.37	.27	.20	.10
Phosphorus.........do....	1.04	1.23	.67	.67
Magnesium.........do....	.50	.58	.29	.28
Riboflavin.....micrograms per gram of byproduct..	15.44	15.27	8.54	7.78
Thiamine.........do....	4.20	5.40	1.67	2.13
Niacin.........do....	84.22	94.88	46.43	54.27
Pantothenic acid.........do....	22.60	29.00	8.10	25.90

TABLE 2.—*Amino acid content of the byproducts expressed as percentage of air-dried sample and percentage of protein*

Amino acid	Dried solubles obtained by—				Dried grains with solubles obtained by—			
	Fungal amylase process		Malt amylase process		Fungal amylase process		Malt amylase process	
	Percentage of sample	Percentage of protein	Percentage of sample	Percentage of protein	Percentage of sample	Percentage of protein	Percentage of sample	Percentage of protein
Arginine	1. 2	4. 4	1. 2	3. 7	1. 0	4. 1	1. 2	4. 8
Glycine	. 9	3. 2	1. 3	[illegible]. 0	. 6	2. 4	. 6	2. 2
Histidine	. 7	2. 4	. 7	2. 2	. 5	2. 1	. 5	1. 9
Isoleucine	1. 4	5. 0	1. 6	5. 0	1. 2	4. 7	1. 2	4. 7
Leucine	3. 3	11. 5	3. 6	11. 0	2. 3	11. 8	2. 8	11. 0
Lysine	1. 0	3. 4	1. 0	3. 0	. 8	3. 2	. 8	3. 2
Methionine	. 8	2. 9	. 9	2. 8	. 7	2. 7	. 6	2. 5
Phenylalanine	1. 3	4. 5	1. 4	4. 2	1. 2	4. 8	1. 2	4. 7
Threonine	1. 2	4. 2	1. 3	4. 0	. 9	3. 8	1. 0	3. 8
Tryptophane	. 17	. 60	19	. 59	. 15	. 60	. 15	. 58
Tyrosine	1. 0	3. 5	1. 1	3. 4	. 7	2. 7	. 7	2. 7
Valine	1. 6	5. 7	1. 7	5. 3	1. 4	5. 7	1. 4	5. 5

between the fungal amylase and malt amylase products are not considered particularly significant. However, the fact that lower percentages of nitrogen-free extract of both dried solubles and dried grains with solubles were obtained by the malt amylase process suggests greater conversion and fermentation of the carbohydrates by this method. From a feeding standpoint, the correspondingly higher protein, thiamine, nicotinic acid and pantothenic acid contents of the malt amylase products are worthy of note also.

TOXICITY AND PALATABILITY OF THE BYPRODUCTS

By Ivan L. Lindahl and R. E. Davis

As stated earlier, the fungal enzymes used in the distilling process were produced by a mold, a special strain of *Aspergillus niger*. Grains, mixed feeds, and roughages damaged by molds have been reported to produce toxic symptoms and digestive disorders when consumed by animals (*22*). Therefore, in the present study, distiller's dried grains with solubles from each process of distillation were fed to sheep and cattle to determine whether the grains recovered from the fungal amylase-converted mashes had any toxic effects, and whether they differed in palatability from the distiller's grains with solubles as produced by the malt amylase process.

Tests With Sheep

The methods used with sheep and the results obtained have been reported by Lindahl and coworkers (*18*). However, for convenience, information comparable with that given for cattle is included here.

Twelve mature ewes were self-fed the byproducts and were supplied with water and salt ad libitum at all times. At first the ewes were fed 25 percent of concentrate mixture, consisting of one part of distiller's dried grains with solubles to one part of pulverized white oats, and 75 percent of ground alfalfa hay. After the first week of the pretest period (table 3), every second day the percentage of concentrate mixture was increased by 2 percent and the alfalfa reduced accordingly, until the animals were receiving a mixture of equal parts of concentrate and hay. After the animals were on full feed, the concentrate and ground alfalfa hay were offered free-choice in separate compartments of self-feeders. During the pretest period only the malt amylase byproduct was fed to determine whether the two groups were comparable with respect to feed intake. Table 3 shows that they were about equal in this respect. During the tests the two types of byproducts were fed in alternate periods of 15 days each. The results are given in table 3.

The results indicated that the distiller's grains with solubles that were produced by the fungal amylase process were nontoxic. Feeding four times as much of the byproducts as is normally fed had no detrimental effect on the animals. Furthermore, Lindahl, Davis, and Ellis (*18*) showed that seven times as much as would be fed as a protein supplement did no harm to sheep although the product was fed for long periods. The results also indicated that the sheep prefer the malt amylase byproducts to those produced by the fungal amylase process. However, the latter evidently are palatable, since they were consumed in large quantities throughout the tests.

TABLE 3.—*Results of the palatability tests with two groups of six sheep each fed distiller's dried grains with solubles recovered by the two processes*

Test [1]	Group No.	Type of byproduct fed	Average daily feed consumption per animal: Total feed	Distiller's byproducts	Alfalfa hay	Loss (−) or gain (+) in weight per animal
			Pounds	*Pounds*	*Pounds*	*Pounds*
Pretest	1	Malt amylase	3.91	(2)	(2)	+17.3
	2	do	3.95	(2)	(2)	+21.4
First test	1	do	3.85	1.23	1.38	−3.8
	2	Fungal amylase	3.83	1.12	1.59	−2.4
Second test [3]	1	do	3.89	.97	1.94	+3.4
	2	Malt amylase	3.91	1.02	1.86	+1.1
Third test [3]	1	do	4.16	.81	2.54	+2.3
	2	Fungal amylase	3.79	.55	2.69	−.6
Fourth test [3]	1	do	3.00	.58	1.82	−1.1
	2	Malt amylase	3.43	.65	2.13	+2.5

[1] The pretest period was 36 days in length; each of the test periods, 15 days.
[2] Concentrate and alfalfa fed as a mixture.
[3] Groups reversed.

TESTS WITH CATTLE

Six mature Hereford cows were fed oat straw and distiller's dried grains with solubles in the ratio of 8 parts of the former to 1½ parts of the latter. This ratio was chosen to provide the necessary digestible crude protein and total digestible nutrients for the wintering of pregnant beef cows, according to the feeding standard of Morrison (*25*). The oat straw was offered at the rate at which the cows would clean it up, and the distiller's grains with solubles were fed in proportion to the straw consumed. Three of the cows were started on the distiller's grains with solubles produced by the malt amylase process and three on the grains produced by the fungal amylase process. After 105 days the two groups were reversed and the feeding continued for an additional 228 days. After the reversal period of feeding the cows were fed, for an additional 86 days, a mixture of equal parts of the dried grains with solubles and distiller's solubles in place of the dried grains with solubles. The method of feeding was identical with that followed in the first phase of the work.

The results of the experiment are given in table 4. At no time did the animals refuse the distiller's byproducts produced by either process. Furthermore, they did not indicate any preference for one type of byproduct over the other. No toxic or other detrimental effects of feeding the fungal amylase byproduct were observed. Two cows dropped normal calves during the experiment, and a third cow dropped a normal calf on the second day after the experiment ended.

TABLE 4.—*Results of the palatability tests with cattle fed distiller's byproducts recovered by the two processes*

FIRST 105 DAYS—DRIED GRAINS WITH SOLUBLES

Cow No.	Type of byproduct fed	Average daily feed consumption			Loss (−) or gain (+) in weight
		Total feed	Distiller's byproducts	Straw	
		Pounds	*Pounds*	*Pounds*	*Pounds*
173-4	Fungal amylase	11.75	1.85	9.90	−39.6
34-2	do	14.37	2.27	12.10	−35.2
78-A	do	11.75	1.85	9.90	−19.8
166-2	Malt amylase	16.98	2.68	14.30	+13.2
39-B	do	15.69	2.49	13.20	−22.0
39-1	do	16.98	2.68	14.30	−44.0

NEXT 228 DAYS—DRIED GRAINS WITH SOLUBLES (GROUPS REVERSED)

Cow No.	Type of byproduct fed	Total feed	Distiller's byproducts	Straw	Loss (−) or gain (+) in weight
173-4	Malt amylase	11.75	1.85	9.90	−66.0
34-2 [1]	do	14.37	2.27	12.10	−330.0
78-A	do	11.75	1.85	9.90	−147.4
166-2	Fungal amylase	16.98	2.68	14.30	0
39-B	do	15.69	2.49	13.20	0
39-1	do	16.98	2.68	14.30	+72.6

LAST 86 DAYS—EQUAL PARTS OF DRIED GRAINS WITH SOLUBLES AND DISTILLER'S SOLUBLES

Cow No.	Type of byproduct fed	Total feed	Distiller's byproducts	Straw	Loss (−) or gain (+) in weight
166-2 [2]	Fungal amylase	16.98	2.68	9.90	−11.0
39-B	do	15.69	2.49	13.20	0
39-1 [1]	do	16.98	2.68	14.30	−211.2
173-4	Malt amylase	11.75	1.85	9.90	−44.0
34-2	do	14.37	2.27	12.10	−26.4
78-A	do	13.02	2.07	10.96	+13.2

[1] This animal dropped a calf, which accounts for the unusually large loss of weight.
[2] This animal was fed only 26 days, when it was slaughtered to reduce the herd.

DIGESTIBILITY OF THE BYPRODUCTS

By IVAN L. LINDAHL and R. E. DAVIS

The most recently published digestion coefficients of distiller's dried grains (*13, 14, 19, 20*) showed that these products were highly digestible and good sources of total digestible nutrients. As these results were reported at about the beginning of the present century and the methods and processes for the recovery of the byproducts have been modernized during the last few years, an experiment (No. 1) was conducted to reinvestigate the digestion coefficients for corn dried grains and corn dried grains with solubles and to determine the digestibility of milo dried grains with solubles.

In a second experiment, a comparison was made of the indirectly determined digestion coefficients of the dried grains with solubles[5] produced by the fungal amylase and the malt amylase procedures. Drown and Forbes of the Kentucky Agricultural Experiment Station (7) have recently made digestibility studies with steers fed rations supplemented with these byproducts. They found no significant differences in the digestibility of the two rations.

To obtain further information on the effect of these supplements on the digestibility of practical diets, a third experiment was conducted. In this the digestibility and metabolizable energy content of a practical lamb feeding diet supplemented with each of the two distiller's dried grains with solubles were compared with those of a diet supplemented with linseed oil meal.

Experiment 1

In this experiment only conventional (malt amylase process) distiller's byproducts were used. To insure that they would be as representative as possible of those on the open market, distiller's corn dried grains and distiller's corn dried grains with solubles were obtained from three distilleries and distiller's milo dried grains with solubles from two distilleries. Equal parts of the individual shipments were mixed and only the composite samples were used in the digestion trials. The composition of the individual shipments and the average composition of the composite samples as used during the trials are given in table 5.

Five mature Hampshire wethers were used in each of two trials. To minimize the effect of external conditions, the trials were "staggered" so that not all the sheep were on the same trial at the same time. The animals were kept in metabolism cages during the experiment. The collection period of feces was 10 days, preceded by a 10-day preliminary period. Collection bags were used to obtain the feces. They were emptied every 24 hours and the feces immediately put into a drying oven at a temperature of 60° C., and kept there for 24 hours. The dried feces were then transferred to a covered bucket. At the end of the collection period, the feces were allowed to come to moisture equilibrium, after which they were weighed, ground, and mixed and an aliquot taken for the analytical work.

The basal diet used consisted of 60 percent yellow corn meal and 40 percent chopped alfalfa hay. Salt was added to this mixture in such proportions as to insure a daily intake of not less than 7 gm. per animal. Water was supplied ad libitum. The average composition of the basal diet is also given in table 5.

Two levels of the byproducts were used. In the first trial, the byproducts made up approximately 12.5 percent of the total diet, resulting in a total crude protein content of 12.5 percent. In the second trial, they made up 25 percent of the mixture. The plane of nutrition as far as the total digestible nutrients were concerned was held nearly constant throughout the experiment. The average plane of nutrition, calculated from the digestibility of the diets used, is given in table 6.

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[5] The indirect determination was made by obtaining the difference between the digestion coefficients of the basal diet and the diet containing the byproducts.

TABLE 5.—*Composition of byproducts obtained from distilleries and of the average of these as used in the digestion trials* [1]

Byproduct	Sample No.	Moisture	Ash	Crude protein	Ether extract	Crude fiber
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Distiller's corn dried grains.	1	10. 38	1. 32	31. 40	11. 70	12. 53
Do	2	10. 76	1. 68	25. 72	8. 50	12. 97
Do	3	8. 36	1. 74	24. 73	10. 65	14. 56
Average		7. 89	1. 72	27. 49	10. 03	13. 27
Distiller's corn dried grains with solubles.	4	9. 24	4. 64	27. 39	10. 32	8. 19
Do	5	11. 07	3. 75	25. 22	9. 32	9. 05
Do	6	8. 33	3. 19	25. 34	11. 92	11. 89
Average		8. 55	3. 96	26. 14	9. 83	9. 01
Distiller's milo dried grains with solubles.	7	9. 02	5. 40	30. 24	9. 36	8. 46
Do	8	5. 94	1. 80	35. 70	15. 15	13. 90
Average		7. 22	3. 52	32. 97	11. 67	11. 33
Basal diet		10. 80	4. 28	10. 84	3. 02	14. 18

[1] Composition of samples was obtained when they were received; average composition is that of the composite sampled at the time it was fed and is not the average of the samples when received from the distilleries.

The diets, as well as the byproducts, were sampled daily during the collection periods and an aliquot of the composite sample was taken for analysis at the end of the trials. The methods of the Association of Official Agricultural Chemists (*1*) were used for analyzing the diets and feces. The distiller's dried grains with solubles were analyzed for moisture and ether extract according to the methods given on page 3.

The mean digestion coefficients of the basal diet and the diet supplemented with the low level of distiller's byproducts—which is comparable to that used in normal feeding—are given in table 7. Although the basal diet used in these trials is normally considered to be adequate for the fattening of lambs, the addition of distiller's dried grains at approximately 12.5 percent of the total feed intake had a beneficial effect on the digestibility of the feed mixture. The digestion coefficients of the ether extract were significantly higher in all cases and there was a definite tendency for the digestibility of the crude protein and the crude fiber to be increased. Swift and coworkers (*35*) found that the addition, to the diet, of as much as 6.4 percent of corn oil increased the digestibility of all constituents of a mixed ration for sheep. Since the distiller's grains used in these trials are good sources of ether extract and the original basal diet contained adequate protein, according to Morrison (*25*), it is plausible that the increased ether extract was the most important factor in the supplementation of the diet.

TABLE 6.—*Average plane of nutrition during digestion trials in experiment 1*

Diet	Level of feeding	Percentage of maintenance requirements contributed as— [1]	
		Digestible crude protein	Total digestible nutrients
Basal		113	110
Basal and distiller's corn dried grains	Low	153	121
Do	High	176	120
Basal and distiller's corn dried grains with solubles.	Low	162	128
Do	High	182	128
Basal and distiller's milo dried grains with solubles.	Low	150	120
Do	High	204	133

[1] Based on values given by Brody (*5*).

There were no significant differences in the digestibility of the diets supplemented with corn dried grains and those supplemented with milo dried grains.

The mean indirectly determined digestion coefficients for the distiller's dried grains are given in table 8. There was a tendency for the digestibility of all constituents to be lower when the byproducts were fed at the high level than at the low level. However, when analyzed statistically, the differences were significant in only four cases. When the byproducts were fed at a low level, the large inherent errors in the indirect determination of the digestion coefficients made it difficult to assign significance to the differences between the two levels. Watson and coworkers (*39*, *40*) found that the digestion coefficients for certain concentrates drop with an increased plane of nutrition. In the present investigation lower digestion coefficients were also obtained when the byproducts were fed at the higher levels without increasing the plane of nutrition as far as the total digestible nutrients were concerned. It is possible that in the trials in which the byproducts were fed at high levels the high ratio of the concentrates affected the microflora of the rumen of the animals sufficiently to lower the digestibility of the alfalfa in the basal diet. Additional research apparently is needed along this line.

The average results for the two levels of feeding, in terms of percentage of digestible crude protein and total digestible nutrients of the dried grains (table 9), agree very closely with the results given by Schneider (*30*) except for the digestible crude protein in the distiller's corn dried grains with solubles.

TABLE 7.—*Apparent mean digestion coefficients of basal diet and distiller's byproducts in experiment 1*

Diet	Digestion coefficients of—[1]				
	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Basal	77. 52±0. 87	69. 33±2. 31	73. 89±2. 59	43. 87±1. 24	88. 78±0. 62
Basal and low level of corn dried grains	77. 92±1. 43	*73. 94±1. 60	**78. 86±1. 15	*46. 54±1. 36	87. 90±0. 73
Basal and low level of corn dried grains with solubles	78. 17±1. 81	74. 13±4. 48	*79. 59±4. 07	46. 71±2. 82	88. 20±0. 93
Basal and low level of milo dried grains with solubles	78. 50±0. 78	*73. 64±2. 15	*78. 39±1. 51	45. 66±1. 63	88. 86±0. 38

[1] *=significant; **=highly significant.

TABLE 8.—*Apparent mean digestion coefficients (indirectly determined)*[1] *of the distiller's byproducts—experiment 1*

Byproduct	Digestion coefficients of—[1]				
	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
BYPRODUCTS FED AT LOW LEVEL					
Corn dried grains	81.87±9.51	87.87±8.38	90.34±6.82	68.13±21.44	78.51±6.68
Corn dried grains with solubles	82.00±11.55	87.37±14.14	91.35±6.66	72.58±28.47	83.03±7.27
Milo dried grains with solubles	86.57±11.67	87.08±12.89	92.83±8.34	66.29±21.76	88.01±12.82
BYPRODUCTS FED AT HIGH LEVEL[2]					
Corn dried grains	*67.24±6.08	*74.12±5.24	88.46±2.86	50.62±9.64	*63.65±7.81
Corn dried grains with solubles	70.20±3.12	75.53±3.63	88.97±3.26	*24.94±10.84	75.04±1.86
Milo dried grains with solubles	79.99±4.36	76.97±3.07	93.22±1.26	74.75±11.76	82.17±5.52

[1] Calculated by difference from the digestibility of the basal diet.
[2] *= Significantly lower than at the low level of feeding.

TABLE 9.—*Percentages of digestible crude protein and total digestible nutrients of distiller's dried grains obtained in expeirment 1, compared with those given by Schneider (30)*

Byproduct	Source of information	Level of feeding	Total dry matter	Digestible crude protein	Total digestible nutrients
			Percent	*Percent*	*Percent*
Corn dried grains	Schneider		93. 1	22. 2	77. 5
Do	Present investigation.	Low	92. 1	24. 2	84. 7
Do	do	High	92. 1	20. 4	72. 3
Corn dried grains with solubles.	Schneider		93. 6	13. 3	78. 4
Do	Present investigation.	Low	91. 4	22. 8	84. 9
Do	do	High	91. 4	19. 7	73. 6

EXPERIMENT 2

In this experiment the indirectly determined digestion coefficients of distiller's dried grains with solubles from the malt amylase process were compared with those of the grains from the fungal amylase process. The basal diet consisted of 60 percent of yellow corn and 40 percent of chopped alfalfa hay. Its average composition was as follows: Moisture, 9.59 percent; ash, 3.35 percent; crude protein, 11.94 percent; ether extract, 2.51 percent; crude fiber, 12.71 percent; and nitrogen-free extract, 59.91 percent. The composition of distiller's dried grains with solubles is given in table 1. After the digestion coefficients were determined for the basal diet, the distiller's grains were added in the proportion of 25 parts of distiller's grains to 75 parts of the basal diet. The plane of nutrition during the experiment was approximately 120 percent of maintenance as far as the total digestible nutrients were concerned.

The experiment was conducted in the same manner as the previous one, except that 10 gm. of a salt mixture in place of common salt was fed daily to each wether. The salt mixture was made up as follows: Iodized salt, 10 kg.; manganese sulfate, 60 gm.; cobalt chloride, 1 gm.; copper sulfate, 5 gm.; zinc chloride, 2 gm.; and ferrous ammonium citrate, 30 gm.

The mean digestibility coefficients are given in table 10. There were no significant differences in the digestibility of the products produced by the two processes.

The apparent digestibility coefficients of the dried grains with solubles used in this work were higher than those of the composite grains with solubles used in the previous study when the byproducts were fed at the same level and with the same type of basal diet. Lindsey and coworkers (*20*) found variations in the digestion coefficients of different batches of distiller's grains which they attributed to the fact that grains other than corn made up part of the mash. Differences in the methods of recovery of the byproducts at different distilleries may also affect the digestibility of the byproducts. The

TABLE 10.—*Apparent mean digestion coefficients (indirectly determined)*[1] *of the distiller's dried grains with solubles produced by the two distilling processes, experiment 2*

Byproduct	Digestion coefficients of—				
	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Dried grains with solubles by the malt amylase process	82. 09±4. 22	81. 29±5. 17	88. 32±1. 66	65. 63± 7. 25	84. 83±3. 86
Dried grains with solubles by the fungal amylase process	81. 70±5. 74	78. 22±7. 54	89. 50±1. 88	65. 09±16. 80	84. 93±5. 52

[1] Calculated by difference from the digestibility of the basal diet.

ether extract of the dried grains with solubles used in this experiment was significantly higher than that of the composite dried grains with solubles, a fact that may also have had an effect in increasing the digestibility of the grains.

Experiment 3

In this experiment the digestion coefficients, percentage of nitrogen retained, and metabolizable energy were determined for lamb-fattening diets supplemented with linseed oil meal and with distiller's dried grains with solubles produced by the two distilling processes. The diets used were random samplings of ton lots of the "full feed" diets as used in the lamb fattening experiment described on pages 18 to 22. One of the diets used contained 46.63 percent of cracked corn and 3.37 percent of linseed oil meal; a second contained 45.08 percent of cracked corn and 4.92 percent of malt distiller's dried grains with solubles; and a third, 44.72 percent of cracked corn and 5.28 percent of fungal amylase dried grains with solubles. Each of the three diets contained 50 percent of No. 2 mixed timothy-clover hay. The chemical composition of the ingredients used in the diets and of the diets themselves is given in table 11.

Six wether lambs were used in each trial and the trials were conducted as described for experiment 1. In addition, the urine was collected in glass jars containing sufficient sulfuric acid to keep the urine in an acid state at all times. Daily collections were made to volume and aliquoted daily. The composite samples were kept under refrigeration until they were analyzed for nitrogen and energy content.

Chemical analyses were made as described on page 9. In addition, energy determinations were obtained with an oxygen bomb calorimeter. The urine samples were dried in an apparatus that collected the ammonia lost during drying. The number of grams of nitrogen lost during the drying of the urine was multiplied by 5.447 to obtain the equivalent energy in kilogram calories. In the calculation of the metabolizable energy of the diets, the methane produced was estimated according to the equation of Swift and coworkers (*34*). Correction for gain of body nitrogen was made by adding 7.45 kilogram calories to the urinary energy for each gram of nitrogen stored (*11*).

TABLE 11.—*Composition of (1) the ingredients in the diet and (2) the diets themselves used in experiment 3*

Ingredients and diets used	Moisture	Crude protein	Ash	Ether extract	Crude fiber	Nitrogen-free extract	Gross energy
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Kg. Cal./Gram*
Ingredient—							
No. 2 mixed timothy clover hay	9. 92	10. 14	4. 93	1. 56	33. 11	40. 29	3. 99
Corn	9. 14	9. 20	1. 30	3. 09	2. 27	75. 00	3. 99
Linseed oil meal	9. 44	33. 84	5. 87	1. 72	9. 55	39. 58	4. 19
Malt amylase distiller's dried grains with solubles	7. 31	25. 69	3. 49	12. 52	11. 82	39. 17	5. 05
Fungal amylase distiller's dried grains with solubles	6. 62	24. 92	3. 46	12. 01	10. 32	42. 67	4. 86
Diet supplemented with—							
Linseed oil meal	9. 60	10. 71	3. 68	2. 51	17. 07	56. 43	4. 08
Malt amylase distiller's dried grains with solubles	9. 19	10. 73	3. 53	2. 94	17. 63	55. 98	4. 18
Fungal amylase distiller's dried grains with solubles	9. 35	10. 60	3. 46	2. 82	17. 26	56. 52	4. 20

The mean apparent digestion coefficients and percentage of metabolizable energy of the diets are given in table 12. The data on the retention of nitrogen by the lambs are given in table 13. These tables show no significant differences between any of the diets in their digestibility, in the percentage of metabolizable energy, or in nitrogen retention by the lambs.

TABLE 12.—*Apparent mean digestion coefficients and percentage of metabolizable energy of the three diets used in experiment 3*

Diet	Digestion coefficients of—						
	Dry matter	Crude protein	Ether extract	Nitrogen-free extract	Crude fiber	Gross Energy	Percentage of gross energy metabolized
Diet supplemented with—	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Linseed oil meal	67. 58±2. 54	56. 42±3. 54	78. 07±1. 67	73. 70±2. 60	41. 02±2. 74	65. 86±2. 60	54. 43±2. 47
Malt amylase distiller's dried grains with solubles	67. 24±0. 89	55. 39±0. 88	80. 24±1. 08	78. 12±0. 83	42. 24±1. 95	66. 24±1. 08	55. 34±0. 94
Fungal amylase distiller's dried grains with solubles	66. 86±2. 66	55. 28±3. 22	79. 86±1. 76	78. 07±1. 84	39. 73±2. 79	65. 47±3. 27	54. 64±3. 22

TABLE 13.—*Percentage of nitrogen retained by lambs on supplemented diets used in experiment 3*

Diet	Nitrogen retained on basis of amount fed	Digested nitrogen retained
	Percent	*Percent*
Diet supplemented with—		
Linseed oil meal	22.16±3.44	39.32±5.48
Malt amylase distiller's dried grains with solubles	23.32±3.14	42.13±5.98
Fungal amylase distiller's dried grains with solubles	24.04±2.10	43.54±3.24

VALUE OF DISTILLER'S BYPRODUCTS IN PRACTICAL LIVESTOCK DIETS

TESTS WITH FATTENING LAMBS

By IVAN L. LINDAHL and R. E. DAVIS

Comparatively few lamb-feeding trials in which distiller's dried grains were used as the protein supplement have been made. Willman, Morrison, and Klosterman (*42*) report that in four experiments in which they used corn distiller's corn dried grains with solubles as supplements to a low-protein diet for lambs, this supplement produced nearly as good results as did linseed oil meal. In these experiments the diets were composed of shelled corn, corn silage, a small quantity of mixed hay, ground limestone, salt, and protein supplement. Because distiller's corn grains are lower in protein content than is linseed oil meal, somewhat more of the former was needed to balance the diet. In these four trials the distiller's grains had 91 percent of the feeding value of linseed oil meal, but in a fifth experiment corn dried grains did not give as good results. In other trials by the same investigators, the distiller's grains were satisfactory when a larger quantity was fed to replace part of the corn in the diet. When a mixture of one-third distiller's grains and two-thirds corn was fed, the distiller's grains had a slightly greater feeding value than corn.

In the present experiments, dried grains with solubles produced by each of the two processes were compared with linseed oil meal as protein supplements to a lamb-fattening diet composed of No. 2 mixed clover-timothy hay and yellow corn. The protein supplements were mixed with corn meal in such proportions that when these mixtures were combined with the chopped hay, the crude protein content of the diets, throughout the feeding period, was between 10.3 and 10.7 percent. This level was chosen because Morrison (*25*) has shown that fattening diets containing 10.3 to 10.5 percent of crude protein result in as good gains and finish as those containing higher percentages. Furthermore, it was thought that any differences in the quality of the supplements would be more evident at this level than at higher levels. As distiller's dried grains with solubles contain nearly the same percentage of total digestible nutrients as does corn, the concentrate mixtures used in the feeding trials were compounded to contain the same quantity of crude protein as the corn, with the distiller's grains replacing an equal quantity of corn. One of the mixtures contained 93.26 percent of cracked corn and 6.74 percent of linseed oil meal; a second contained 90.17 percent of cracked corn and 9.83 percent of the malt amylase dried grains with solubles; and the third, 89.43 percent of cracked corn and 10.57 percent of the fungal amylase dried grains with solubles.

The mixtures of concentrates and chopped hay were self-fed throughout the feeding period, which lasted for 82 days—from October 18, 1949, to January 8, 1950. In the beginning the lambs were fed 25 percent of concentrate and 75 percent of hay. After the first week, the concentrate was increased by 2 percent every second day, with a corresponding decrease in the percentage of hay until the animals were receiving 50 percent of concentrate and 50 percent of chopped hay (the "full feed" diet). Crude-protein determinations on random samplings of 1,000-pound lots of the full-feed diets gave the following: Diet supplemented with linseed oil meal, 10.71 percent; with malt amylase dried grains with solubles, 10.73 percent; and with fungal amylase dried grains with solubles, 10.60 percent. The composition of the ingredients of the diets, as well as the diets themselves, is given in table 11.

Two groups of five animals each were used for testing each protein supplement. The first group consisted of animals weighing approximately 75 pounds each at the beginning of the feeding period; the second group, approximately 55 pounds. These 30 animals were selected from a shipment of 56 Columbia and Columbia-Southdale ram lambs from the United States Morgan Horse Farm at Middlebury, Vt. The groups were as uniform as possible with respect to the inheritance of the animals, weight, previous gain, condition, and age.

Before the beginning of the trials, all the lambs were castrated by means of emasculators, wormed, and vaccinated against enterotoxemia. During the feeding period they were supplied with phenothiazine-treated salt and clean water *ad libitum*. All animals were graded for slaughter finish at the beginning and at the end of the test period. They were weighed once a week and the weekly feed consumption was recorded throughout the period. Three animals from each group, a total of 18, were slaughtered on January 9, 1950, in order to obtain carcass grades and dressing percentages. Feed was removed from the animals 24 hours before time of slaughter.

The changes in weight and condition of the lambs during the feeding period, together with the carcass quality and dressing percentages, are given in table 14. It shows that for all groups the changes in condition, the carcass quality, and the dressing percentage were satisfactory. Both groups receiving the malt amylase dried grains with solubles made slightly higher total gains than the other groups, but they also consumed the most feed, as shown in table 15. The amount of feed required and the cost per 100 pounds of gain are given in table 16. There was no material difference in these respects in favor of any of the supplements.

The results of this experiment indicate that distiller's dried grains with solubles from either malt- or fungal amylase-converted mashes can satisfactorily replace linseed oil meal as a protein supplement in fattening lambs. The economic feasibility of using distiller's grains with solubles in place of linseed oil meal would depend on the relative costs of the products as well as the cost of corn. More distiller's byproducts than linseed oil meal are required to balance the ration; however, this disadvantage is slightly offset by the smaller amount of corn needed when the byproducts are used.

TABLE 14.—*Changes in weight and condition of lambs in the supplement-fed groups during the 82-day feeding period*

Lamb No.	Weight at beginning	Weight at end	Gain	Condition at beginning	Condition at end	Carcass quality	Dressing percentage
GROUP 1A, FED LINSEED OIL MEAL SUPPLEMENT							
	Pounds	*Pounds*	*Pounds*				
24	74.5	111.5	37.0	Common+	Good−		
510	75.0	107.5	32.5	Medium+	Good+	Choice−	45.52
449	78.0	97.5	19.5	Good−	Choice	Choice	44.53
519	72.5	100.0	27.5	Medium−	Choice−	Choice−	44.07
456	77.0	94.5	17.5	Medium	Good+		
Average	75.4	102.2	26.8	Medium	Good+	Choice−	44.71
GROUP 1B, FED MALT AMYLASE SUPPLEMENT							
27	74.0	110.0	36.0	Common+	Good		
547	77.5	109.5	32.0	Medium−	Choice+	Choice+	42.72
454	76.5	100.5	24.0	Medium	Choice−	Choice−	43.15
530	68.5	105.5	37.0	Good−	Choice	do	44.98
536	68.0	99.0	31.0	Medium	do		
Average	72.9	104.9	32.0	Medium	Choice−	Choice−	43.62
GROUP 1C, FED FUNGAL AMYLASE SUPPLEMENT							
9	76.5	112.0	35.5	Medium+	Choice−		
443	74.0	94.5	20.5	Medium	Good+	Good+	47.54
520	78.0	101.0	23.0	do	Choice	Choice	47.16
448	74.0	99.0	25.0	Medium+	Choice−	do	43.52
503	69.0	94.0	25.0	do	Choice		
Average	74.3	100.1	25.8	Medium+	Choice−	Choice−	46.07

GROUP 2A, FED LINSEED OIL MEAL SUPPLEMENT

484	53.0	81.0	28.0	Medium−	Good+		
457	56.0	88.0	32.0	Common	Good−	Commercial+	41.43
513	53.0	77.5	24.5	Medium+	Choice−		
529	55.5	77.5	22.0	Medium	do	Good	43.05
524	55.5	78.5	23.0	do	Good	Good+	46.71
Average	54.6	80.5	25.9	Medium−	Good+	Good−	43.73

GROUP 2B, FED MALT AMYLASE SUPPLEMENT

426	51.5	69.5	18.0	Common	Good−		
481	60.0	92.0	32.0	Medium−	Good	Good+	41.34
550	54.5	81.5	27.0	do	do		
497	55.0	88.0	33.0	Medium	Choice−	Good+	44.97
468	57.5	84.0	26.5	Common+	Good	Good	42.68
Average	55.7	83.0	27.3	Medium−	Good	Good	43.00

GROUP 2C, FED FUNGAL AMYLASE SUPPLEMENT

483	54.0	78.0	24.0	Medium−	Good		
545	51.0	89.5	38.5	do	Choice−	Good+	44.77
518	52.0	62.0	10.0	Common	Medium		
512	56.5	84.0	27.5	Medium	Good+	Good	46.06
460	60.5	88.0	27.5	do	Choice−	Choice	47.06
Average	54.8	80.3	25.5	Medium−	Good	Good+	45.96

TABLE 15.—*Total feed consumed per group during the 82-day lamb-feeding trial*

Group	Supplement used	Total feed consumed
		Pounds
1A	Linseed oil meal	1, 473. 8
1B	Malt amylase dried grains with solubles	1, 613. 9
1C	Fungal amylase dried grains with solubles	1, 394. 2
2A	Linseed oil meal	1, 274. 5
2B	Malt amylase dried grains with solubles	1, 403. 9
2C	Fungal amylase dried grains with solubles	1, 295. 6

TABLE 16.—*Feed required and cost per 100 pounds of gain for fattening groups of lambs fed various protein supplements*

Feed	Group 1, fed supplements of—			Group 2, fed supplements of—		
	Linseed oil meal	Malt amylase distiller's grains	Fungal amylase distiller's grains	Linseed oil meal	Malt amylase distiller's grains	Fungal amylase distiller's grains
No. 2 mixed hay pounds	610	500	609	553	574	571
Corn do	457	405	422	402	410	398
Linseed oil meal do	33			29		
Malt amylase distiller's grains pounds		44			45	
Fungal amylase distiller's grains pounds			50			47
Cost per 100 pounds of gain dollars [1]	23. 94	21. 97	23. 37	21 26	22. 35	21. 99

[1] The following prices per ton (Maryland Grain Market Summary, Jan. 6, 1950) were used in calculating the cost per 100 pounds' of gain: No. 2 mixed hay, $24.17; cracked corn, $65.74; linseed oil meal, $92.33; distiller's dried grains with solubles, $84.76.

TESTS WITH GROWING SWINE

By J. W. STEVENSON and N. R. ELLIS

Comprehensive research at the Illinois Agricultural Experiment Station and other State stations has shown that distiller's dried solubles when used in swine rations contribute substantial amounts of water-soluble vitamins (known and unknown), as well as protein, minerals, and other nutrients (*3, 9, 10, 15, 29, 36, 41*).

In the present investigation, diets containing distiller's corn solubles recovered from malt- and fungal amylase-converted mashes, together with a diet containing a composite sample of distiller's corn solubles made by mixing equal parts of solubles obtained from four commercial distilleries, were compared with a diet containing linseed oil meal in place of the distiller's solubles. The composition of the diets is given in table 17.

In making the comparisons, three simultaneous tests were carried out in the same manner. Each test was conducted with four litter mates from each of 12 litters, aged eight to nine weeks. In each test, the pigs were distributed equally into four groups based on sex, litter, and weight. The diets were self-fed. The experiment was begun on October 26, 1949, and continued for 16 weeks. Feed consumption by groups and individual pigs weights were recorded at 2-week intervals. The results are given in table 18.

TABLE 17.—*Composition of diets used in swine-feeding experiments*

Ingredients	Protein content	Composition of diets containing—			
		Linseed oil meal	Composite solubles	Malt amylase solubles	Fungal amylase solubles
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Yellow corn meal	8.69	68.5	66.0	66.0	66.0
Soybean oil meal	44.60	12.0	10.5	10.5	10.5
Meat and bone scrap	46.58	7.0	7.0	7.0	7.0
Alfalfa meal	16.32	5.0	5.0	5.0	5.0
Linseed oil meal	34.20	6.0			
Distiller's solubles (composite)	30.56		10.0		
Malt amylase distiller's solubles	32.40			10.0	
Fungal amylase distiller's solubles.	28.30				10.0
Mineral mixture		1.5	1.5	1.5	1.5
Total		100.0	100.0	100.0	100.0
Protein in mixture [1]		17.4	17.5	17.7	17.3

[1] The corn-protein supplement ratio was adjusted to furnish approximately 15 percent protein when the pigs reached an average weight of 125 pounds.

No significant differences between the various diets were found in the rate or economy of gain. In general, the pigs grew well on all the diets. Feed efficiency was good, averaging about 356 pounds of diet per 100 pounds of gain. The fungal amylase-process solubles appeared to be slightly less palatable to swine than the malt amylase-process solubles. However, no toxic effects were observed when the former made up as much as 10 percent of the diet. The pigs receiving distiller's corn solubles from all sources showed symptoms of pantothenic acid deficiency, such as lameness, stiffness, and "goose stepping," illustrating the relatively rapid loss of this vitamin from distiller's grain solubles. There were no marked differences in this respect between fungal amylase and malt amylase solubles.

TABLE 18.—*Rate and economy of gains made by weanling pigs during 16 weeks on diets containing distiller's corn solubles as compared with those made on a diet containing linseed oil meal*

Pig group no.	Supplement to diet	Average initial weight per pig	Average final weight per pig	Average daily gain per pig	Feed consumed per 100 pounds of gain
	FIRST FEEDING TEST				
		Pounds	*Pounds*	*Pounds*	*Pounds*
55	Linseed oil meal	28. 7	140. 5	1. 00	343
58	Distiller's solubles (composite)	28. 7	151. 0	1. 09	330
61	Malt amylase distiller's solubles	29. 0	160. 0	1. 17	342
64	Fungal amylase distiller's solubles	29. 2	148. 5	1. 06	334
	SECOND FEEDING TEST				
56	Linseed oil meal	35. 7	152. 2	1. 04	374
59	Distiller's solubles (composite)	36. 0	164. 5	1. 15	357
62	Malt amylase distiller's solubles	36. 0	148. 7	1. 01	370
65	Fungal amylase distiller's solubles	36. 0	152. 0	1. 04	384
	THIRD FEEDING TEST				
57	Linseed oil meal	35. 2	173. 0	1. 23	360
60	Distiller's solubles (composite)	35. 2	160. 0	1. 11	364
63	Malt amylase distiller's solubles	34. 7	179. 0	1. 28	354
66	Fungal amylase distiller's solubles	35. 0	184. 0	1. 33	366
	AVERAGE				
	Linseed oil meal	33. 2	155. 2	1. 09	359. 3
	Distiller's solubles (composite)	33. 3	158. 5	1. 12	350. 6
	Malt amylase distiller's solubles	33. 2	162. 6	1. 15	355. 0
	Fungal amylase distiller's solubles	33. 4	161. 5	1. 14	361. 4

TESTS WITH GROWING CHICKENS

By J. L. MILLIGAN and H. R. BIRD

Distiller's dried solubles have long been recognized as a good source of riboflavin, which is one of the vitamins that must be added in the form of special supplements to present-day poultry diets. The solubles are also a good source of other B-complex vitamins and unknown growth factors (*36*, *12*). For these reasons, distiller's dried solubles are often included in mixed feeds for chickens.

Conceivably any deviation in manufacturing procedure, such as a change in type or source of enzymes used, could result in differences in the content of available riboflavin and other growth factors, thus altering the feeding value for poultry. The possibility of a shift from the use of barley malt to the use of fungal amylase in the fermentation industries necessitated measurement of the relative feeding value, for poultry, of the distiller's dried solubles produced by both processes.

In three series of experiments comparing the value of the two types of solubles for growing chickens, Rhode Island Red chicks whose dams were fed a good breeder diet were placed on test at one day of age in electrically heated batteries. Each group contained 20 chicks selected according to weight. Feed and water were available at all times. During the 6-week test periods, records on weekly weights, mortality, deficiency symptoms, and feed efficiency were kept. The emphasis was placed on growth, since a partial deficiency of riboflavin results primarily in poor weight gains and only occasionally in paralysis. Approximately 1.3 mg. of riboflavin per pound of feed is required for growing chickens to eight weeks of age.

Table 19 gives the composition of the basal diets used. Diet A was designed to measure the ability of both types of solubles to function as riboflavin sources in a diet borderline for that vitamin and similar to some wartime commercial diets. Diet B was planned to measure additional nutritional values of the solubles. It was somewhat lower in riboflavin content than diet A. As both types of solubles were equal (by photofluorometric assay) in riboflavin content, they were added to both diets at the same levels—5, 10, and 15 percent. All supplements were added in place of corn. Following is the total quantity of riboflavin supplied at each level of supplementation of the two basal diets. In either of these diets, 5 percent of solubles should supply all the riboflavin needed.

	Milligrams of riboflavin per pound of diet
Basal Diet A and—	
No supplement	1.26
5 percent solubles	1.57
10 percent solubles	1.88
15 percent solubles	2.20
Basal diet B and—	
No supplement	1.08
5 percent solubles	1.39
10 percent solubles	1.70
15 percent solubles	2.02

Table 20 summarizes the results of the tests. Diet A was not used in the last series of tests because it proved to be so nearly adequate in riboflavin and in other growth factors that the effect of the distiller's dried solubles was obscured. In series 2, diet A without supplementation produced unusually good growth, with the result that the effect of supplementation with distiller's solubles was completely masked. Such a result must be expected occasionally when rations nearly adequate in the critical vitamins are used as basal diets. The Connecticut broiler mash was used as a positive control diet. Among other ingredients, this diet contained liver meal, fish meal, and a high percentage of corn and was abundantly fortified in riboflavin. It was a typically high-energy broiler diet that was known from experience to support excellent growth.

As riboflavin supplements, both types of distiller's solubles served satisfactorily with either chick basal diet; in general they increased growth. The incidence of "curled toe" paralysis was slight and of uncertain relationship to the riboflavin content except in the groups fed the unsupplemented diet B, in which the number of cases and the severity were high. In general, feed efficiencies of chicks fed either type of solubles increased in direct relationship to the level fed, regardless of whether diet A or B was employed. Mortality was high on diet B but apparently unrelated to the type of solubles fed.

TABLE 19.—*Composition of basal diets used in chick-feeding experiment*

Ingredient	Basal diet A	Basal diet B
	Percent	*Percent*
Corn	38.5	41.6
Barley	20.0	20.0
Alfalfa leaf meal	3.0	
Soybean oil meal	35.0	35.0
Bonemeal	1.5	1.5
Limestone	1.0	1.0
Salt (containing 4 percent manganese supplement)	.7	.7
Feeding oil containing vitamins A and D	.2	.2
Vitamin B_{12} concentrate [1]	.1	
Total	100.0	100.0
Niacin (crystalline) milligrams per pound	6.6	6.6
Calculated protein percent	18.85	18.62
Riboflavin by assay milligrams per pound	1.26	1.08

[1] Contained 12.5 mg. of vitamin B_{12} per pound of feed according to manufacturer.

Several results in connection with diet B supplementation warrant further study. First, although 5 percent of solubles should have furnished all the riboflavin needed, increasing the level of either type of solubles in the diet to 10 or 15 percent produced correspondingly increased growth. Second, in six of eight groups, when chicks were fed malt amylase solubles supplementary to basal diet B, growth was somewhat greater than when the fungal amylase product was fed at the same level. Possible causes of these two effects were investigated in subsequent work.

Analysis revealed that the crude protein content was 28.3 percent in the fungal amylase product and 32.4 percent in the malt amylase product. When the former product was fed at the 15-percent level, the diet furnished approximately 3 percent more protein than the basal diet. At the 15-percent level, the malt amylase solubles furnished 0.6 percent more protein in the diet than the fungal amylase product. The last four groups in table 20 were used to show the effects of feeding growing chickens 10 and 15 percent of both types of distiller's solubles when the protein level in the supplemented diet was held to that of the basal diet. The adjustments were made by changing the corn-soybean ratio. The groups fed 10 and 15 percent of solubles without adjustment of the crude protein showed no growth advantage over groups fed similarly with the crude protein level adjusted. There-

TABLE 20.—*Response of chicks to distiller's byproducts*

Group No.	Diet	Supplement of—		Weight at 6 weeks as percentage of weight of negative control group [1]			Average feed efficiency [2]	Mortality	Incidence of "curled toe" paralysis [3]
		Fungal amylase solubles	Malt amylase solubles	Series 1	Series 2	Series 3			
		Percent	*Percent*	*Percent*	*Percent*	*Percent*		*Percent*	*Percent*
1	A			100.0	100.0		0.320	7.5	2.7
2	A	5		104.6	98.7		.333	7.5	0
3	A		5	112.4	([5])		.364	5.0	0
4	A	10		111.7	92.2		.338	12.5	2.9
5	A		10	112.8	82.4		.358	5.0	0
6	A	15		120.1	97.8		.387	2.5	2.6
7	A		15	123.1	94.6		.380	12.5	0
8	B			100.0	100.0	100.0	.239	29.1	30.8
9	B	5		95.6	108.1	108.8	.267	14.5	6.4
10	B		5	101.2	123.5	139.8	.274	21.8	2.3
11	B	10		127.7	([5])	114.9	.334	15.0	8.8
12	B		10	117.7	133.3	121.2	.302	14.5	0
13	B	15		120.4	123.4	132.3	.304	12.7	0
14	B		15	139.2	152.7	128.0	.359	7.3	0
15	CBD [4]			143.8	161.8	173.6	.359	10.9	0
16	B	[6] 10				137.1	.360	20.0	0
17	B		[6] 10			133.4	.274	35.0	0
18	B	[6] 15				114.5	.329	20.0	0
19	B		[6] 15			140.7	.396	5.0	0

[1] In series 1, chicks receiving only basal diet A averaged 394.2 gm. in weight; basal diet B, 296.6 gm. In series 2, chicks receiving only basal diet A averaged 506.7 gm.; basal diet B, 332.7 gm. In series 3, chicks receiving only basal diet B averaged 246.3 gm.

[2] Feed efficiency = the total gain divided by the total feed consumption.

[3] Average severity × 100. "Curled toe" paralysis was graded individually on the basis of 0–4 for increasing severity.

[4] Connecticut broiler diet.

[5] Chilled first week, therefore eliminated.

[6] Protein level of the supplemented diet fed to this group was adjusted to that of the basal diet.

fore, the crude protein content was not the cause of the greater growth with higher levels of supplementation. The results did not clearly demonstrate a superiority of either type of solubles over the other.

More detailed analyses of the protein fraction showed that either of the distiller's solubles added approximately 0.1 percent of methionine to the diet. Milligan, Machlin, Bird, and Heywang (*24*) demonstrated that supplementing a similar diet with 0.1 percent DL-methionine increased growth even in the presence of vitamin B_{12} supplements. Therefore, it is possible that the response of growing chickens to supplementary levels of solubles above those needed to satisfy the riboflavin requirement might be the result of the additional methionine.

Both types of solubles were analyzed for vitamin B_{12} content[6] by the chick assay method described by Bird, Rubin, and Groschke (*2*). They were found to contain small quantities of vitamin B_{12} and might furnish as much as 2.7 μg. per pound of feed. However, in view of the difficulty of determining the content of this vitamin in crude products of low potency, the validity of these results is open to question. According to data presented by Milligan and Combs (*23*), 1.5 μg. of supplementary vitamin B_{12} per pound of feed increased the growth of undepleted New Hampshire chicks over that of similar chicks fed none of this vitamin when the all-vegetable diet contained 24 percent of protein.

Finally, one must recognize the possibility of the presence, in both types of distiller's solubles, of vitamin B_{13} described by Novak and coworkers (*26*). The possibly higher content of this vitamin in the malt amylase product might be the cause of its borderline advantage over the fungal amylase product.

SUMMARY AND CONCLUSIONS

In recent years experiments have shown that the use of amylase produced by fungal enzymes can supplement or replace barley malt in the alcoholic fermentation of grain, with considerable financial saving to the distilling industry. Therefore, as distiller's byproducts occupy an important place in the national livestock feed picture, it was considered highly desirable to determine whether those produced by the new process could replace the byproducts recovered from malt-converted mashes. The two products were compared for chemical composition, toxicity, palatability, digestibility, and their effect on the growth and fattening of animals. The studies were made in 1949 and 1950 at the Agricultural Research Center, Beltsville, Md.

Results showed that the composition of the distiller's byproducts recovered from the fungal amylase-converted mashes compares well with the composition of representative distiller's corn byproducts. Furthermore, no toxic or other detrimental effects of feeding large quantities of fungal amylase byproducts were observed.

Cattle showed no preference for the malt amylase byproducts over the fungal amylase byproducts. Although swine and sheep seemed to prefer the former, the differences in palatability were not large enough to affect significantly the feeding results.

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[6] The analyses for vitamin B_{12} content were conducted by Robert J. Lillie of the Bureau of Animal Industry.

There were no significant differences between the two processes in the digestibility of the distiller's grains with solubles. When these two byproducts were used as protein supplements to lamb-fattening diets, there was no significant difference in their effect on the digestibility or the metabolizable energy content of the diets. When fed with oat straw to wintering pregnant beef cows, both were suitable as the protein supplement and as a partial source of total digestible nutrients.

As a protein supplement in fattening diets for lambs, distiller's dried grains with solubles recovered from either the malt- or fungal amylase-converted mashes can satisfactorily replace linseed oil meal.

As carriers of B vitamins and as a source of protein in swine diets, distiller's solubles produced by the fungal amylase process can replace solubles produced by the malt amylase process. There were no significant differences in growth and feed efficiency of the swine fed the two products.

As a riboflavin source for growing chickens, distiller's dried solubles produced by either process served satisfactorily. A slightly higher growth response was obtained from the use of malt amylase solubles when added to a vegetable protein diet composed mostly of corn and soybean oil meal. The increased gain was probably due to the somewhat higher crude protein content of the malt product. Each type of solubles supplemented the basal diets not only with riboflavin but also with methionine (for which there was a borderline deficiency) and possibly with vitamin B_{12}. Differences between the two types of distiller's solubles were slight and both should be equally valuable in commercial diets. If in the future the poultry-feed industry shifts to all-vegetable-protein diets for growing chickens, distiller's solubles, because of their methionine content, may be used in these diets rather than synthetic riboflavin.

When fungal amylase grains are produced and fed in a manner comparable to that described in this bulletin, they can be substituted satisfactorily for the conventional distiller's byproducts in livestock and poultry feeding.

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