Title: Energy and amino acid digestibility of corn distillers syrup by-products in growing pigs – **NPB #07-143**

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Date Submitted: 5/5/10

Industry Summary:

Increased market competition for corn between the livestock and poultry industry and the ethanol industry has led to record high feed prices in recent years. As a result, pork producers have been searching for lower cost alternative feed ingredients and feeding strategies. Due to the abundance of low cost liquid by-products (thin stillage and condensed soluble) being produced in dry-grind ethanol plants located near major pork production regions, some pork producers are installing liquid feeding systems to take advantage of this low cost alternative feed. Very little information is available regarding the feeding value of thin stillage and condensed distillers soluble in growing swine diets. In addition, because of the current lack of a significant feed market for liquid condensed solubles, ethanol plants add the soluble to the coarse grains fraction to produce distillers dried grains with solubles (DDGS). Adding high amounts of solubles often leads to syrup balls in DDGS. Syrup balls are thought to be a negative quality attribute in DDGS, and preliminary research conducted at the University of Illinois, suggests that they are rather insoluble which infers that they may be poorly digested in swine. No research information has been published on the nutrient digestibility of syrup balls in DDGS.

Therefore, purpose of this study was to determine the energy, amino acid, nitrogen and phosphorus digestibility of thin stillage, condensed distillers soluble, ground and intact syrup balls, and DDGS when fed to growing pigs.

Amino acid digestibility of ground and intact syrup balls was equal to, or higher than that of DDGS, whereas digestibility of liquid condensed distillers solubles was lower than that of DDGS for total essential amino acids, but not for lysine. Pulse dried thin stillage had the lowest amino acid digestibility, which was likely a result of heat damage during the pulse drying process. These results indicate that the presence of syrup balls does not decrease amino acid digestibility of DDGS and condensed distillers soluble has essential amino acid digestibility lower than DDGS. It was expected that amino acid digestibility of liquid thin stillage would be comparable to that found in liquid condensed distillers solubles, but due to the need to dry the thin stillage to

These research results were submitted in fulfillment of the Nutritional Efficiency Consortium research projects.
Contributing organizations for 2007 include: Arizona Pork Council, DPI Global, Eli Lilly/Elanco, Iowa Corn Growers Association, Iowa Pork Producers Association, Illinois Corn Marketing Board, Illinois Pork Producers Association, Kansas Corn Commission, Kansas Pork Association, Lucta USA, Minnesota Pork Board, Missouri Pork Producers Association, Monsanto, Mississippi Pork Producers Association, Montana Pork Producers Council, National Corn Growers Association, North Carolina Pork Council, Inc., National Pork Board, Nebraska Pork Producers Association, Inc., Ohio Pork Producers Council, Pioneer Hi-Bred International, Inc., Utah Pork Producers Association and the Wisconsin Pork Association.

This report is published directly as submitted by the projects principal investigator. This report has not been peer reviewed.

concentrate the dry matter for more accurate digestibility determinations, amino acid digestibility was reduced due to heat damage. The amount of digestible and metabolizable energy in ISB, GSB, LCS, and PDTS is relatively high and these ingredients are acceptable for use in growing swine diets. Nitrogen digestibility is also relatively high compared to other by-product ingredients. Phosphorus digestibility of all of these co-products is high and far exceeds phosphorus digestibility in corn and soybean meal. In conclusion, feeding DDGS with ground or intact syrup balls has little impact on the nutritional value of DDGS for growing swine. The presence of syrup balls does not decrease amino acid digestibility of DDGS. However, formulating diets containing LCS requires accounting for lower amino acid digestibility since the LCS evaluated in this study has lower EAA digestibility than DDGS.

Scientific Abstract:

Energy, amino acids, nitrogen, and phosphorus digestibility of corn distillers solubles-related co-products in growing pigs.

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The solubles component of distillers dried grains with solubles (DDGS) may contribute to the low and variable digestibility of energy, lysine and other amino acids, nitrogen, and phosphorus. Combining solubles and grains sometimes produces “syrup balls” and their digestibility is unknown. The objective of this experiment was to determine digestible and metabolizable energy, apparent and standardized ileal amino acid digestibility (SID), and nitrogen and phosphorus digestibility of corn distillers solubles co-products and to determine if the presence of syrup balls in DDGS impacts nutrient digestibility. The ingredients evaluated were DDGS, intact syrup balls (ISB), ground syrup balls (GSB), liquid condensed solubles (LCS), and pulse dried thin stillage (PDTS) obtained from the same ethanol plant. Condensed solubles is produced by evaporation of thin stillage (TS). These ingredients were added at a rate of 20% to a corn based basal diet for energy, nitrogen, and phosphorus digestibility determinations. All test ingredients were used as the only source of amino acids in the experimental diets for amino acid digestibility determinations. Pigs were individually housed in 36 metabolic crates in an environmentally-controlled, metabolism unit and were allowed a 12-d period to adapt to their assigned experimental diets (fed at a levels of 3.5 times maintenance energy requirements), followed by a 3-d period in which all feces and urine from each pig were collected for energy, N and P digestibility determinations. In a duplicate 6 x 6 latin square with 7-d periods, the 6 treatments consisted of a N-free diet and the 5 test ingredients. Pigs had 5-d of adaptation to each diet, and on d 6 and 7, ileal digesta were collected from the distal part of the ileum for 8 h. The amount of digestible and metabolizable energy in ISB, GSB, LCS, and PDTS is relatively high and these ingredients are acceptable for use in growing swine diets. Nitrogen digestibility is also relatively high compared to other by-product ingredients. More specifically, the amino acid digestibility of GSB and ISB were equal or higher than that of DDGS. Digestibility of CS was lower than that of DDGS for total essential amino acids (EAA), but not for lysine. The TS had the lowest amino acid digestibility, perhaps due to heat damage during spray drying. Phosphorus digestibility of all of these co-products is high and far exceeds phosphorus digestibility in corn and soybean meal. In conclusion, feeding DDGS with ground or intact syrup balls has little impact on the nutritional value of DDGS for growing swine. The presence of syrup balls does not decrease amino acid digestibility of DDGS. However, formulating diets containing LCS requires accounting for lower amino acid digestibility since the LCS evaluated in this study has lower EAA digestibility than DDGS.

Key words: corn distillers solubles, growing pigs, amino acid digestibility, DE and ME

Introduction:

There is increasing interest in the U.S. pork industry to use liquid feeding systems as a means to utilize various low-cost liquid co-products, particularly thin stillage (TS) and condensed distillers solubles (CDS) produced by the fuel ethanol industry. Dry-grind ethanol plants produce two co-products, the solids (grains fraction) and TS. After distillation and centrifugation of the TS, LCS is produced. Thin stillage is a high-moisture fraction that contains approximately 4 to 8% DM (Raush and Belyea, 2006), and goes through an evaporator to produce CDS that has approximately 30 to 40% DM (Raush and Belyea, 2006). Condensed distillers soluble can be marketed as a liquid feed ingredient or combined with the coarse solids to form distillers dried grains with solubles (DDGS). Little is known about the feeding value of thin stillage and condensed solubles to pigs.

Removing water from thin stillage is expensive, and excessive heating can reduce nutrient digestibility, especially the amino acid lysine. Under some conditions, the mixing of condensed solubles with coarse solids can produce hard agglomerations called syrup balls. Syrup balls increase average particle size and variability in DDGS, and may contribute to lower energy and amino acid digestibility. Preliminary results from the University of Illinois showed that the amount of syrup balls in 7 samples of DDGS previously analyzed for amino acid bioavailability in chicks (Pahm, 2008) ranged from 0 to 20%. In general, samples with high amounts of syrup balls had poor lysine availability in chicks. No studies have been conducted to determine amino acid, energy, and phosphorus digestibility of syrup balls by pigs. Nutrient digestibility estimates of the impact of syrup balls in DDGS are needed to determine if they substantially reduce the quality and nutritional value of DDGS when fed to swine.

In order to utilize these liquid by-products effectively in pork production systems, estimated of energy, amino acid and phosphorus digestibility must be determined. Furthermore, nutrient digestibility estimates of the impact of syrup balls in dried distillers grains with solubles (DDGS) are needed to determine if they substantially reduce the quality and nutritional value of DDGS when fed to growing swine.

Objectives:

1. To determine the digestible and metabolizable energy content of thin stillage, condensed distillers solubles, syrup balls, and ground syrup balls when fed to growing swine.
2. To determine the digestible phosphorus content of thin stillage, condensed distillers solubles, syrup balls, and ground syrup balls when fed to growing swine.
3. To determine standardized ileal digestibility of thin stillage, condensed distillers solubles, syrup balls, and ground syrup balls when fed to growing swine.

Materials & Methods:

Two experiments were conducted to meet the objectives of this project. The first experiment was conducted at the University of Minnesota Southern Research and Outreach Center in Waseca, MN to determining the digestible energy (DE), metabolizable energy (ME), nitrogen digestibility and digestible phosphorus content of thin stillage, condensed solubles, intact and ground syrup balls, and DDGS. The second experiment was conducted at the University of Illinois to determine the Standardized Ileal Amino Acid Digestibility of thin stillage, condensed solubles, intact and ground syrup balls, and DDGS syrup balls. The Institutional Animal Care and Use Committee at the University of Minnesota and the University of Illinois reviewed and approved the protocols for these experiments.

Corn distiller's co-products

A single batch of DDGS and co-products was obtained from the National Corn-to-Ethanol Research Center (Southern Illinois University, Edwardsville, IL). The products obtained were DDGS, DDGS with syrup balls (extra solubles were added intentionally to produce an extra amount of syrup balls), condensed solubles, and thin stillage. Nutrient analysis of these corn co-products is shown in Table 1. One of the original objectives of this study was to feed liquid thin stillage and condensed distillers solubles to pigs to determine nutrient digestibility. However, preliminary results from feeding liquid thin stillage to pigs indicated that due to its low dry matter content, dry matter intake was extremely low prohibiting our ability to obtain good estimates of nutrient digestibility. Therefore, we chose to dry the liquid thin stillage (Pulse Combustion Systems, Payson, AZ) in order to be able to feed higher amounts of dry matter intake of this ingredient to ultimately obtain better nutrient digestibility measurements.

The ethanol plant evaporator was operated at a temperature of 63ºC and a pressure of 20,000 pascal. This oversized evaporator required a residence time on the order of 2.5 to 3 d. For drying the DDGS, the dryer outlet temperature varied from 100 to 180ºC. Part of the DDGS with syrup balls was sieved through a seed cleaner (Western model 30 Gyrating Cleaner - Union Iron Works Decatur, IL). Two screens with an area of 1.62 square meters each were used. The screen size was determined after sifting DDGS in different mashes to determine which sieve would be more appropriate to capture the syrup balls. The screens (Mc Nichols Co. Tampa, FL) had mesh sizes of 10 and 14 openings per 2.5cm. The syrup balls were collected from the second screen. Half of the syrup balls were ground through a hammer mill (Jacobson Universal #4 Jacobson Machine Works) at 7200 rpm with a 1.27 cm screen. The other half of the syrup balls fraction was fed as intact syrup balls.

Table 1. Analyzed nutrient concentration of ingredients (DM-basis).

Item	DDGS[1]	Intact syrup balls	Ground syrup balls	Liquid condensed solubles	Dried thin stillage
DM, %[2]	87.89	80.23	79.42	86.41	94.79
CP, %	29.19	22.83	23.55	15.51	21.55
ADF, %	13.10	8.23	7.89	0.00	0.17
NDF, %	35.46	25.70	24.83	0.00	0.10
Ca, %	0.03	0.04	0.04	0.07	0.10
P, %	0.70	0.87	0.89	1.72	2.38
Indispensable AA, %					
Arg	1.29	1.05	1.03	0.72	0.92
His	0.73	0.58	0.57	0.43	0.52
Ile	1.09	0.80	0.77	0.40	0.57
Leu	3.46	2.43	2.35	0.75	1.06
Lys	1.01	0.87	0.84	0.77	0.80
Met	0.64	0.48	0.45	0.17	0.21
Phe	1.45	1.07	1.03	0.43	0.56
Thr	1.07	0.88	0.84	0.53	0.69
Trp	0.21	0.19	0.19	0.13	0.18
Val	1.43	1.08	1.05	0.63	0.92
Dispensable AA, %					
Ala	2.02	1.51	1.47	0.80	1.16
Asp	1.83	1.51	1.38	0.90	1.26
Cys	0.53	0.43	0.40	0.22	0.33
Glu	4.20	2.92	2.81	1.20	2.15
Gly	1.07	0.87	0.85	0.69	0.99
Pro	2.16	1.58	1.59	0.92	1.21
Ser	1.28	1.04	1.01	0.59	0.69
Tyr	1.13	0.85	0.82	0.35	0.41

[1]Distillers dried grains with solubles.
[2]as-fed basis.

Experiment 1 – Energy,phosphorus, and nitrogen digestibility

The control diet was based on corn and was formulated to satisfy the mineral and vitamin requirements suggested by NRC (1998) for 85 kg barrows. The DDGS, intact syrup balls (ISB), ground syrup balls (GSB), liquid condensed solubles (LCS), and dried thin stillage (DTS) experimental diets were formulated using the control diet as a basal to which 20% of the respective ingredients were added. Liquid condensed solubles was provided at 20% of the diet on an as-fed basis. Composition of experimental diets are shown in Table 2.

Table 2. Composition of experimental diets.

Ingredient	Control	DDGS[1]	ISB[2]	GSB[3]	LCS[4]	DTS[5]
Corn, %	96.38	76.38	76.38	76.38	76.38	76.38
Dicalcium phosphate, %	1.12	1.12	1.12	1.12	1.12	1.12
Limestone, %	0.80	0.80	0.80	0.80	0.80	0.80
Salt, %	0.40	0.40	0.40	0.40	0.40	0.40
VTM premix, %	0.50	0.50	0.50	0.50	0.50	0.50
Celite, %	0.80	0.80	0.80	0.80	0.80	0.80
DDGS, %	-	20.00	-	-	-	-
ISB, %	-	-	20.00	-	-	-
GSB, %	-	-	-	20.00	-	-
LCS, %	-	-	-	-	20.00[6]	-
DTS, %	-	-	-	-	-	20.00

[1]Distillers dried grains with solubles.
[2]Intact syrup balls.
[3]Ground syrup balls.
[4]Liquid condensed solubles.
[5]Dried thin stillage.
[6]As-fed basis.

Thirty six barrows weighing approximately 88.9 kg were assigned randomly to one of the 6 experimental diets (6 replications/treatment). Pigs were individually housed in 36 metabolic crates in an environmentally-controlled, metabolism unit. Pigs were fed an amount of their respective experimental diets equivalent to 3.5 times their daily maintenance energy requirement for a 12-day adjustment period followed by a 3-day collection period, in which all feces and urine from each pig were collected. Crates were equipped with a steel stainless feeder and nipple waterers, which provided continuous access to water throughout the experiment. Feed was supplied in two daily meals. Feed waste was weighed and recorded. Rooms were heated and ventilated to a target temperature of about 19°C.

Fecal and urine samples were collected on 800 and 1700, during the three days of the collection period. The total volume of urine was collected into the bucket containing 20 mL of 2N hydrochloric to avoid loss of nitrogen. Urine volume was measured using 1 L, 100 mL, and 50 mL glass cylinders. One 150 mL subsample was taken for each of the two daily collections, resulting in a sample of approximately 900 mL for the entire period and kept in a plastic bottle. During the collection period, urine and fecal samples were kept under refrigeration and frozen at -20 °C after the completion of the experiment, until assayed.

Gross energy content of experimental diets, feces, and urine was determined by bomb calorimetry. Nitrogen content of feed, feces, and urine was determined by a Keltec 2300 device (Foss North America, Eden Prairie, MN). From these data, DE, ME, and nitrogen-corrected ME content was calculated for each of the test ingredients using the difference approach outlined by Adeola (2001). Phosphorus concentrations in feed, feces, and urine was be determined using IPC procedures to estimate phosphorus digestibility. The results were analyzed using Proc Mixed procedure of SAS (SAS Institute Inc., Cary, NC) (Stein H.H. et al 1999). Individual pig was the experimental unit.

Experiment 2 - Amino acid digestibility

Six different diets were formulated (Table 3 and 4). Chromic oxide (0.4 %, as-fed basis) was included in the diets as an inert marker. Each ingredient tested was the only source of amino acid in a diet.

Table 3. Composition of diets (as-fed basis).

	Diet					
Item	N-Free	DDGS[1]	Intact syrup balls	Ground syrup balls	Condensed solubles basal[2]	Dried thin stillage
Corn starch, %	79.35	17.55	16.55	16.55	-	14.30
Sugar	10.00	20.00	20.00	20.00	92.48	20.00
Soybean oil	3.00	-	1.00	1.00	1.00	-
Limestone	0.80	1.35	1.35	1.35	3.38	1.60
Dicalcium Phosphate	1.25	-	-	-	-	-
Solka Floc	4.00	-	-	-	2.00	3.00
Vitamins and mineral mix[3]	0.30	0.30	0.30	0.30	0.75	0.30
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Potassium carbonate	0.40	-	-	-	-	-
Magnesium oxide	0.10	-	-	-	-	-
Chromic oxide	0.40	0.40	0.40	0.40	0.40	0.40
DDGS[3]	-	60.00	-	-	-	-
Syrup balls intact	-	-	60.00	-	-	-
Ground syrup balls	-	-	-	60.00	-	
Thin stillage	-	-	-	-	-	60.00

[1]Distillers dried grains with solubles.

[2]Condensed solubles liquid was fed with condensed solubles basal on top. This mixture was called condensed solubles diet. The ratio among the dry and liquid part was 60% of the liquid and 40% of the basal.

[3]Provided the following quantities of vitamins and micro minerals per kilogram of complete diet: Vitamin A, 11,120 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.41 mg; thiamin, 0.24 mg; riboflavin, 6.6 mg; pyridoxine, 0.24 mg; vitamin B_{12}, 0.031 mg; D-pantothenic acid, 24 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 0.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 125 mg as zinc oxide.

Table 4. Analyzed nutrient concentration in experimental diets (as-fed basis).

Item	N free	DDGS[1]	Intact syrup balls	Ground syrup balls	Condensed solubles basal[2]	Dried thin stillage
CP, %	0.33	16.16	12.80	12.47	0.07	12.61
DM	92.33	91.28	86.96	87.12	99.75	91.28
Indispensable AA, %						
Arg	0.01	0.78	0.62	0.59	0.00	0.56
His	0.00	0.43	0.35	0.33	0.00	0.29
Ile	0.01	0.65	0.48	0.47	0.00	0.33
Leu	0.02	2.02	1.46	1.44	0.00	0.65
Lys	0.01	0.59	0.50	0.48	0.00	0.45
Met	0.00	0.39	0.28	0.27	0.00	0.15

Phe	0.01	0.86	0.63	0.62	0.00	0.34
Thr	0.01	0.65	0.50	0.49	0.00	0.43
Trp	<0.04	0.13	0.10	0.10	<0.04	0.08
Val	0.01	0.85	0.65	0.62	0.00	0.52
Dispensable AA, %						
Ala	0.01	1.23	0.94	0.92	0.00	0.71
Asp	0.02	1.14	0.83	0.87	0.00	0.77
Cys	0.00	0.24	0.25	0.24	0.00	0.22
Glu	0.00	1.96	1.97	1.96	0.00	1.37
Gly	0.01	0.51	0.53	0.51	0.00	0.57
Pro		0.01	0.98	0.99	0.98	0.00
Ser	0.01	0.59	0.60	0.59	0.00	0.81
Tyr	0.01	0.47	0.48	0.47	0.00	0.46

[1]Distillers dried grains with solubles.

[2]Condensed solubles liquid was fed with condensed solubles basal on top. This mixture was called condensed solubles diet. The ratio among the dry and liquid part was 60% of the liquid and 40% of the basal.

A T-cannula was inserted in the distal ileum of each pig as described by Stein et al. (1998), following feed withdraw for 18 h. Feed was provided to at least 3 times the estimated maintenance requirement (106 kcal ME x $BWkg^{0.75}$; NRC, 1998). The ME density was calculated as 3,790 kcal/kg for the N-free diet, 3,866 kcal/kg for the intact and ground syrup balls diet, 3,547 kcal/kg for the thin stillage diet, 3,822 kcal/kg for the DDGS diet, 3,445 kcal/kg for the diet that was fed on the top of the condensed solubles and 1,380 kcal/kg for the condensed solubles as fed. In the calculations, it was assumed that ME values of syrup balls were identical to the ME in DDGS (3,989 kcal/kg DM; Stein, 2007). The ME for the condensed solubles and thin stillage were calculated assuming a DE value of 4,107 kcal/kg DM (Stein and de Lange, 2007), the DM values measured in this experiment, and ME equal to 96% of DE.

The animals had ad libitum access to water throughout the experiment. They were fed at 0700 and 1630. On collection days, the caps were removed from the cannulas, and a 237-mL plastic bag (Fits Playtex, Gerber, or Evenflow Nursers/Holders baby bottle bag, Walgreen Co.) was attached to the outer part of the cannula with a cable zip tie. Immediately after bags were full, or at least once every 30 min, bags were removed and frozen.

All sample analyses, except amino acids, were performed in duplicate and samples were re-analyzed if differences between duplicates exceeded 5%. The samples were thawed and mixed within animal and period and a subsample was taken for analysis. Ingredients and diets were analyzed for DM (procedure 4.1.06; AOAC, 2007). Digesta samples were freeze dried, ground, and analyzed for amino acids (procedure 45.3.05; AOAC, 2007), crude protein (procedure 4.2.08; AOAC, 2007), and Cr was determined according to the procedure of Fenton and Fenton (1979). Before amino acid analysis, proteins were hydrolyzed with 6M HCl for 24 h at 110°C (procedure 45.3.05 (E), AOAC, 2007). Methionine and Cys were analyzed by initially oxidizing the samples with performic acid (Llames and Fontaine, 1994). Tryptophan was analyzed after hydrolysis in 4 *M* barium hydroxide at 110ºC for 20h (Llames and Fontaine, 1994). Samples of ingredients were analyzed for Ca and P by inductively coupled plasma atomic emission spectroscopy (procedure 3.2.06; AOAC, 2007), ADF (procedure 973.18 (A-D), AOAC, 2007), and NDF using the procedure of Holst (1973).

Apparent ileal digestibility values for amino acids (AA) were calculated as described by Stein et al. (1999).

$$\text{AID } (\%) = (1 - [(AA_{digesta}/AA_{diet}) \times (Cr_{diet}/Cr_{digesta})]) \times 100$$

where AID is the apparent ileal digestibility of an AA (%), $AA_{digesta}$ is the AA concentration in the ileal digesta DM (g/kg), AA_{diet} is the AA concentration in the diet DM (g/kg), Cr_{diet} is the chromium concentration in the diet DM (g/kg), and $Cr_{digesta}$ is the chromium concentration in the ileal digesta DM (g/kg).

The endogenous loss/kg DM intake (**IAA_{end}**) of each AA was determined from pigs fed the N-free diet based on the following equation:

$$IAA_{end} = [AA_{digesta} \times (Cr_{diet}/Cr_{digesta})]$$

where IAA_{end} is the basal endogenous loss of an AA (g/kg DMI), $AA_{digesta}$ is the concentration of that AA in the digesta, Cr_{diet} and $Cr_{digesta}$ are the chromium concentrarion in diet and digesta (g/kg of DM). The average IAA_{end} were used to calculate SID of the other diets.

The SID was calculated by the following equation:

$$SID (\%) = AID + [(IAA_{end}/AA_{diet}) \text{ x } 100]$$

where SID is the standardized ileal digestibility (%).

Data were analyzed using PROC MIXED (SAS Inst. Inc., Cary, NC). The pig was the experimental unit. An α value of 0.05 was used to determine differences among means and the pig was the experimental unit for all analyses. Pig, period and diet were used as class variables. Pig and period were considered random effects.

Results:

The DE and ME content of DDGS in this study was higher than previously reported by Stein and Shurson (2009). This may have been due to the high proportion of solubles (which are high in fat) added to the coarse grains fraction to manufacture the DDGS used in this experiment. Digestible energy content of DDGS, intact syrup balls (ISB), ground syrup balls (GSB), and dried thin stillage (DTS) were similar, but higher than DE in liquid condensed solubles ($P < 0.05$). Similarly, metabolizable energy content and ME corrected for nitrogen (ME_n) was similar among DDGS, ISB, GSB, and DTS. However, ME and ME_n content were higher for ISB and DTS compared to GSB ($P < 0.05$). Liquid condensed solubles hds the lowest ME and ME_n content of all ingredients (2,958 kcal/kg). Nitrogen and phosphorus digestibility of all test ingredients were high.

The amino acid, CP, ADF, NDF, Ca and P analyses of DDGS (Table 1) agree with previously published values (Stein, 2007). Crude protein standardized ileal digestibility (SID) of intact syrup balls (ISB) and ground syrup balls (GSB) was greater ($P < 0.05$) than the SID for CP in DDGS, CS, and SDTS. Distillers dried grains with solubles (DDGS) had similar SID for CP when compared to liquid condensed solubles (LCS), and those values were greater when compared to dried thin stillage (DTS; $P < 0.05$). Distillers dried grains with solubles, ISB, and GSB had similar SID (Table 5) for the average of all AA ($P < 0.05$). Condensed solubles and DTS had similar SID for some individual AA (Arg, Leu, Phe) and they had lower SID for most individual AA (His, Ile, Lys, Met, Thr, Trp, Val) when compared to DDGS, ISB and GSB ($P < 0.05$).

Table 5. Standardized ileal digestibilities (%) of CP and AA in the diets [1]

Item	Diet					SEM	*P*-value
	DDGS[2]	Intact syrup balls	Ground syrup balls	Condensed solubles	Thin stillage spray dried		
CP	73.9^{x}	85.2^{w}	85.9^{w}	67.8^{y}	55.3^{z}	3.8	< 0.01
Indispensable AA							
Arg	$89.2^{x,y}$	95.2^{x}	$92.3^{x,y}$	86.6^{y}	80.4^{z}	3.4	< 0.01
His	75.2^{y}	79.7^{x}	79.1^{x}	72.9^{y}	60.8^{z}	1.7	< 0.01
Ile	76.1^{x}	78.5^{x}	78.6^{x}	61.3^{y}	56.9^{z}	2.0	< 0.01
Leu	82.3^{x}	84.5^{x}	84.8^{x}	60.1^{y}	59.4^{y}	1.8	< 0.01
Lys	61.5^{y}	72.0^{x}	71.0^{x}	63.1^{y}	41.6^{z}	3.1	< 0.01
Met	82.8^{x}	81.9^{x}	82.5^{x}	41.9^{z}	48.3^{y}	2.0	< 0.01
Phe	80.9^{x}	82.9^{x}	83.4^{x}	62.8^{y}	60.2^{y}	1.8	< 0.01
Thr	66.0^{x}	67.5^{x}	68.3^{x}	44.3^{y}	39.2^{z}	2.4	< 0.01
Trp	71.1^{x}	70.1^{x}	72.9^{x}	60.9^{y}	51.5^{z}	2.0	< 0.01
Val	73.2^{x}	76.8^{x}	76.4^{x}	61.4^{y}	54.9^{z}	2.0	< 0.01

IAA[3]	81.1^{x}	83.4^{x}	83.8^{x}	61.0^{y}	60.4^{y}	1.9	<0.01
Dispensable AA							
Ala	74.4^{x}	78.5^{x}	76.9^{x}	55.7^{y}	52.7^{y}	2.6	< 0.01
Asp	64.0^{x}	66.6^{x}	66.9^{x}	39.4^{y}	36.0^{y}	2.5	< 0.01
Cys	69.2^{x}	71.9^{x}	71.7^{x}	50.1^{y}	48.2^{y}	2.7	< 0.01
Glu	77.2^{x}	80.3^{x}	80.4^{x}	54.6^{y}	50.0^{z}	2.2	< 0.01
Gly	37.4^{x}	48.0^{x}	41.8^{x}	17.3^{y}	8.3^{y}	8.1	< 0.01
Pro	17.1^{x}	24.9^{x}	9.5^{x}	-69.2^{y}	-60.7^{y}	25.6	< 0.01
Ser	74.2^{x}	75.7^{x}	76.3^{x}	53.7^{y}	44.3^{z}	2.1	< 0.01
Tyr	81.1^{x}	83.4^{x}	83.8^{x}	61.0^{y}	60.4^{y}	1.9	< 0.01
DAA[4]	61.8^{x}	66.2^{x}	63.4^{x}	30.0^{y}	30.4^{y}	5.3	<0.01

[w,x,y,z] Values within a row lacking a common superscript letter are different ($P < 0.05$).
[1]Values are means of 10 observations per treatment.
[2]Distillers dried grains with solubles.
[3]Values are means of all indispensable AA (IAA).
[4]Values are means of all dispensable AA (DAA).

Discussion:

According to these results, these corn co-products are acceptable ingredients for use in growing sine diets. The presence of syrup balls in DDGS is not a problem because energy and amino acid digestibility of ISB and GSB was not different than the digestibility in DDGS. Even though preliminary results from the University of Illinois have shown that syrup balls are “hard” and insoluble in different solutions, it appears that this is not a significant problem because the animals could digest and absorb amino acids in both ISB and GSB comparable to DDGS.

The lower digestibility of aminoacids in liquid condensed solubles was surprising because it had not been exposed to high drier temperatures typical of those used to produce DDGS. When intact proteins are heated in the presence of reducing substances, lysine is usually damaged more extensively than other AA because its free amino group is available and may participate in the Maillard reaction (Pahm, 2008). Most measures of AA digestibility in DDGS show that pattern (Stein, 2007). We have no explanation for the present observation that in condensed solubles the digestibility of Met and Thr were reduced more than that of Lys.

Values for SID of DDGS agree with Stein (2007) values resulting from the analyses of 36 samples of DDGS. The thin stillage was too dilute to provide intake of enough AA, within the ingestive capacity of the animals, to allow accurate measurements of digestibility. We calculated the necessary intake of the liquid product and it would exceed 18 litters per day. Our solution was to dry the material. Unfortunately, the pulse drying procedure used apparently caused extensive heat damage resulting in markedly reduced amino acid digestibility in the dried thin stillage. The temperature and parameters used in pulse-drying the thin stillage used in this study were established from results of a test run, with the temperature kept as low as possible in order to avoid reduction in nutritional value. The product temperature did not exceed 315ºC throughout the drying process, and the exhaust air temperature was 558ºC. The residence time averaged 12 h and product was not recycled in the dryer.

Similar to results reported in a literature review of studies evaluating phosphorus digestibility of DDGS (Stein and Shurson, 2009), corn co-products produced from the dry-grind ethanol industry have high phosphorus digestibility (> 65%) compared to corn and soybean meal, which are common ingredients used in U.S. swine diets. This suggests that feeding corn distillers co-products can meet the phosphorus needs of growing pigs while reducing manure phosphorus excretion if diets are formulated on a digestible P basis.

These results suggest that the presence of syrup balls (either ground or intact) does not adversely affect energy and amino acid digestibility of DDGS and the liquid condensed soluble evaluated in this study has lower SID amino acids than DDGS.

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