DISTILLERS DRIED GRAINS WITH SOLUBLES (DDGS) AND THE USE OF PHYTASE TO ADDRESS DIGESTIBILIY ISSUES IN PIGS

DRÊCHES DE DISTILLERIE AVEC SOLUBLES ET UTILISATION DE LA PHYTASE POUR COMBATTRE LES PROBLÈMES DE DIGESTIBILITÉ CHEZ LES PORCS

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ABSTRACT

Distillers dried grains with solubles (DDGS) and other co-products from the fuel ethanol industry may be used in diets fed to swine without compromising pig performance. Because DDGS and high protein distillers dried grain (HP DDG) are fermented during production of ethanol, the digestibility of phosphorus in these co-products is much greater than in corn and corn germ that have not been fermented. The standardized total tract digestibility (STTD) of P in DDGS and HP DDG may, therefore, exceed 70%, whereas the STTD of P in corn and corn germ usually is less than 40%. If microbial phytase is added to the products, STTD values for DDGS and HP DDG may exceed 80%. Because of this high digestibility of P and because of the relatively high concentration of P in DDGS, no inorganic P is needed in diets fed to weanling pigs from approximately 11 kg if the combination of DDGS and microbial phytase is added to the diet. Diets containing both DDGS and phytase will support pig growth performance that is similar to that of pigs fed diets containing corn, soybean meal, and dicalcium phosphate, but the excretion of P from the pigs is reduced by approximately 50%.

RÉSUMÉ

Les drêches de distillerie avec solubles (DDS) et d'autres coproduits de l'industrie de l'éthanol-carburant peuvent être utilisés dans les rations servies aux porcs sans compromettre la performance zootechnique. Parce que les DDS et les drêches de distillerie à haute teneur en protéines sont fermentées durant le processus de production de l'éthanol, la digestibilité du phosphore (P) contenu dans ces coproduits est beaucoup plus élevée que dans le maïs et le germe de maïs qui n'ont pas été fermentés. Par conséquent, le coefficient normalisé de digestibilité globale (STTD) du P des DDS et des drêches à haute teneur en protéines dépasse 70 %, tandis que celui du P du maïs et du germe de maïs ne dépasse généralement pas 40 %. Si la phytase d'origine microbienne est ajoutée aux produits, les coefficients de digestibilité totale pour les drêches peuvent dépasser 80 %. En raison de la digestibilité élevée du P et de la concentration relativement élevée en P des DDS, aucun P inorganique n'est nécessaire dans les rations servies aux porcs en sevrage à partir d'environ 11 kg, si la combinaison DDS et phytase microbienne est ajoutée à la ration. Les rations contenant une combinaison de DDS et de phytase permettront une performance de croissance semblable à celle obtenue chez les porcs recevant des rations de maïs, tourteau de soya et phosphate dicalcique, mais l'excrétion de P sera réduite de 50 %.

Introduction

Distillers dried grains with solubles (**DDGS**) is a co-product from the dry-grind processing of corn to produce either ethanol or beverages. Distillers dried grains with solubles has been used in the swine feed industry for more than 50 years, but the quantities of DDGS and other co-products that are available to the feed industry have increased dramatically over the last few years because of the expansion of the fuel ethanol industry. It has been suggested that DDGS produced from ethanol distillation has a different composition than DDGS produced from beverage production (Spiehs et al., 2002), but that is not always the case (Pahm et al., 2008a). It has also been suggested that the region in which the grain that is used in the production of DDGS is grown influences the composition of DDGS (Fastinger and Mahan, 2006), but it has been demonstrated that the variation in nutritional value of corn DDGS among regions is no greater than within regions in the US (Pahm et al., 2008a; Stein et al., 2009).

Distillers dried grains with solubles contains all the distilled grain and more than 70% of the condensed solubles produced after fermentation (Pahm et al., 2008b). If no solubles are added to the distilled grain, the product is called distillers dried grains (**DDG**). This product may have a greater nutritional value than DDGS, because addition of solubles to the distilled grain may increase the heat damage of the AA in the product (Pahm et al., 2008b). The grain may be de-hulled and de-germed before fermentation and if that is the case, the corn germ that is separated from the grain may be used in the swine feed industry, but this product has a relatively high concentration of non-starch polysaccharides (Widmer et al. 2007). The endosperm from the de-hulled and de-germed grain is fermented for ethanol production, and the co-product from this production is high protein distillers dried grains with solubles (**HP DDGS**) or high protein distillers dried grain (**HP DDG**). At this point, there is, however, no commercial production of HP DDGS, whereas there is a considerable production of HP-DDG (Widmer et al. 2007; Kim et al., 2009). If oil is extracted from the DDGS, a de-oiled DDGS is produced (Jacela et al. 2007). De-oiled DDGS contains less ether extract, and therefore, also less energy, than conventional DDGS. Oil may also be removed by centrifugation, which is less efficient than removal by extraction, and a low-fat DDGS containing 7 – 8% fat will be the result of this process.

In the US, most distillers co-products are produced from corn, but sorghum is also used in some units (Urriola et al. 2009). In Canada and Europe, most DDGS is produced from wheat, but some units may use barley, field peas, or combinations of several cereal grains. The composition of the distillers co-products vary according to the type of grain used in the fermentation and the technologies used to produce the product (Table 1).

Phosphorus concentration and digestibility in distillers co-products

The concentration of P in corn DDGS and sorghum DDGS is usually between 0.6 and 0.8%, but because of the greater concentration of P in wheat than in corn and sorghum, wheat DDGS contains more than 1% P (Stein and Shurson, 2009; Widyaratne et al., 2009). When corn grain is dehulled and de-germed, the majority of the P ends up in the germ fraction and corn germ, therefore, contains approximately 1.1% P, whereas HP-DDG contains only approximately 0.40% P (Widmer et al., 2007; Almeida, 2010). The apparent total tract digestibility (**ATTD**) of P in corn and sorghum is less than 30% (NRC, 1998; Bohlke et al., 2005; Pedersen et al., 2007a), because most of the P in these grains is bound in the phytate complex (Eeckhout and de Paepe, 1994). Because of the presence of some intrinsic P in wheat, the ATTD of P in wheat is usually between 30 and 50% (NRC, 1998; Zimmermann et al., 2002).

The phytate bound P may be partially degraded as cereal grains are fermented, and the ATTD of P in DDGS produced from corn is, therefore between 50 and 73% (Pedersen et al., 2007a; Stein et al., 2009; Almeida, 2010; Almeida and Stein, 2010). Likewise, in corn HP DDG, the ATTD is approximately 64%, which is close to the value measured for corn DDGS (Widmer et al., 2007; Almeida, 2010). It appears, therefore, that the digestibility of P in corn co-products that have been fermented is close to or above 60%. In contrast, in corn germ, which is not a fermented co-product, the ATTD of P is only 33%, which is close to the values for corn (Widmer et al., 2007; Almeida, 2010). It is, therefore, apparent that fermentation of the corn grain increases the ATTD of P. For wheat DDGS, the ATTD of P is approximately 52% (Nyachoti et al., 2005; Widyaratne and Zijlstra, 2007; Widyaratne et al., 2009). It appears, therefore, that the ATTD of P in wheat DDGS is not greater than the digestibility of P in corn DDGS although the digestibility of P in wheat is greater than in corn.

The relative availability of P in corn DDGS has also been measured and values between 70 and 90% have been reported in experiments where dicalcium phosphate was used as a standard (Burnell et al., 1989; Whitney and Shurson, 2001; Jenkin et al., 2007). If it is assumed that the ATTD of P in dicalcium phosphate is approximately 81% (Petersen and Stein, 2006), then the values for relative availability of P correspond to ATTD values between 56 and 72%, which is in agreement with the values for ATTD of P that were measured directly in corn DDGS.

The digestibility of P may also be expressed as standardized total tract digestibility (STTD) of P. Values for STTD are measured by correcting values for the ATTD of P for basal endogenous losses of P (Almeida and Stein, 2010). It is believed that values for STTD of P are more additive in mixed diets than values for ATTD of P and the industry is, therefore moving towards using values for STTD of P rather than values for ATTD of P or relative availability of P. The STTD of P in corn is between 25 and 40% and the STTD of P in corn DDGS is between 70 and 80% (Almeida, 2010; Almeida and Stein, 2010). The STTD of P in HP DDG produced from corn was measured in one experiment and a value of 77.1% was reported, which is in agreement with the STTD values reported for corn DDGS (Almeida, 2010). For corn germ, the STTD of P is only 40% (Almeida, 2010), which is close to the STTD of P in corn. These observations indicate that both ATTD and STTD of P in corn germ are similar to that in corn. Both corn and corn germ are unfermented feed ingredients and the phytate bound P has, therefore, probably not been released from the phytate complex. In contrast, the ATTD and STTD of the fermented products, HP DDG and DDGS, are relatively similar and much greater than in corn and corn germ.

Effects of adding microbial phytase to corn co-products

There are only a few experiments in which the effects of adding microbial phytase to distillers co-products were measured (Table 2). In these experiments it was shown that the ATTD and STTD of P in DDGS tended to increase by 6 to 8 percentage units if microbial phytase was added to the diet (Almeida, 2010; Almeida and Stein, 2010). The addition of microbial phytase to HP DDG resulted in an increase of the ATTD and STTD of P by approximately 11 percentage units, but the ATTD and STTD of P in corn germ increased by almost 20 percentage units if microbial phytase was added to the diet (Almeida, 2010). It is, therefore, apparent that the effect of microbial phytase is less in DDGS and HP DDG than in corn and in corn germ. The reason for this observation is most likely that there is less phytate bound P, and therefore, less substrate for phytase, in DDGS and HP DDG than in corn and corn germ.

Because the concentration and the STTD of P in DDGS is much greater than in corn and soybean meal, much more digestible P will be supplied to the diets if DDGS is used and the need for adding inorganic P to these diets is, therefore, greatly reduced. If microbial phytase is also included in the diet, even more digestible P will be supplied from the vegetable feed ingredients, and is was recently reported that if both DDGS and microbial phytase is used in diets fed to weanling pig, no inorganic P is needed (Almeida and Stein, 2010). In these experiments, pigs fed diets containing 20% DDGS and 500 units of microbial phytase had a growth performance that was similar to that of pigs fed the positive control diet (Table 3). However, the excretion of P in the feces was much less than the excretion of P from pigs fed the control diet that was based on corn, soybean meal and dicalciumphosphate (Table 4). It is, therefore, possible to completely eliminate the need for inorganic P in diets fed to pigs, if the combination of DDGS and microbial phytase is used.

Conclusion

Co-products from the fuel ethanol industry such as DDGS, HP DDG, and corn germ contain significantly more P than cereal grains. For DDGS, the P concentration is between 0.60 and 0.80%, whereas HP DDG contains approximately 0.40% P and corn germ contains more than 1% P. For all the fermented co-products such as DDGS and HP DDG, values for the ATTD of P is between 50 and 70%, whereas the ATTD of P in corn germ, which is a co-product that has not been fermented, is only around 33%, which is close to the digestibility of P in corn. The concentration of digestible P is, therefore, much greater in distillers co-products than in corn or sorghum, and less indigestible P is, therefore, needed in the diets, if these co-products are used. The ATTD and the STTD of P can be increased in corn, corn germ, and HP DDG by the addition of microbial phytase to the diets and the the ATTD and STTD of P in DDGS tend to increase if phytase is added to the diet. Because of the relatively high concentration of P and the high digestibility of P in DDGS, diets containing both DDGS and phytase may be fed to weanling pigs without using any inorganic P. Such diets will result in growth performance of pigs that is similar to that of pigs fed corn-soybean meal diets, but the excretion of P from these pigs is much less than from pigs fed diets containing corn, soybean meal and dicalciumphosphate.

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Table 1. Chemical composition of corn, sorghum, wheat, and distillers co-products produced from corn, sorghum and wheat (as-fed basis)[1]

Item	Ingredient								
	Corn	Sorghum	Wheat	Corn DDGS	Sorghum DDGS	Wheat DDGS	Corn DDG	De-oiled corn DDGS	Corn germ
N	4	1	1	34	3	2	1	1	1
Gross energy, kcal/kg	3,891	3,848	3,830	4,776	4,334	4,817	-	-	4,919
Crude protein, %	8.0	9.8	12.44	27.5	31.0	38.2	28.8	31.2	14.0
Calcium, %	0.01	0.01	0.04	0.03	-	0.15	-	0.05	0.03
Phosphorus, %	0.22	0.24	0.38	0.61	0.64	1.04	-	0.76	1.09
Crude fat, %	3.3	2.9	2.0	10.2	7.7	3.6	-	4.0	17.6
Crude fiber, %	-	-	2.4	-	7.2	7.6	-	-	-
Starch, %	-	-	-	7.3	-	-	3.83	-	23.6
Neutral detergent fiber, %	7.3	7.3	14.2	25.3	34.7	32.4	37.3	34.6	20.4
Acid detergent fiber, %	2.4	3.8	2.9	9.9	25.3	17.0	18.2	16.1	5.6
Total dietary fiber, %	-	-	-	42.1	-	-	-	-	-
Ash	0.9	-	-	3.8	3.6	4.76	-	4.64	3.3
Indispensable amino acids, %									
Arginine	0.39	0.32	0.57	1.16	1.10	1.53	1.15	1.31	1.08
Histidine	0.23	0.23	0.29	0.72	0.71	0.92	0.68	0.82	0.41
Isoleucine	0.28	0.37	0.43	1.01	1.36	1.35	1.08	1.21	0.45
Leucine	0.95	1.25	0.83	3.17	4.17	2.66	3.69	3.64	1.06
Lysine	0.24	0.20	0.36	0.78	0.68	0.65	0.81	0.87	0.79
Methionine	0.21	0.18	0.21	0.55	0.53	0.53	0.56	0.58	0.25
Phenylalanine	0.38	0.47	0.53	1.34	1.68	1.92	1.52	1.69	0.57
Threonine	0.26	0.29	0.33	1.06	1.07	1.21	1.10	1.10	0.51
Tryptophan	0.09	0.07	0.16	0.21	0.35	0.40	0.22	0.19	0.12
Valine	0.38	0.48	0.55	1.35	1.65	1.70	1.39	1.54	0.71
Dispensable amino acids, %									
Alanine	0.58	0.86	0.44	1.94	2.90	1.48	2.16	2.13	0.91
Aspartic acid	0.55	0.60	0.62	1.83	2.17	1.92	1.86	1.84	1.05
Cysteine	0.16	0.18	0.27	0.53	0.49	0.73	0.54	0.54	0.29
Glutamic acid	1.48	1.92	3.57	4.37	6.31	9.81	5.06	4.26	1.83
Glycine	0.31	0.29	0.50	1.02	1.03	1.62	1.00	1.18	0.76
Proline	0.70	0.77	1.14	2.09	1.40	4.11	2.50	2.11	0.92
Serine	0.38	0.37	0.48	1.18	2.50	1.88	1.45	1.30	0.56
Tyrosine	0.27	0.25	0.27	1.01	-	-	-	1.13	0.41

[1] Data from Bohlke et al. (2005); Feoli et al. (2007); Pedersen et al. (2007a and b); Widmer et al. (2007); Widyaratne and Zijlstra (2007); Lan et al. (2008); Pahm et al. (2008a); Stein et al. (2006 and 2009); Urriola et al. (2009); Widyaratne et al. (2009).

Table 2. Concentration (%) and apparent total tract digestibility (ATTD) of P (%) in cereal grain and distillers co-products

	Ingredient						
Item	Corn	Sorghum	Wheat	Corn DDGS	Wheat DDGS	Corn HP DDG	Corn germ
N	4	1	1	15	4	1	1
Phosphorus, %	0.22	0.24	0.38	0.61	1.04	0.37	1.09
ATTD, P, %	25.0	25.0	30.0	58.9	51.9	64.1	33.0
ATTD, P, %, with phytase	57.8	-	45.0	71.0	-	79.5	55.7
STTD, P	33.7	-	-	74.9	-	77.1	40.7
STTD, P with phytase	66.0	-	-	79.2	-	88.0	59.0

[1]Data from Sauvant et al., (2004); Bohlke et al. (2005); Nyachoti et al. (2005); Pedersen et al. (2007a); Widmer et al. (2007); Widyaratne and Zijlstra (2007); Lan et al. (2008); Stein et al. (2006 and 2009); Widyaratne et al. (2009); Almeida (2010); Almeida and Stein (2010).

Table 3. Effects of distillers dried grains with solubles (DDGS) and phytase on growth performance of weanling pigs[1]

	Diet:	Corn-SBM[2]		Corn-SBM-DDGS[3]			*P*-value		
Item	Phytase, FTU/kg[4]:	0	500	0	500	SEM	DDGS	Phytase	DDGS×Phytase
	DCP, %[5]:	1.15	0.35	0.65	-				
Initial BW, kg		11.14	11.16	11.14	11.15	0.365	0.234	0.129	0.606
Final BW, kg		21.79	21.30	21.87	21.96	0.540	0.075	0.334	0.155
ADG, kg		0.507	0.483	0.511	0.515	0.011	0.067	0.303	0.147
ADFI, kg		0.772	0.789	0.811	0.806	0.025	0.065	0.665	0.465
G:F		0.661	0.614	0.634	0.640	0.012	0.952	0.052	0.014

[1]Data are means of 10 observations per treatment. Data from Almeida and Stein (2010).
[2]SBM = soybean meal.
[3]Diets contained 20% DDGS.
[4]FTU = phytase units.

[5]DCP = dicalcium phosphate.

Table 4. Phosphorus balance and apparent total tract digestibility (ATTD) of P for pigs fed corn-soybean meal (SBM) diets or corn-SBM-distillers dried grains with solubles (DDGS) diets without or with microbial phytase[1]

	Diet:	Corn-SBM		Corn-SBM-DDGS[2]			*P*-value		
Item	Phytase, FTU/kg[3]:	0	500	0	500	SEM	DDGS	Phytase	DDGS×Phytase
	DCP, %[4]:	1.15	0.35	0.65	-				
P intake, g/d		3.74	2.89	3.79	3.16	0.131	0.178	< 0.01	0.351
Fecal P output, g/d		1.68	0.82	1.43	0.82	0.042	< 0.01	< 0.01	< 0.01
ATTD of P, %		56.1	71.5	62.3	74.1	1.240	< 0.01	< 0.01	0.153
P retention, %		56.03	71.48	62.16	74.01	1.234	< 0.01	< 0.01	0.156

[1] Data represent the mean of 6 observations per treatment. Data from Almeida and Stein (2010).
[2] Diets contained 20% DDGS.
[3] FTU = phytase units.
[4]DCP = dicalcium phosphate.