Evaluation of Distillers Dried Grains with Solubles as a Feed Ingredient for Broilers

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ABSTRACT Two experiments were conducted to evaluate the use of distillers dried grains with solubles (DDGS) from modern ethanol plants in broiler diets. Experiment 1 was a 2 × 2 factorial experiment with diets containing 2 levels of DDGS (0 and 15%) and 2 diet densities (high and low). The high- and low-density diets were formulated to contain 22% CP and 3,050 kcal ME_n/kg and 20% CP and 3,000 kcal ME_n/kg, respectively. Eight pens of 6 chicks were fed an experimental diet from 0 to 18 d of age. Weight gain and feed efficiency (gain:feed ratio) of the chicks receiving the high-density diets were ($P < 0.05$) better than those of chicks fed the low-density diets. However, within the 2 density levels there was no difference in performance of chicks fed diets with 0 or 15% DDGS. In experiment 2, 6 replications of 50 chicks were fed 1 of 4 dietary treatments for 42 d. The diets were formulated to be isocaloric and isonitrogenous and contained 0, 6, 12, or 18% DDGS. There was no significant difference in performance or carcass yield throughout the 42 d experiment except for a depression in BW gain and feed conversion when chicks were fed diets with 18% DDGS in the starter period. These studies indicate that DDGS from modern ethanol plants is an acceptable feed ingredient for broiler diets and can be safely used at 6% in the starter period and 12 to 15% in the grower and finisher periods.

(*Key words*: distillers dried grains with solubles, broiler, feed ingredient, carcass yield)

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INTRODUCTION

Historically, distillers dried grains with solubles (DDGS) has been a by-product of the beverage industry, for the most part, with several different grains used in the fermentation process. In the late 1930s, feed producers began to incorporate DDGS into livestock rations, but before this, it was a by-product with limited value (Scott, 1970). The beverage industry was not the only source of DDGS; ethanol plants also produced this ingredient. Recently, ethanol production has been encouraged in the United States, as ethanol is cleaner burning, provides more energy than petroleum, and is a partially renewable resource. Ethanol producers responded to this emphasis in the mid to late 1990s by building new plants. The DDGS from these plants is largely from corn fermentation and undergoes a supposedly gentler drying process than DDGS produced by the beverage industry, both of which may allow "new generation" DDGS to be a more valuable ingredient than before.

The production of DDGS has continued to increase and it is predicted that by 2005, there will be approximately 5.5 to 7 million metric tons available to feed producers (Shurson, 2003). Distillers dried grains with solubles have been used in commercial poultry diets at a level of 5% or less for many years. Incorporation of DDGS at higher levels may provide an additional outlet for the increasing amounts available (Noll et al., 2001). Researchers have observed positive results when DDGS was incorporated in broiler diets. Day et al. (1972) observed an increase in weight gain when broilers were fed diets containing low levels of DDGS (2.5 and 5%). Insko et al. (1937) suggested that "distillery slop", that is, DDGS before it undergoes drying, could replace 80% of corn in a standard poultry diet. Other researchers have concluded that up to 25% DDGS can be incorporated in broiler diets if dietary energy is held constant (Waldroup et al., 1981). However, it is presumed that most of the DDGS used in these studies came from the beverage industry and DDGS from modern ethanol plants may differ in nutrient composition. As very little research has been published pertaining to the use of DDGS from modern ethanol plants, and limited nutritional information is available, our objective was to evaluate the use of this new generation DDGS in broiler diets.

MATERIALS AND METHODS

General Procedures

Two experiments were performed to test the level at which DDGS from modern ethanol plants could be success-

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Abbreviation Key: DDGS = distillers dried grains with solubles; SBM = soybean meal.

TABLE 1. Nutritional composition of distillers dried grains with solubles (DDGS, as-fed basis) used in experiments 1 and 2

	DDGS	
	Estimated	Analyzed
TME_n, kcal/kg	2,800	2,905[1]
Dry matter, %	87	86
CP, %	27	29.1
Lysine, %	0.94	0.85 (75)[2]
Methionine, %	0.60	0.56 (89)
TSAA, %	1.00	1.18 (82)
Threonine, %	0.95	1.05 (76)
Arginine, %	1.00	1.25 (84)
Tryptophan, %	0.20	0.28 (84)
Fat, %	10.00	9.80
Ash, %	4.50	3.90
Sodium, %	0.13	0.11

[1]TME_n for DDGS was determined in 10 conventional roosters.

[2]Values in parentheses are the availability percentage estimates determined in cecectomized roosters.

fully incorporated into broiler diets. The DDGS used in the experiments was completely derived from corn and came from an ethanol plant in Aurora, Nebraska, which was built in the early 1990s. The sample had a golden yellow color, a coarse appearance, and a distinctively sweet smell. The diets for both experiments were formulated on a total amino acid basis using the Brill least cost feed formulation program.[2] The nutrient levels of DDGS used for the diet were estimated based on previous analysis of various samples (N. M. Dale and A. B. Batal, 2003, unpublished data) and book values (Table 1). Lysine and methionine were supplemented to the diets as needed to maintain consistent amino acid levels between experimental diets.

The DDGS used in both studies underwent proximate analysis;[3] TME_n and true amino acid digestibility were determined by the procedure described by Sibbald (1976, 1979). Ten conventional and cecectomized Single Comb White Leghorn roosters were fasted for 24 h and then crop intubated with 30 g of the DDGS sample for determination of TME_n and true amino acid digestibility, respectively. Feces were collected for a 48-h period, dried, and weighed. The dried samples were then ground and sent for analysis (Table 1).[3]

Experiment 1

All procedures concerning animal care and use were approved by the University of Georgia. Experiment 1 was a preliminary experiment to test a 15% level of DDGS in starter diets for broilers. Chicks were housed in an environmentally controlled building and placed into thermostatically controlled starter batteries[4] with raised wire floors. Cobb × Cobb-500 straight run chicks were divided into 8 replications per treatment of 6 chicks and fed 1 of 4 dietary treatments ad libitum from 0 to 18 d of age. A 2 × 2 factorial experiment was used, with 2 high-density diets containing 0 or 15% DDGS and 2 low-density diets containing 0 or 15% DDGS (Table 2). The high-density diets were formulated to contain 22% CP and 3,050 kcal ME_n/kg and the low-density diets contained 20% CP and 3,000 kcal ME_n/kg. The purpose for including the low-density diet was to allow for the evaluation of DDGS under limiting nutritional conditions. Weight gain and feed efficiency (gain:feed) were determined for each pen at 7, 14, and 18 d of age.

Experiment 2

Experiment 1 provided an indication that 15% DDGS could be used in practical starter diets. The objective of experiment 2 was to examine the effects of DDGS on broiler performance and carcass yield through market weight. Graded levels of DDGS up to and exceeding 15% were evaluated in a 42-d broiler growth study. Six replications per treatment of 50 straight run Cobb × Cobb-500 chicks per pen were housed in a curtain side building. The house had litter floors and the pens were separated by wire mesh to create 2.4 × 3.7 m (8 × 12 ft) pens. Each pen contained 2 bell waterers and 2 galvanized steel feeders. Feed and water were provided ad libitum throughout the study. Four experimental diets containing 0, 6, 12, and 18% DDGS were formulated for the starter (0 to 16 d), grower (17 to 31 d), and finisher (32 to 42 d) periods (Table 3). Diets were formulated to be isonitrogenous and isocaloric with constant lysine and methionine levels for each treatment within each of the 3 periods. The same parameters as in the preliminary experiment (weight gain, feed intake, and feed efficiency) were examined in experiment 2, these parameters being measured at 16, 31, and 42 d of age. To investigate a possible effect of DDGS on processing characteristics, 10 birds (5 females and 5 males) from each pen were randomly selected for processing at 42 d of age. Feed was removed 10 h before processing. After processing, carcasses were chilled for 12 h and yield was determined for breast, wings, and front and back halves. The entire carcass was weighed and the back half, comprising the leg quarters joined to the lower back, was removed, leaving the white meat front half. Both wings and the pectoralis major and minor were removed from the front half.

Statistical Analysis

Data from both experiments were subjected to ANOVA procedure for completely randomized design (Steel and Torrie, 1980) using the GLM procedures of SAS (SAS Institute, 1990). Statistical significance of differences among treatments was assessed using the least significant difference test (Steel and Torrie, 1980). Data from experiment 1 were analyzed by ANOVA to determine significance of main effects (density and DDGS) and interactions (density × DDGS). A probability level of $P < 0.05$ was used to determine statistical significance.

[2]Feed Management System, Inc., Brooklyn Center, MN.

[3]UGA Nutrition Lab, University of Georgia, Poultry Science Bldg. Athens, GA and Experiment Station Chemical Laboratories, University of Missouri-Columbia, room 4, Agriculture Bldg., Columbia, MO.

[4]Petersime Incubator Co., Gettysburg, OH.

TABLE 2. Composition of dietary treatments on as-fed basis (experiment 1)

	High density		Low density	
Ingredients	Control	DDGS	Control	DDGS
	(%)			
Corn, yellow, ground	56.48	48.83	63.77	56.24
Soybean meal (48)	36.79	29.22	31.36	23.78
DDGS[1]	—	15.00	—	15.00
Fat, poultry	2.69	3.03	0.77	1.01
Dicalcium phosphate	1.74	1.38	1.77	1.39
Limestone	1.25	1.36	1.26	1.38
Salt	0.50	0.47	0.50	0.47
Vitamin premix[2]	0.25	0.25	0.25	0.25
DL-Methionine	0.22	0.20	0.20	0.18
L-Lysine	—	0.18	0.04	0.22
Trace mineral premix[3]	0.08	0.08	0.08	0.08
Contents by calculation				
TME_n, kcal/kg	3,050	3,050	3,001	3,001
Protein, %	22	22	20	20
Lysine, %	1.23	1.23	1.12	1.12
Methionine, %	0.58	0.59	0.54	0.54

[1]DDGS = distillers dried grains with solubles.

[2]Vitamin mix provided the following (per kilogram of diet): thiamin·mononitrate, 2.4 mg; nicotinic acid, 44 mg; riboflavin, 4.4 mg; D-Ca pantothenate, 12 mg; vitamin B_{12} (cobalamin), 12.0 μg; pyridoxine·HCl, 2.7 mg; D-biotin, 0.11 mg; folic acid, 0.55 mg; menadione sodium bisulfate complex, 3.34 mg; choline chloride, 220 mg; cholecalciferol, 1,100 IU; trans-retinyl acetate, 5,500 IU; all-rac-tocopherol acetate, 11 IU; ethoxyquin, 150 mg.

[3]Trace mineral mix provides the following (per kilogram of diet): manganese ($MnSO_4 \cdot H_2O$), 60 mg; iron ($FeSO_4 \cdot 7H_2O$), 30 mg; zinc (ZnO), 50 mg; copper ($CuSO_4 \cdot 5H_2O$), 5 mg; iodine (ethylene diamine dihydroiodide), 1.5 mg.

RESULTS

Experiment 1

There was no difference in the weight gains of chicks fed the high- and low-density diets containing either 0 or 15% DDGS at 7 d of age (Table 4). At 14 and 18 d of age, differences in weight gain were observed between the high- and low-density diets. Body weight gain of chicks receiving the high-density diets was significantly better than chicks fed the low-density diets. However, within each diet density, there was no difference in the weight gain of chicks fed diets containing either 0 or 15% DDGS.

No differences in feed intake between chicks fed the high- or low-density diets or the 0 or 15% levels of DDGS were observed. At 7 d of age there was a significant difference in feed efficiency (gain:feed) between all 4 of the dietary treatments, with the lowest feed efficiency observed when chicks were fed the low-density diet with 15% DDGS (Table 4). There was no difference in feed efficiency at 14 d of age when the chicks were fed the high-density diet with 0 or 15% DDGS. However, chicks fed the low-density diet with 15% DDGS had reduced feed efficiency compared with chicks fed the low-density diet with 0% DDGS or the high-density diets. At 18 d of age, feed efficiencies of chicks fed the high-density diets were improved over chicks fed the low-density diets, but within each diet density there was no difference in feed efficiency between chicks fed 0 or 15% DDGS (Table 4). This indicates that the nutrient matrix used for DDGS was reasonable. No interactions between density × DDGS were observed.

Experiment 2

The inclusion of 18% DDGS in the diet depressed chick weight gain during the starter (0 to 16 d) period (Table 5). There was also a slight numerical decrease in weight gain with 12% DDGS. During the grower and finisher periods there was no difference in weight gain between any of the dietary treatments. However, the overall weight gain (42 d) for chicks fed diets with 18% DDGS was depressed, principally due to the reduced gain during the starter period.

No differences in feed intake were observed between any of the dietary treatments throughout the experiment. Feed efficiency (gain:feed) was depressed during the starter period when chicks were fed diets with 18% DDGS and there was a numerical decrease in feed efficiency due to the inclusion of 12% DDGS (Table 5). No differences in feed efficiency were observed between any of the dietary treatments during the grower and finisher period or throughout the 42-d experiment. Feeding 0, 6, 12, or 18% DDGS to broiler chicks had no effect on carcass yield when observing the selected carcass parts: front and back halves (white and dark meat areas), wings, and breasts (Table 6).

The color of the DDGS was quantified with a Minolta colorimeter[5] and had recorded values of L* (white and black) = 58.52, a* (red and green) = 6.38, b* (yellow and blue) = 20.48. Cromwell et al. (1993) reported that darker DDGS samples tend to have lower amino acid concentrations. Testing the color of our DDGS sample will allow for future comparisons with other DDGS samples.

[5]Minolta CR300 colorimeter, Minolta Corporation, Ramsey, NJ.

TABLE 3. Composition of dietary treatments on as-fed basis (experiment 2)

	Starter				Grower				Finisher			
Ingredients	Control	6% DDGS	12% DDGS	18% DDGS	Control	6% DDGS	12% DDGS	18% DDGS	Control	6% DDGS	12% DDGS	18% DDGS
	(%)											
Corn, yellow, ground	58.39	55.16	51.97	48.69	62.83	59.62	56.41	53.13	68.52	65.31	60.77	55.47
Soybean meal (48)	36.47	33.49	30.49	27.50	31.50	28.49	25.50	22.51	26.48	23.48	21.67	20.53
DDGS[1]	—	6.00	12.00	18.00	—	6.00	12.00	18.00	—	6.00	12.00	18.00
Fat, poultry	1.82	2.02	2.22	2.49	2.50	2.70	2.91	3.17	2.12	2.32	2.74	3.27
Defluorinated phosphate	1.78	1.63	1.47	1.32	1.54	1.39	1.23	1.07	1.29	1.14	0.97	0.81
Limestone	0.62	0.72	0.81	0.90	0.69	0.79	0.88	0.97	0.72	0.81	0.90	0.99
Salt	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.35	0.36	0.36	0.36
Vitamin premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.22	0.22	0.21	0.20	0.23	0.22	0.21	0.21	0.15	0.14	0.12	0.10
L-Lysine	—	0.06	0.13	0.20	0.01	0.09	0.16	0.23	0.04	0.11	0.14	0.14
Trace mineral premix[3]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Coccidiostat[4]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	—	—	—	—
Contents by calculaion												
TME$_n$, kcal/kg	3,031	3,031	3,031	3,034	3,120	3,120	3,120	3,123	3,159	3,159	3,159	3,159
Protein, %	22	22	22	22	20	20	20	20	18	18	18	19
Lysine, %	1.23	1.22	1.22	1.22	1.10	1.10	1.10	1.10	0.98	0.98	0.98	0.98
Methionine, %	0.59	0.59	0.60	0.60	0.57	0.57	0.57	0.58	0.46	0.47	0.46	0.46

[1]DDGS = distillers dried grains with solubles, estimated TME$_n$ = 2,800 kcal/kg, 27% CP, and 0.94% lysine.

[2]Vitamin mix provided the following (per kilogram of diet): thiamin·mononitrate, 2.4 mg; nicotinic acid, 44 mg; riboflavin, 4.4 mg; D-Ca pantothenate, 12 mg; vitamin B$_{12}$ (cobalamin), 12.0 μg; pyridoxine·HCl, 2.7 mg; D-biotin, 0.11 mg; folic acid, 0.55 mg; menadione sodium bisulfate complex, 3.34 mg; choline chloride, 220 mg; cholecalciferol, 1,100 IU; trans-retinyl acetate, 5,500 IU; all-rac-tocopherol acetate, 11 IU; ethoxyquin, 150 mg.

[3]Trace mineral mix provides the following (per kilogram of diet): manganese ($MnSO_4 \cdot H_2O$), 60 mg; iron ($FeSO_4 \cdot 7H_2O$), 30 mg; zinc (ZnO), 50 mg; copper ($CuSO_4 \cdot 5H_2O$), 5 mg; iodine (ethylene diamine dihydroiodide), 1.5 mg.

[4]Coccidiostat = Coban 60, Elanco Animal Health, Indianapolis, IN.

DISCUSSION

Based on the BW gain and feed efficiencies from experiment 1, it could be concluded that 15% DDGS may be used safely in commercial (high-density) diets. However, the lower feed efficiency (gain:feed) observed during the first 7 d and the numeric reduction thereafter suggest that an inclusion level of 15% DDGS may be excessive during the starter period. These assumptions were confirmed by the results of experiment 2, in which 12 and 18% DDGS depressed chick performance during the starter period.

Soybean protein is known to have a more favorable amino acid pattern for chick growth than corn. When 18% DDGS was incorporated into the diet, the percentage protein of corn origin doubled (4.6 to 8.6%), whereas the percentage protein from soybean meal (SBM) decreased. It is

TABLE 4. Effects of feeding distillers dried grains with solubles (DDGS) to broilers on weight gain and feed efficiency (experiment 1)[1]

	Weight gain (g/chick)			Gain:feed (g:kg)		
Treatment	d 7	d 14	d 18	d 7	d 14	d 18
High density, 0% DDGS	133	401^{a}	556^{a}	956^{a}	938^{a}	782^{a}
High density, 15% DDGS	134	399^{a}	555^{a}	991^{b}	936^{a}	772^{a}
Low density, 0% DDGS	130	376^{b}	523^{b}	898^{c}	874^{b}	712^{b}
Low density, 15% DDGS	124	362^{b}	518^{b}	854^{d}	847^{c}	705^{b}
Pooled SEM	3.6	7.2	8.2	8.5	8.7	8.6
Density						
High	134	400^{a}	555^{a}	944^{a}	938^{a}	777^{a}
Low	127	369^{a}	521^{a}	876^{a}	861^{a}	709^{a}
Pooled SEM	2.5	5.1	5.8	6.0	6.1	6.1
DDGS						
0%	132	388	540	928^{a}	906	747
15%	129	380	536	893^{b}	892	738
Pooled SEM	2.5	5.1	5.8	6.0	6.1	6.1
Source of variation	P					
Density	0.06	0.01	0.01	0.01	0.01	0.01
DDGS	0.46	0.29	0.71	0.01	0.12	0.31
Density × DDGS	0.34	0.47	0.83	0.06	0.14	0.82

[a,b]Means within a column and section with no common superscript differ significantly ($P < 0.05$).

[1]Means represent 8 pens per treatment, 6 chicks per pen.

TABLE 5. Effects of feeding distillers dried grains with solubles (DDGS) to broilers on weight gain and feed efficiency (experiment 2)[1]

	Weight gain (g/chick)			Gain:feed (g:kg)		
DDGS, %	d 0 to 16	d 17 to 31	d 0 to 42	d 0 to 16	d 17 to 31	d 0 to 42
0	414[a]	1,052	2,314[a]	746[a]	597	566
6	416[a]	1,055	2,289[a]	739[a]	600	554
12	399[ab]	1,049	2,291[a]	715[ab]	604	565
18	387[b]	1,039	2,243[b]	702[b]	599	554
Pooled SEM	7.2	7.2	14.4	11.2	5.7	6.7

[a,b]Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]Means represent 6 pens per treatment, 50 chicks per pen.

believed that at 18% DDGS, the high level of dietary protein of corn origin and the corresponding decrease in soybean protein may have contributed to the depressed performance due to a marginal lysine deficiency. The estimated lysine value (0.94%) of DDGS used in the diet formulation was higher than the analyzed value (0.85%). The depressed performance observed at the higher inclusion levels was likely due to the overestimation of lysine in DDGS and decreases in the level of soybean protein, the main lysine source in the diet, resulting in a marginal lysine deficiency. At lower inclusion levels of DDGS, there appeared to be sufficient lysine from the soybean protein and thus no negative effect due to the overestimation of the lysine concentration was observed. A marginal lysine deficiency may also explain the growth depressing effect of DDGS in the more sensitive low-density diet fed in experiment 1. Our results seem to agree with those of Hughes and Hauge (1945), who observed that when DDGS was used as the sole source of protein in a broiler diet there was a marginal deficiency of lysine, causing a slight decrease in performance.

Waldroup et al. (1981) found that up to 25% DDGS could be used in broiler starter diets when the energy level was constant. In their study, the inclusion of 25% DDGS was substituted for both corn and SBM without lysine supplementation. Based on the results herein it would be expected that a depression in performance would be observed with the higher incorporation levels of DDGS and no supplementation of lysine. However, this was not observed, which is likely due to a more accurate estimation of lysine concentration. Parsons and Baker (1983) reported that at least 20% of the dietary SBM could be replaced by DDGS in the absence of lysine supplementation, and up to 30% of the SBM could be replaced with DDGS in the presence of added lysine. Parsons and Baker (1983) also concluded that more than 25% DDGS could be used in broiler diets if lysine was added and dietary energy was sufficient to support optimum performance. In our study, diets were formulated for a constant energy level and the diets were supplemented with lysine to maintain a constant total lysine level across all dietary treatments. However, depressed performance was observed during the starter period with the inclusion of 18% DDGS. Diets used by Waldroup et al. (1981) had higher fat levels than the diets used herein (5.5 to 8.4 vs. 1.8 to 2.2%) and were formulated to a higher ME (3,200 vs. 3,030 kcal/kg). Thus, the fiber or energy contents of the diets may further explain the differences between maximal levels observed in studies. The diets used herein were formulated to be isonitrogenous, in contrast to those of Waldroup et al. (1981), when the minimum protein level was 23% but was not kept constant and increased as the inclusion level of DDGS increased. This may be another explanation of differences between experiments.

TABLE 6. Effect of feeding distillers dried grains with solubles (DDGS) to broilers on carcass weights and yields (experiment 2)[1]

DDGS, %	Carcass	Breast meat	Wings	Front half[2]	Back half[3]
	(g)				
0	1,673	284	193	719	761
6	1,662	274	194	713	755
12	1,653	278	193	713	747
18	1,639	272	193	705	741
Pooled SEM	22.7	7.5	2.7	11.8	10.9
	(%)[4]				
0	71.2	16.9	11.5	43.0	45.5
6	70.9	16.5	11.7	42.9	45.4
12	70.3	16.8	11.7	43.2	45.2
18	70.8	16.6	11.8	43.0	45.2
Pooled SEM	0.80	0.29	0.09	0.29	0.33

[1]Means represent 6 pens per treatment, 10 birds per pen.

[2]Front half = the half of the carcass containing the breast, wings, and back (white meat).

[3]Back half = the half of the carcass containing the leg quarters joined at the lower back (dark meat).

[4]Yields = percentage of chilled carcass weights, carcass yield = percentage of live weight.

At an early age, chick performance was depressed when the diet contained 18% DDGS. It appeared that the younger birds (up to 18 d) were less able to tolerate high levels of DDGS, but this was not of consequence during the grower and finisher stages. It appears that increased inclusion levels of DDGS resulted in a marginal lysine deficiency, which was most limiting when the birds were young and had the highest amino acid requirements. During the grower and finisher periods, no significant differences were observed at any level of inclusion, which suggested that once beyond the starter period chicks could efficiently use higher levels of DDGS. Distillers dried grains with solubles from modern ethanol plants have proven to be a highly acceptable feed ingredient in commercial broiler diets. A conservative maximum level of DDGS to use in the starter diets is 6% and it could be speculated based on previous research that levels of 9% and above could be used as long as the level does not exceed 12%. However, in the grower and finisher period it appears feasible to increase DDGS in the diet to 12 to 15%.

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