SHORT COMMUNICATION: Enhanced distillers dried grains with solubles (DDGS) has greater concentration of digestible and metabolizable energy than DDGS when fed to growing and finishing pigs

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Soares, J. A., Singh, V., Stein, H. H., Srinavasan, R. and Pettigrew, J. E. 2011. **SHORT COMMUNICATION: Enhanced distillers dried grains with solubles (DDGS) has greater concentration of digestible and metabolizable energy than DDGS when fed to growing and finishing pigs**. Can. J. Anim. Sci. **91**: 663–667. To better use distillers dried grains with solubles (DDGS) for non-ruminants, some of the fiber may be removed. The ‘‘elusieve’’ process removes approximately 10% of DDGS material, mostly fiber, yielding enhanced DDGS (E-DDGS). An experiment was conducted to compare the DE and ME in E-DDGS to those in DDGS when fed to growing and finishing pigs. Overall, E-DDGS has greater DE, ME and ME_n than DDGS.

Key words: Distillers dried grains with solubles, energy, enhanced distillers dried grain with solubles, pigs

Soares, J. A., Singh, V., Stein, H. H., Srinavasan, R. et Pettigrew, J. E. 2011. **BRÈVE COMMUNICATION: Les drèches sèches de distillerie avec matières solubles (DDGS) bonifiées renferment plus d’énergie digestible et métabolisable que les DDGS ordinaires pour les porcs d’engrais et de finition**. Can. J. Anim. Sci. **91**: 663–667. On pourrait extraire une partie des fibres des drèches sèches de distillerie avec matières solubles (DDGS) destinées aux non-ruminants pour les améliorer. Le procédé « elusieve » retire environ 10 % des substances des DDGS, soit essentiellement les fibres, pour donner des DDGS bonifiées (E-DDGS). Les auteurs ont effectué une expérience pour comparer l’énergie digestible et l’énergie métabolisable (ME) des E-DDGS et des DDGS servies à des porcs pendant leur engraissement et la finition. Dans l’ensemble, les E-DDGS renferment plus d’énergie digestible, de ME et de ME_n que les DDGS.

Mots clés: DDGS, énergie, drèches sèches de distillerie avec matières solubles bonifiées, porcs

Reduction of the fiber content of distillers dried grains with solubles (DDGS) may improve their nutritional value for non-ruminant animals. Some fiber can be removed from DDGS by a combination of sieving and elutriating the DDGS (Srinivasan et al. 2005), called the elusieve process. It is a post-production process, so it does not require changes in existing dry-grind ethanol plants.

The elusieve process (Srinivasan et al. 2005) removes mostly fiber from the original material, yielding enhanced DDGS (E-DDGS) that has a total dietary fiber (TDF) concentration that is approximately 3.5 percentage units lower (from 28.7% to 25.2%) than conventional DDGS. Removal of the fiber concentrates the CP and fat (Table 1). When fed to cecectomized roosters, E-DDGS contains 7% more TME_n than DDGS (Kim et al. 2007), but there are no data on the ME and feeding value of E-DDGS to pigs.

The objective of this experiment was to test the hypothesis that DE, ME and ME_n for swine in E-DDGS are greater than in conventional DDGS for both growing and finishing pigs, and to determine the magnitude of the advantage.

The Institutional Animal Care and Use Committee at the University of Illinois, which has comparable guidelines to those laid down by the Canadian Council on Animal Care, reviewed and approved the protocol (#06241) for the experiment.

Thirty growing barrows (initial BW of 23.0 kg ± 2.8 kg) and 30 finishing barrows (initial BW of 73.0 ± 1.8 kg) originating from the mating of Line 337 boars to C 22 females (Pig Improvement Company, Hendersonville, TN) were used in the experiment. Within each stage of growth, pigs were allotted to a randomized complete

Abbreviations: **ADF**, acid detergent fiber; **BW**, body weight; **CP**, crude protein; **DDGS**, distillers dried grains with solubles; **DM**, dry matter; **E-DDGS**, enhanced distillers dried grains with solubles; **NDF**, neutral detergent fiber; **TDF**, total dietary fiber

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Table 1. Analyzed nutrient composition of ingredients (as-fed basis)[z]

	Ingredients					
Item	Corn	SBM[y]	DDGS[x]-1	DDGS[x]-2	E-DDGS[x]-1	E-DDGS[x]-2
DM (%)	84.87	88.26	90.16	88.77	91.62	90.16
CP (%)	7.24	47.94	28.14	26.74	30.01	28.20
Ether extract (%)	4.49	0.63	9.94	10.85	10.36	11.27
ADF (%)	2.93	4.71	8.42	8.43	9.43	7.93
NDF (%)	13.20	6.99	37.44	28.98	33.41	25.98
TDF[w] (%)	–	–	29.61	27.79	25.10	25.34
Ca (%)	0.005	0.31	0.26	0.28	0.26	0.28
P (%)	0.29	0.77	0.76	0.80	0.86	0.85
GE (kcal kg^{-1})	3754	4126	4651	4610	4752	4732
Indispensable AA (%)						
Arg	–	–	1.25	1.28	1.37	1.30
His	–	–	0.70	0.72	0.76	0.74
Ile	–	–	0.98	0.99	1.05	1.02
Leu	–	–	3.07	3.10	3.34	3.18
Lys	–	–	0.89	0.95	0.93	0.92
Met	–	–	0.55	0.54	0.60	0.55
Phe	–	–	1.30	1.32	1.41	1.34
Thr	–	–	0.98	1.02	1.04	1.01
Trp	–	–	0.16	0.16	0.19	0.18
Val	–	–	1.31	1.35	1.42	1.38
Dispensable AA (%)						
Ala	–	–	1.87	1.92	2.03	1.95
Asp	–	–	1.74	1.73	1.86	1.73
Cys	–	–	0.50	0.49	0.54	0.49
Glu	–	–	3.95	4.00	4.22	3.90
Gly	–	–	1.05	1.09	1.12	1.09
Pro	–	–	1.90	1.90	20.01	1.96
Ser	–	–	1.19	1.26	1.27	1.23
Tyr	–	–	0.96	1.02	1.05	1.03

[z] AA and TDF were not analyzed in corn and SBM.
[y] SBM, soybean meal.
[x] DDGS, distillers dried grains with solubles; E-DDGS = enhanced DDGS.
[w] TDF, total dietary fiber.

block design with five dietary treatments and six replicates per treatment. The 30 pigs at each stage of growth were used in two blocks of 15 pigs replicated over time.

Two batches of DDGS were obtained from Dakota Gold Research Association (Sioux Falls, SD). Approximately one-half of each source was used to produce E-DDGS as previously described (Srinivasan et al. 2005). Thus, there were two sources of DDGS and two sources of E-DDGS used in the experiment (Table 1).

Five different diets were formulated for each stage of growth. Diets were formulated to meet or exceed National Research Council (1998) requirements (Table 2). The basal diet contained corn, soybean meal, vitamins, and minerals. The four experimental diets were formulated by replacing 40% of the basal diet with DDGS or E-DDGS.

Pigs were placed in metabolism crates that permitted total, but separate, collection of urine and feces. Pigs were fed their experimental diets for 14 d. The voluntary feed intake of all pigs was measured during the first week while the pigs adapted to the metabolism cages and the diets. The amount of feed provided to all pigs during the following week was set at 90% of the average of voluntary intake during the first week for each stage of growth.

The animals had ad libitum access to water throughout the experiment. They were fed at 0800 and 1700. All feed offered was consumed by all pigs throughout the experiment. On day 8 of the experiment, chromic oxide (0.5%) was mixed into the morning meal. Fecal collections started when the marker appeared for the first time in the feces. On day 13, chromic oxide was again included in the diet and fecal collections stopped when the marker appeared in the feces. Feces were collected twice daily and stored at −20°C. After the collection period, feces were weighed and dried in an oven at 55°C, ground, mixed, and sub-sampled for analysis. Urine collections started immediately after feeding the morning meal and stopped on day 13 immediately after feeding the morning meal. Urine was filtered through a cheese cloth before being collected twice daily from buckets containing 20 mL of 6 N sulfuric acid that were placed under the metabolism cages. At each collection time, the collected urine was diluted by water up to 2 L and 5% of the collected urine was retained and stored at −20°C. At the conclusion of the experiment, urine

Table 2. Composition of diets (as-fed basis)

	Diet			
	Growing		Finishing	
Item	Basal	Test diet	Basal	Test diet
Ingredient (%)				
Corn	73.00	43.80	83.01	49.86
Soybean meal	20.42	12.25	11.00	6.60
Soybean oil	1.67	1.00	1.67	1.00
Limestone	0.70	0.42	0.72	0.43
Dicalcium phosphate	1.60	0.96	1.00	0.60
L-lys HCL	0.50	0.30	0.50	0.30
DL-met	0.13	0.08	0.07	0.04
L-thr	0.17	0.10	0.22	0.13
L-trp	0.06	0.04	0.05	0.03
Mecadox premix[z]	1.00	1.00	1.00	1.00
Vitamin premix[y]	0.17	0.10	0.17	0.10
Micromineral premix[x]	0.58	0.35	0.50	0.30
Basal diet				
Test ingredient[w]	–	40.00	–	40.00
Energy and nutrients, analyzed				
GE (kcal kg^{-1})	3751	4121	3805	4111
CP (%)	17.01	18.52	12.97	17.62
NDF (%)	9.30	20.60	7.93	17.46

[z] Diet contained 55 mg carbadox kg^{-1}.

[y] Supplied per kilogram of complete diet: retinyl acetate, 2273 μg; cholecalciferol, 17 μg; DL-α-tocopheryl acetate, 88 mg; menadione sodium bisulfite complex, 4 mg; niacin, 33 mg; D-Ca-pantothenate, 24 mg; riboflavin, 9 mg; vitamin B_{12}, 35 μg; choline chloride, 324 mg.

[x] Supplied per kilogram of complete diet: Fe, 90 mg ($FeSO_4$ H_2O); Zn, 100 mg (ZnO); Mn, 20 mg (MnO); Cu, 8 mg ($CuSO_4H_2O$); I, 0.35 mg (CaI_2); Se, 0.3 mg (Na_2Se_3); and NaCl, 3 g.

[w] Test Ingredient = DDGS-1, DDGS-2, E-DDGS-1, E-DDGS-2.

samples were thawed, mixed, and sub-sampled for analysis.

All analyses were performed in duplicate and samples were re-analyzed if differences between duplicates exceeded 5%. Feces, ingredients, and diets were analyzed for DM (procedure 4.1.06; AOAC International 2007). Urine, feces, ingredients and diets were analyzed for GE by bomb calorimetry (Parr, model 6300; Parr Instruments, Moline, IL) and CP by combustion (Elementar, Rapid N Cube; procedure 4.2.08; AOAC International 2007). Urine samples were freeze dried prior to being analyzed for GE. Samples of ingredients and diets were analyzed for ether extract (procedure 4.5.06; AOAC International 2007), Ca, and P by inductively coupled plasma atomic emission spectroscopy (procedure 3.2.06; AOAC International 2007), ADF (procedure 973.18 (A-D), AOAC International 2007), and NDF using the procedure of Holst (1973). Ingredients were analyzed for TDF (procedure 4.6.03; AOAC International 2007) and AA (procedure 45.3.05; AOAC International 2007). Before AA analysis, samples were hydrolyzed with 6 M HCl for 24 h at 110°C (procedure 45.3.05 (E), AOAC International 2007). Methionine and Cys were analyzed after initially oxidizing the samples with performic acid (Llames and Fontaine 1994). Tryptophan was analyzed after hydrolysis in 4 M barium hydroxide at 110°C for 20h (Llames and Fontaine 1994).

At the conclusion of the experiment, data for feed intake were summarized and the average daily GE intake was calculated for each diet. The energy lost in feces and urine and the DE and ME intake of each pig were calculated (Adeola 2001). By subtracting 60% of DE and ME in the basal diet from the DE and ME in the experimental diets, the DE and ME contributed by each ingredient were calculated and these values were then divided by 40% to calculate the DE and ME for each ingredient. The ME_n was calculated for each pig according to Ewan (1976) using a correction factor of 5.41 kcal g^{-1} urinary N.

Data were analyzed using PROC MIXED (SAS Institute, Inc., Cary, NC) with the default covariance structure: variance component. For the analyses of energy balance of the diets, the model included type of products (DDGS vs. E-DDGS) as a fixed effect, and the analyses of the energy concentration of the ingredients, the model included type of product, phase and their interaction as fixed effects. Both models included block and source as random effects, but because there was no effect, block was removed from the final model. An α value of 0.05 was used to determine differences among means, and the pig was the experimental unit for all analyses.

For growing pigs (Table 3), diets containing the two sources of E-DDGS had greater ($P<0.05$) DE values than diets containing DDGS, but for ME ($P = 0.11$) and ME_n ($P = 0.09$), the differences were less clear. For finishing pigs, diets containing the two sources of E-DDGS had greater ($P<0.05$) DE, ME, and ME_n when compared with diets containing the two sources of DDGS. Diets made from the two batches of DDGS obtained on different days from the same ethanol plant did not differ in energy values (DE, ME and ME_n) for growing or finishing pigs.

Among ingredients, E-DDGS had higher values ($P<0.05$) for DE, ME, and ME_n than did DDGS (Table 4). There was no difference between phases regarding energy values of DDGS and E-DDGS (Table 4).

The DE, ME and ME_n of E-DDGS were 6–7% greater than those values for DDGS, with the superiority of E-DDGS averaging 240 kcal DE kg^{-1} DM, 183 kcal ME kg^{-1} DM and 209 kcal ME_n kg^{-1} DM. When fed to cecectomized roosters, E-DDGS had 7% higher TME_n than DDGS (Kim et al. 2007), in good agreement with present results. The greater density of DE and ME in E-DDGS than in conventional DDGS is likely mainly a result of the lower TDF concentration.

The material removed by the elusieve process is mostly fiber (Kim et al. 2007). During production of the two sources of E-DDGS that were used, approximately 10% of the original DDGS was removed. However, because of the greater DE and ME in E-DDGS, it was calculated that only 6% of the DE and ME in DDGS was removed during the process.

Table 3. Energy balance for diets (as-fed basis) containing distillers dried grains with solubles (DDGS) and enhanced DDGS (E-DDGS)[z]

	Diet						
Item	Basal	DDGS-1	DDGS-2	E-DDGS-1	E-DDGS-2	SEM	*P* value[y]
Growing pigs							
Feed intake (kg d^{-1})	1.20	1.20	1.20	1.20	1.20	–	–
GE intake (kcal d^{-1})	4501	4945	4968	5057	4994	–	–
GE in feces (kcal d^{-1})	633	997	976	959	912	38	0.23
DE (kcal kg^{-1})	3223	3290	3327	3415	3402	32	0.01
GE in urine (kcal d^{-1})	189	278	269	342	272	21	0.13
ME (kcal kg^{-1})	3065	3058	3103	3130	3175	40	0.11
ME$_n^x$ (kcal kg^{-1})[x]	2978	2989	3027	3066	3097	37	0.09
Finishing pigs							
Feed intake (kcal d^{-1})	2.20	2.20	2.20	2.20	2.20	–	–
GE intake (kcal d^{-1})	8371	9045	8978	9118	9043	–	–
GE in feces (kcal d^{-1})	1089	1789	1586	1661	1446	71	0.10
DE (kcal kg^{-1})	3310	3298	3360	3389	3453	32	0.02
GE in urine (kcal d^{-1})	195	271	290	315	326	24	0.14
ME (kcal kg^{-1})	3221	3174	3228	3246	3305	33	0.05
ME$_n^x$ (kcal kg^{-1})	3153	3081	3144	3177	3237	33	0.02

[z] Data are means of six observations per treatment.
[y] Type: DDGS vs. E-DDGS.
[x] Nitrogen-corrected ME.

Table 4. Concentration of DE, ME and ME$_n$ (as-fed basis) in distillers dried grains with solubles (DDGS) and enhanced distillers dried grains with solubles (E-DDGS)

		Ingredient				*P* value			
		DDGS-1	DDGS-2	E-DDGS-1	E-DDGS-2	SEM	Type[z]	Phase[y]	Interaction
DM (%)		90.16	88.77	91.62	90.16				
DE (kcal kg^{-1})	Growing pigs	3391	3483	3703	3670	80	0.01	0.13	**0.87**
	Finishing pigs	3280	3436	3508	3670				
ME (kcal kg^{-1})	Growing pigs	3047	3159	3226	3340	89	0.01	0.26	**0.96**
	Finishing pigs	3104	3239	3283	3432				
ME$_n$ (kcal kg^{-1})	Growing pigs	3007	3102	3198	3276	86	0.01	0.69	**0.66**
	Finishing pigs	2972	3132	3213	3362	–	–	–	–

[z] Type: DDGS vs. E-DDGS.
[y] Phase: growing pigs vs. Finishing pigs.

The CP and AA analyses of corn and DDGS (Table 1) agree with previously published values (Kim et al. 2007). Kim et al. (2007) also reported that E-DDGS has greater protein concentration than DDGS (37.2 vs. 29.9%). The values of DE and ME of DDGS (Table 4) were lower than the average of 10 samples reported by Pedersen et al. (2007): 3628 kcal DE kg^{-1} (range: 3446 to 3957) and 3416 kcal ME kg^{-1} (range: 3226 to 3738) on an as-fed basis.

As the pig grows, there is an increase in the number of microbes in the hindgut, suggesting that finishing pigs may have a greater capacity than growing pigs for utilizing the energy from fibrous materials (Kass et al. 1980). It is important, therefore, to evaluate both stages of growth when using ingredients that contain high fiber concentration. However, in this experiment, no differences between phases were observed.

In conclusion, E-DDGS produced by the elusieve process has 6–7% greater DE, ME and ME$_n$ for pigs than DDGS, and therefore, greater nutritional value. However, only 94% of the DE, ME and ME$_n$ in DDGS was captured in E-DDGS, indicating that some of the usable energy in DDGS is in the removed material.

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Adeola, L. 2001. Digestion and balance techniques in pigs. Pages 903–916 *in* A. J. Lewis and L. L. Southern, eds. Swine nutrition. 2nd ed. CRC Press, Washington, DC.

AOAC International. 2007. Official methods of analysis. 18th ed. Rev. 2. W. Howitz and G. W. Latimer, Jr., eds. AOAC International, Gaithersburg, MD.

Ewan, R. C. 1976. Utilization of energy of feed ingredients by young pigs. Pages 16–21 *in* Proc. 31st. Distillers Feed Research Council, Cincinnati, OH.

Holst, D. O. 1973. Holst filtration apparatus for Van Soest detergent fiber analysis. J. AOAC **56**: 1352–1356.

Kass, M. L., VanSoest, P. J. and Pond, W. G. 1980. Utilization of dietary fiber from alfalfa by growing swine. I. Apparent digestibility of diet components in specific segments of the gastrointestinal tract. J. Anim. Sci. **50**: 175–191.

Kim, E., Parsons, C., Singh, V. and Srinivasan, R. 2007. Nutritional evaluation of new corn distillers dried grains with solubles (DDGS) produced by the enzymatic milling (E-Mill) and elusieve processes. Poult. Sci. **86** (Suppl. 1): 397 (Abstr.).

Llames, C. R. and Fontaine, J. 1994. Determination of amino acids in feeds: collaborative study. J. AOAC Int. **77**: 1362–1402.

National Research Council. 1998. Pages 110–142 *in* Nutrient requirements of swine. 10th rev. ed. National Academy Press, Washington, DC.

Pedersen, C., Boersma, M. G. and Stein, H. H. 2007. Digestibility of energy and phosphorus in ten samples of distillers dried grains with solubles fed to growing pigs. J. Anim. Sci. **85**: 1168–1176.

Srinivasan, R., Moreau, R. A., Rausch, K. D., Belyea, R. L., Tumbleson, M. E. and Singh, V. 2005. Separation of fiber from distillers dried grains with solubles (DDGS) using sieving and elutriation. Cereal Chem. **82**: 528–533.