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Standardized total tract digestibility of phosphorus in blood products fed to weanling pigs¤

Digestibilidad de tracto-total estandarizada del fósforo en subproductos de sangre para cerdos destetos

Digestibilidade de trato total de fósforo em subprodutos de sangue para leitões desmamados

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Summary

Objective**: an experiment was conducted to measure the apparent (ATTD) and the standardized (STTD) total tract digestibility of P in spray dried plasma protein (SDPP), and in two sources of dried blood meal fed to weanling pigs. **Methods**: four diets were formulated. Three diets contained each of the three blood products. The only source of P in these diets was the blood products that were used. Each of three diets contained 60 - 60.4% cornstarch, 15% sucrose, 3% soybean oil, 1.3 or 0.9% limestone, 0.4% salt, and 0.3% vitamin and mineral premix in addition to 20% of each of the test ingredients (SDPP, porcine blood meal, or avian blood meal). The fourth diet was a P-free diet that was used to measure the basal endogenous phosphorus losses from the pigs that were fed this diet. Twenty four weanling pigs (initial BW: 18.8 ± 3.2 kg) were randomly allotted to the four dietary treatments with six pigs per treatment. Pigs had 5 days of adaptation to diets followed by 5 days of total collection of feces. **Results**: the ATTD of P was greater ($p<0.01$) for pigs that were fed SDPP (91.31%) than for pigs that were fed either porcine blood meal (76.46%) or avian blood meal (57.67%), and pigs that were fed porcine blood meal also had greater ($p< 0.01$) ATTD of P than pigs that were fed avian blood meal. There were no differences in the STTD of P between pigs that were fed porcine blood meal (89.74%) or avian blood meal (86.11%), but the STTD of P in these two ingredients was less ($p < 0.05$) than the STTD of P in SDPP (102.79%). **Conclusions**: the present experiment demonstrated that blood products are excellent sources of organic P. Spray dried plasma protein has a greater STTD of P than porcine or avian blood meal.

Key words: *blood products, digestibility, phosphorus, pigs.*

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Resumen

<u>Objetivo</u>: se realizó un experimento para medir la digestibilidad aparente (ATTD) y estandarizada (STTD) de tracto total del fosforo (P), tanto en plasma seco (SDPP) como en dos fuentes de harina de sangre para cerdos recién destetados. <u>Métodos</u>: se formularon cuatro dietas. Tres dietas contenían cada uno de los tres subproductos de sangre. Las únicas fuentes de P en estas dietas fueron los subproductos de sangre utilizados. Cada una de las tres dietas contenía 60% de almidón de maíz, 15% de sacarosa, 3% de aceite de soja, 1.3% de piedra caliza, 0.4% de sal, y 0.3% de premezcla vitamínica y mineral, además de 20% de cada uno de los ingredientes bajo análisis (SDPP, harina de sangre porcina, o harina de sangre aviar). La cuarta dieta era una formulación libre de P, utilizada para medir la pérdida de fósforo endógeno de los cerdos que la consumieron. Veinticuatro cerdos recién destetados (peso inicial: 18.8 ± 3.2 kg) fueron asignados al azar a los cuatro tratamientos dietarios, con seis cerdos por tratamiento. Los cerdos tuvieron 5 días de adaptación a la dieta, seguidos por 5 días de colección total de heces. <u>Resultados</u>: la ATTD del P fue mayor (p<0.01) para los cerdos que fueron alimentados con SDPP (91.31%) que para los alimentados con harina de sangre porcina (76.46%) o harina de sangre aviar (57.67%). Los cerdos alimentados con harina de sangre porcina también tuvieron una mayor (p<0.01) ATTD del P que los alimentados con harina de sangre aviar. No hubo diferencias en la STTD del P entre los animales alimentados con harina de sangre de porcina (89.74%) y harina de sangre aviar (86.11%), pero la STTD del P en estos dos ingredientes fue menor (p<0.05) que la STTD del P en SDPP (102.79%). <u>Conclusiones:</u> el presente experimento demuestra que los productos sanguíneos son excelente fuente de fosforo orgánico. La proteína de plasma seco tiene una mayor STTD del P en comparación con las harinas de sangre porcina o aviar.

Palabras clave: *digestibilidade, fósforo, suínos, subproductos de sangue*.

Resumo

<u>Objetivo</u>: foi realizado um experimento para medir a digestibilidade aparente (ATTD) e padronizada (STTD) do trato total de fósforo (P), no plasma seco (SDPP) e duas fontes de farinha de sangue para suínos recém desmamados. <u>Métodos</u>: quatro dietas foram formuladas. Três dietas contendo cada um dos três produtos derivados do sangue. As únicas fontes de P nestas dietas foram os produtos derivados de sangue utilizados. Cada uma das três dietas continham 60%de amido de milho, sacarose 15%, óleo de soja 3%, calcário 1.3%, 0.4% de sal e 0.3% de pre mistura mineral e vitamínica, além de 20% cada um dos ingredientes sob análise (SDPP, farinha de sangue de suínos ou farinha de sangue de ave). A quarta dieta foi uma formulação P livre, usado para medir a perda de fósforo endógeno em suínos que a consumiram. Vinte e quatro suínos recém-desmamados (peso inicial: 18.8 ± 3.2 kg) foram divididos aleatoriamente em quatro tratamentos dietéticos, com seis animais por tratamento. Os suínos tiveram 5 dias de adaptação à dieta, seguido por 5 dias de coleta total de fezes. <u>Resultados</u>: a ATTD do P foi maior (p<0.01) para suínos que foram alimentados SDPP (91.31%) do que para aqueles alimentados com farinha de sangue suína (76.46%) ou farinha de sangue de aves (57.67%). Suínos alimentados com farinha de sangue de suínos também tiverem maior (p<0.01) ATTD de P do que aqueles alimentados com farinha de sangue de aves. Não houve diferença na STTD de P entre os animais alimentados com farinha de sangue suína (89.74%) e farinha de sangue de aves (86.11%), mas a STTD de P nestes dois ingredientes foi menor (p<0.05) do que o STTD de P na SDPP (102.79%). <u>Conclusões</u>: este experimento mostra que os produtos de sangue são excelentes fontes de fósforo orgânico. Proteínas plasmáticas secas tem maior STTD do P em comparação com as farinhas de sangue de suínos e aves.

Palavras chave: *minerais monogástricos, nutrição.*

Introduction

Blood meal and spray dried plasma protein (SDPP) are often included in diets fed to weanling pigs, and blood products are considered excellent sources of protein (Kramer *et al.,* 1978; Kats *et al.,* 1994). Blood products also provide P to the diets and P in blood meal has a relative bioavailability of 92% (NRC, 1998). Relative bioavailability values, however, depend on the standard (e.g., monosodium phosphate, dicalcium phosphate) to which the availability is compared.

The standards used to calculate the relative bioavailability of P in feed ingredients is assumed to be 100% available. Recent research, however, has shown that the relative bioavailability of P in monocalcium phosphate and dicalcium phosphate relative to monosodium phosphate are 80 and 57%, respectively (Petersen *et al.,* 2011). Thus, these values are believed not to be additive in mixed diets. Apparent total tract digestibility (ATTD) of P has been determined in several feed ingredients (Almeida and Stein, 2010), but these values do not account for the basal endogenous P losses, which may be determined by feeding pigs a P-free diet (Petersen and Stein, 2006).

When ATTD values are corrected for basal endogenous P losses (EPL), values for the standardized total tract digestibility (STTD) of P are calculated. These values are believed to be additive in mixed diets and are also believed to better predict the concentration of digestible P in a particular feed ingredient, thus, allowing for more accurate diet formulations. Consequently, the addition of inorganic P and the excretion of P to the environment may be reduced if values for the STTD of P are used in diet formulation as observed by Almeida and Stein (2010). There are, however, no data for the STTD of P in blood products. The objective of this research was, therefore, to measure the ATTD and the STTD of P in SDPP, and in 2 sources of dried blood meal fed to weanling pigs.

Materials and methods

Diets, animals, and experimental design

Porcine blood meal and SDPP were sourced from American Protein Corporation (Ames, IA, USA) while avian blood meal was sourced from Griffin Industries (Cold Spring, KY, USA). Four diets were formulated (Table 1). Three diets contained 20% of each of the three blood products. The fourth diet was a P-free diet that was used to measure the basal endogenous loss of P from the pigs (Almeida and Stein, 2010).

Table 1: Composition of experimental diets (as-fed basis).

Item	Diet			
	SDPP	Porcine blood meal	Avian blood meal	P-Free
Ingredient, %				
AP 920[1]	20.00	-	-	-
AP 100[1]	-	20.00	-	-
Griffin Blood Meal[2]	-	-	20.00	-
Cornstarch	60.00	60.40	60.40	49.22
Sucrose	15.0	15.0	15.0	20.00
Soybean oil	3.0	3.0	3.0	4.00
Solka floc[3]	-	-	-	4.00
Limestone	1.30	0.90	0.90	0.80
Gelatin[4]	-	-	-	20.00
DL-met	-	-	-	0.27
L-Thr	-	-	-	0.08
L-trp	-	-	-	0.14
L-his	-	-	-	0.08
L-ile	-	-	-	0.16
L-val	-	-	-	0.05
Salt	0.40	0.40	0.40	0.40
Vitamin-min. premix[5]	0.30	0.30	0.30	0.30
Potassium carbonate	-	-	-	0.40
Magnesium oxide	-	-	-	0.10
Total	100	100	100	100.00
Analyzed composition,%				
Ca, %	0.62	0.47	0.42	0.35
P, %	0.16	0.15	0.07	-
DM, %	91.16	90.99	90.92	91.94
CP, %	16.58	16.83	19.87	18.09

[1] AP920® and AP100® were sourced from American Protein Corporation, Inc. (Ames, IA, USA).

[2] Griffin blood meal was sourced from Griffin Industries (Cold Spring, KY, USA).

[3] Fiber Sales and Development Corp., Urbana, OH.

[4] Pork gelatin obtained from Gelita Gelatine USA Inc., Sioux City, IA.

[5]The vitamin-micromineral premix provided the following quantities of vitamins and micro minerals per kilogram of complete diet: Vitamin A, 11,128 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.42 mg; thiamin, 0.24 mg; riboflavin, 6.58 mg; pyridoxine, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid, 23.5 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, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

Twenty-four weanling pigs (initial BW: 18.8 ± 3.2 kg) were randomly allotted to the four dietary treatments with six pigs per treatment. Pigs were placed in metabolism cages that were equipped with a feeder and a nipple drinker.

Feeding and sample collection

Pigs were fed twice daily. Feed allowance was calculated as 2.5 times the estimated requirement for maintenance energy (i.e., 106 kcal ME per kg $^{0.75}$; NRC, 1998). Pigs were allowed ad libitum access to water. The adaptation period to the diets consisted of 5 d, which were followed by 5 d of total collection of feces using the marker to marker approach (Adeola, 2001). Chromic oxide was used as the marker and incorporated into the morning meal on day sixth. Fecal collection was initiated when the marker first appeared in the feces. In the morning meal of d 11, chromic oxide was again incorporated into the diet, and fecal collections ceased when the marker appeared in the feces. Fecal materials were collected twice daily and stored at -20 ˚C immediately after collection.

Sample analysis and data processing

Diets, ingredients, and fecal samples were analyzed in duplicates for DM by oven drying for 2 h at 135 ˚C (method 930.15; AOAC Int., 2007), and for P and Ca by inductively coupled plasma spectroscopy (method 985.01; AOAC Int., 2007) after wet ash sample preparation (method 975.03; AOAC Int., 2007). Diets and ingredients were also analyzed for CP (method 990.03; AOAC Int., 2007) using an Elementar Rapid N-cube protein/nitrogen apparatus (Elementar Americas Inc., Mt. Laurel, NJ, USA). The three blood products were also analyzed for AA (method 982.30 E (a, b, c); AOAC Int., 2007).

The ATTD (%) of P in each diet was calculated according to the following equation:

$$\text{ATTD (\%)} = [(Pi - Pf)/Pi] \times 100,$$

where Pi is the total P intake (g) from d 6 to 11 and Pf is the total fecal P output (g) originating from the feed that was provided from d 6 to 11.

The basal endogenous P losses (mg/kg of DMI) were measured from pigs fed the P-free diet according to the following equation:

$$\text{EPL (mg/kg DMI)} = ([Pf/Fi] \times 1{,}000 \times 1{,}000),$$

where EPL is the endogenous P loss and Fi is the total feed (g) intake from d 6 to 11.

The STTD of P was calculated using the following equation:

$$\text{STTD (\%)} = ([Pi - \{Pf - EPL\}/Pi]) \times 100,$$

where STTD (%) is the standardized total tract digestibility of P.

Data were analyzed as a randomized complete design using the GLM procedure of SAS (SAS Institute Inc., Cary, NC, USA). The Proc UNIVARIATE was used to check for the presence of outliers. Observations were considered outliers when they deviated by more than three times the interquartile range from the median of the treatment group. Treatment means were calculated by the LSMeans procedure and the LSD LINES option was used to separate mean values that were significantly different. Each pig was the experimental unit. Significance among means was assessed by using an alpha value of 0.05.

Results

No differences in feed intake were observed among treatments (Table 2). Pigs that were fed SDPP or porcine blood meal consumed more ($p<0.01$) P than pigs that were fed avian blood meal (0.96 or 0.91 vs. 0.42 g/d, respectively). The concentration of P excreted in the feces was greater ($p<0.01$) for pigs that were fed SDPP or porcine blood meal than for pigs that were fed avian blood meal, however, fecal output was greater ($p<0.01$) for pigs that were fed avian blood meal (47.52 g/d) than for pigs that were fed porcine blood meal or SDPP (27.09 or 10.68 g/d, respectively), and pigs that were fed porcine blood meal also had greater ($p<0.01$) fecal output than pigs that were fed SDPP. Fecal P output was less ($p<0.01$) for pigs that were fed SDPP (0.09 g/d) than for pigs that were fed porcine blood meal (0.22 g/d), but not different from pigs that were fed avian blood meal (0.17 g/d), and there was no difference in fecal P output between pigs that were fed porcine blood meal and pigs fed avian blood meal.

Table 2. Apparent (ATTD) and standardized (STTD) total tract digestibility of P in blood products[1].

Item	Ingredient			Pooled SEM	P-value
	SDPP	Porcine blood meal	Avian blood meal		
Feed intake, g/d	545	554	551	18.03	0.83
P intake, g/d	0.96[a]	0.91[a]	0.42[b]	0.02	< 0.01
Fecal output, g/d	10.68[c]	27.09[b]	47.52[a]	3.32	< 0.01
P in feces, %	0.85[a]	0.77[a]	0.37[b]	0.05	< 0.01
P output, g/d	0.09[b]	0.22[a]	0.17[ab]	0.02	< 0.01
ATTD of P, %	91.31[a]	76.46[b]	57.67[c]	3.04	< 0.01
Basal EPL,[2] mg/d	119.35	121.18	120.64	3.95	0.83
STTD of P,[3] %	102.79[a]	89.74[b]	86.11[b]	3.04	0.02

[a-c] Means within a row lacking a common superscript letter differ (p<0.05).

[1] Data are means of six observations for spray dried plasma protein (SPDD), six observations for porcine blood meal, and 3 observations for avian blood meal.

[2] EPL = endogenous P loss. This value was calculated from pigs that were fed a P-free diet at 219 mg/kg DMI. The daily basal EPL (mg/d) for each diet was calculated by multiplying the EPL (mg/kg DMI) by the daily DMI of each diet.

[3] Values for the STTD of P were calculated by correcting values for ATTD of P for basal EPL.

The ATTD of P was greater (p<0.01) for pigs that were fed SDPP (91.31%) than for pigs fed either porcine blood meal (76.46%) or avian blood meal (57.67%), and pigs that were fed porcine blood meal also had greater (p<0.01) ATTD of P than pigs that were fed avian blood meal. There were no differences in the daily basal endogenous losses of P among treatments, which were determined by feeding a P-free diet. There were no differences in the STTD of P between pigs that were fed porcine blood meal (89.74%) or avian blood meal (86.11%), but the STTD of P in these two ingredients was less (p<0.05) than the STTD of P in SDPP (102.79%).

Discussion

Avian blood meal contained much less P than SDPP and porcine blood meal (Table 3). Therefore, P intake was less for pigs that were fed avian blood meal than SDPP or porcine blood meal. The ATTD of P that was determined for SDPP and porcine blood meal is in agreement with values previously reported for the digestibility of P in SDPP and blood meal (NSNG, 2010). The basal endogenous losses of P that were determined in this experiment (219 mg/kg DMI) agree with the value of 211 mg/kg that was recently reported by Almeida and Stein (2010).

Table 3. Analyzed nutrient composition of ingredients (as-fed basis).

Item	Ingredient		
	SDPP	Porcine blood meal	Avian blood meal
Ca, %	0.09	0.31	0.06
P, %	0.66	0.68	0.30
DM, %	91.89	89.95	88.98
CP, %	77.20	83.45	87.02
Indispensible AA, %			
Arg	4.53	4.39	4.57
His	2.47	4.63	5.08
Ile	2.49	3.75	3.84
Leu	7.52	9.32	9.90
Lys	7.16	7.38	7.74
Met	1.08	1.02	0.94
Phe	4.18	5.04	5.49
Thr	4.82	3.85	4.05
Trp	1.57	1.53	0.98
Val	5.31	5.78	6.04
Dispensable AA, %			
Ala	3.86	5.84	6.56
Asp	7.92	7.76	8.07
Cys	0.44	0.81	2.58
Glu	10.54	7.83	8.09
Gly	2.73	3.11	3.27
Pro	4.02	3.26	3.26
Ser	4.30	3.10	2.98
Tyr	3.86	3.03	2.99

Although there was no difference in the STTD of P between porcine and avian blood meal, the ATTD of P in these ingredients was different, which indicates that the ATTD of P in avian blood meal may have been underestimated. In ingredients with low concentrations of AA and CP, values for the apparent ileal digestibility are likely underestimated because of the greater contribution of endogenous AA and CP in digesta (Stein *et al.,* 2005). In the present experiment, the concentration of P in avian blood meal diet (0.07%) was less than that of the porcine blood meal diet (0.15%), which may have resulted in a greater relative contribution of endogenous P losses to the fecal P output from pigs fed the diet containing the avian blood meal compared with pigs fed the diet containing the porcine blood meal.

The disadvantage of using ATTD values (i.e., relative underestimation of digestibility value) can be ameliorated by correcting ATTD values for basal EPL, which yields STTD values that are believed to be more accurate measurements of dietary P digestibility. For AA, values for the standardized ileal digestibility are more additive in mixed diets compared with values for apparent ileal digestibility values (Stein *et al.,* 2005). Thus, it is believed that STTD values for P are also more additive in mixed diets than values for ATTD. This concept, however, has not been verified at this point. The values for STTD of P that were determined in the present experiment are in agreement with recent data (Rostagno *et al.,* 2011).

The STTD of P for SDPP indicates that P in this ingredient is completely digested, whereas for porcine blood meal and avian blood meal, P is almost completely digested. The reason for the difference between the STTD of P in SDPP compared with porcine and avian blood meal may be that some of the P in blood meal may originate from the membranes in blood cells, whereas no cells are present in SDPP and all the P, therefore, is in a soluble form, which is easily absorbed.

In conclusion, blood meal and SDPP are excellent sources of highly digestible P if included in diets fed to pigs. It is likely that supplementation of diets with such ingredients will cause a reduction in the amount of inorganic P that is commonly added to diet fed to pigs, therefore, reducing the cost of diets. Spray dried plasma protein has a greater STTD of P than porcine or avian blood meal, but the P in all three products has a very high digestibility. Inclusion of any of the three products in diets fed to pigs will, therefore, result in a reduction in fecal P excretion leading to less environmental pollution by swine manure.

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