

Comparison of spray-dried blood meal and blood cells in diets for nursery pigs^{1,2}

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ABSTRACT: We used a total of 680 pigs to compare spray-dried blood meal and blood cells in nursery diets. In Exp. 1, 350 barrows (17 ± 2 d of age at weaning) were used to compare three levels of spray-dried blood meal or blood cells (2.5, 5.0, and 7.5%) in the diet fed from d 5 to 19 postweaning (6.6 to 9.9 kg). Inclusion of either blood product improved ADG ($P < 0.005$) and G:F ($P < 0.001$) compared to pigs fed the control diet without added blood products. However, pigs fed spray-dried blood meal had greater ADG ($P < 0.001$), ADFI ($P < 0.04$), and G:F ($P < 0.001$) from d 0 to 7 compared to those fed blood cells. The greatest differences observed between the two blood products occurred at the 5 and 7.5% inclusion levels. No differences ($P > 0.05$) in growth

performance were detected between the two blood products from d 7 to 14. In Exp. 2, 380 barrows (initial BW of 10.7 kg and 41 ± 2 d of age) were used to determine lysine bioavailability of spray-dried blood meal and blood cells via the slope ratio procedure. With G:F ratio as the response criterion, blood meal and blood cells had similar lysine bioavailability relative to crystalline lysine. These experiments indicate that both blood products had similar lysine bioavailability, and that pigs fed spray-dried blood meal had greater performance during the initial 7 d (d 5 to 12 after weaning). However, as the pigs became heavier, there were no differences observed in performance of pigs fed either blood meal or blood cells.

Key Words: Bioavailability, Blood Cells, Blood Meal, Lysine, Nurseries

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Introduction

Dried animal protein products, specifically blood products, are commonly used in diets for nursery pigs. Specifically, the effects of animal plasma (Gatnau and Zimmerman, 1990; Hansen et al., 1993; Steidinger et al., 2000) and blood meal (Hansen et al., 1993; Kats et al., 1994; de Rodas et al., 1995) have been researched. Due to large improvements in performance of early-weaned pigs fed diets containing animal plasma, economic incentives to produce spray-dried animal plasma resulted in the production of red blood cells as a by-product ingredient. Blood cells are relatively similar in nutritional profile and thus have been assumed to have a similar feeding value as blood meal.

To our knowledge, however, there is no published information comparing feeding values of spray-dried blood cells and blood meal in weanling pig diets. Also, limited data exist on the bioavailability of lysine in either spray-dried blood meal or blood cells.

The objectives of our experiments were to compare growth performance of weanling pigs fed increasing levels of blood meal and blood cells, and to determine lysine bioavailabilities of spray-dried blood meal and blood cells using the slope ratio procedure.

Materials and Methods

General

The Kansas State University Institutional Animal Care and Use Committee approved all experimental protocols used in this study.

Pigs (Line 327 sire \times C22 dams; PIC, Franklin, KY) were housed in an environmentally controlled nursery. Each pen (1.2 m²) was equipped with slatted metal flooring and contained a stainless steel self-feeder and one nipple water to allow ad libitum consumption of feed and water.

Pigs in Exp. 1 were all fed a pelleted starter diet (Table 2) until 5 d after weaning. Pigs in Exp. 2 were phase-fed similar diets until 24 d after weaning.

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Table 1. Chemical analyses of spray-dried blood meal and blood cells (Exp. 1 & 2)^a

Item, %	Blood meal	Blood cells
DM	91.80 (93)	91.60 (92)
CP (N × 6.25)	89.10 (88.8)	92.10 (92.0)
Na	0.63 (0.44)	1.12 (0.58)
Cl	0.63 (0.25)	1.30 (1.40)
Amino acid profile		
Arginine	3.84 (3.69)	3.15 (3.77)
Histidine	5.553 (5.30)	5.98 (6.99)
Isoleucine	0.96 (1.03)	0.37 (0.49)
Leucine	11.86 (10.81)	12.60 (12.70)
Lysine	8.27 (7.45)	8.74 (8.51)
Methionine	1.00 (0.99)	1.20 (0.81)
Cystine	1.03 (1.04)	0.64 (0.61)
Phenylalanine	6.27 (5.81)	6.93 (6.69)
Tyrosine	2.59 (2.71)	2.33 (2.14)
Threonine	3.94 (3.78)	3.98 (3.38)
Tryptophan	1.82 (1.48)	1.78 (1.37)
Valine	7.89 (7.03)	8.50 (8.50)

^aValues are expressed on an as-fed basis. Values obtained from NRC (1998) and were used in diet formulation are shown in parentheses.

Experimental diets were fed for 14 d in Exp. 1 and 21 d in Exp. 2 and were fed in meal form in both experiments. Pigs were weighed, and feed disappearance was measured every 7 d during the experiments to determine ADG, ADFI, and feed efficiency (G:F). Samples of the blood meal (California Spray-Dry, Stockton, CA) and blood cells (AP 301G; APC, Inc., Ames, IA) were collected and analyzed for DM, CP, Na, Cl, and individual amino acids (Table 1; AOAC, 1995).

Experiment 1

Three hundred fifty barrows (17 ± 2 d of age at weaning) were used in a 14-d study. Pigs were blocked by initial weight and allotted randomly to one of seven dietary treatments. Each treatment had ten replications (pens) and five pigs per pen. Pigs were weighed and allotted to their respective pens at weaning and then weighed again at the start of the experiment (d 5 postweaning).

Pigs were fed experimental diets from d 5 to 19 postweaning (6.6 to 9.9 kg). Experimental diets included a control diet with no added blood products, diets containing either spray-dried blood meal or spray-dried blood cells at 2.5, 5.0, and 7.5% of the complete diet (Table 2). The blood products replaced soybean meal as the major protein source from the control diet on a total lysine basis. Crystalline amino acids (methionine, threonine, isoleucine, and tryptophan) were included in the diet as the level of the blood products increased to meet or exceed ratios of amino acids relative to lysine as suggested by NRC (1998).

Experiment 2

Three hundred thirty barrows (41 ± 2 d of age) were used in a 21-d growth assay (10.7 to 23.3 kg). Pigs

were blocked by initial weight and allotted randomly to one of 11 dietary treatments. Each treatment had six replications (pens) and five pigs per pen.

Diets included both a negative (0.95% lysine) and positive (1.40% lysine) control with no added blood products or crystalline lysine (Table 3). Additional diets were formulated to increase lysine from levels in the negative control diet by three 0.15% increments (1.10, 1.25, and 1.40%) through the addition of L-lysine HCl, spray-dried blood meal, or blood cells. Corn and soybean meal were held constant in all diets except the positive control; thus the experimental ingredients were the only sources of additional lysine. In addition, all diets were formulated to contain equal ME, Na, and Cl concentrations. Crystalline amino acids (methionine, threonine, isoleucine, tryptophan, and valine) were also included to meet or exceed a minimum ratio relative to lysine as suggested by the NRC (1998).

Statistical Analysis

Data were analyzed as a randomized complete block design using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. In Exp. 1, linear and quadratic polynomial contrasts were used to determine the effects of increasing blood meal and blood cells (0 to 7.5%); while in Exp. 2, similar contrasts were used to determine the effects of increasing levels of crystalline lysine, blood meal, and blood cells (0.95 to 1.40% lysine). Additional contrasts compared pigs fed the control diet(s) to the mean of those fed diets containing added blood products (Exp. 1 and 2) or crystalline lysine (Exp. 2), as well as differences between the two blood products (Exp. 1 and 2). In Exp. 1, initial pig weight (d-5 postweaning) at the start of the experimental period was used as a covariate for determination of ADG, ADFI, G:F, and final wt.

In Exp. 2, regression equations were generated using G:F as the response criterion that included the negative control (0.95% lysine) and treatments for each lysine source within block (1.10, 1.25, and 1.40% lysine). Then, the slopes between sources of lysine were evaluated using the Mixed procedures of SAS according to the methods of Littell et al. (1996). This analysis indicated that there was not any evidence to support that the slopes were different ($P = 0.26$) between lysine sources. Final regression equations were then generated using G:F as the response criterion and pen used as the unit of measure.

Results

Experiment 1

Chemical analyses of blood meal and blood cells that were used in diets formulated for our experiments showed similar values for DM, CP, and amino acid concentration compared to values published by the NRC (1998), which were used in diet formulation (Ta-

Table 2. Diet composition (Exp. 1; as-fed basis)

Item	Phase I ^a	Control	Blood meal			Blood cells		
			2.5%	5.0%	7.5%	2.5%	5.0%	7.5%
Corn	34.37	45.68	49.65	53.62	57.45	50.49	55.22	59.87
Soybean meal (46.5% CP)	12.80	39.45	32.94	26.43	19.93	31.99	24.53	17.09
Spray-dried whey	25.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Spray-dried animal plasma	6.70	—	—	—	—	—	—	—
Select menhaden fish meal	5.00	—	—	—	—	—	—	—
Spray-dried blood meal	—	—	2.50	5.00	7.50	—	—	—
Spray-dried blood cells	1.65	—	—	—	—	2.50	5.00	7.50
Choice white grease	6.00	—	—	—	—	—	—	—
Lactose	5.00	—	—	—	—	—	—	—
Monocalcium P (21% P)	0.75	1.84	1.86	1.86	1.87	1.89	1.94	1.98
Limestone	0.45	0.82	0.80	0.79	0.78	0.90	0.98	1.06
Antibiotic ^b	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.20	0.36	0.33	0.30	0.28	0.32	0.29	0.25
Zinc oxide	0.38	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix ^c	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix ^c	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Calcium chloride	—	0.11	0.14	0.18	0.21	0.08	0.04	—
L-lysine HCl	0.15	—	—	—	—	—	—	—
DL-methionine	0.15	0.08	0.11	0.13	0.16	0.13	0.18	0.24
L-threonine	—	0.01	0.02	0.03	0.05	0.04	0.08	0.13
L-isoleucine	—	—	—	0.01	0.11	—	0.07	0.20
L-tryptophan	—	—	—	—	0.01	0.01	0.02	0.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis								
Lysine, %	1.70	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Methionine:lysine ratio, %	30	31	32	33	34	33	36	38
Met & Cys:lysine ratio, %	57	60	60	60	60	60	60	60
Threonine:lysine ratio, %	65	67	67	67	67	67	67	67
Isoleucine:lysine ratio, %	60	74	67	60	60	65	60	60
Tryptophan:lysine ratio, %	18	22	21	21	21	21	21	21
Chloride, %	0.68	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Sodium, %	0.56	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Potassium, %	0.94	1.19	1.07	0.95	0.83	1.06	0.94	0.81
ME, kcal/kg	3,517	3,171	3,204	3,195	3,180	3,202	3,186	3,171

^a Fed from d 0 to 5 postweaning.

^b Provided 55 mg of carbadox per kg of complete diet.

^c Provided (per kilogram of complete diet): 11,025 IU of vitamin A; 1,654 IU of vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin K (as menadione); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as d-calcium pantothen); 9.9 mg of riboflavin; 0.044 mg of B₁₂; 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.3 mg of Se; 165.4 mg of Zn; and 0.3 mg of I.

ble 1). When compared with NRC (1998), analyzed values for Na and Cl showed slight differences. However, these small differences would not be expected to impact pig performance or cause treatment differences in these experiments.

During d 0 to 5 after weaning, pigs had ADG, ADFI, and G:F of 123 g, 109 g, and 1.13, respectively. During the first week of the experimental period (d 5 to 12 after weaning), pigs fed diets containing blood products had increased G:F ($P < 0.001$) compared to pigs fed the control diet (Table 4). In addition, pigs fed blood meal had increased ADG ($P < 0.001$), ADFI ($P < 0.04$), and G:F ($P < 0.001$) compared to pigs fed blood cells. Furthermore, ADG (linear, $P < 0.005$) and G:F (linear, $P < 0.001$) improved with increasing blood meal, whereas ADFI decreased (linear, $P < 0.01$) and G:F increased (quadratic, $P < 0.03$) with increasing blood cells.

From d 7 to 14 of the experimental period (d 12 to 19 postweaning), ADG and G:F increased ($P < 0.002$) for pigs fed diets containing blood products compared to those fed the control. No differences were observed between pigs fed blood meal and blood cells during this period. Average daily gain increased (linear, $P < 0.03$) as either blood meal or blood cells increased in the diet. In addition, pigs fed diets with increasing levels of blood cells had increased G:F (linear, $P < 0.03$), while pigs fed increasing amounts of blood meal had a tendency for increased G:F (linear, $P < 0.07$).

Overall, pigs fed blood products had greater ADG ($P < 0.005$) and G:F ($P < 0.001$) compared to pigs fed the control diet. Also, ADFI tended to increase ($P < 0.09$) for pigs fed diets that contained blood meal compared with blood cells. As blood meal increased from 0 to 7.5% in the diet, pigs had improved ADG (linear, $P < 0.005$) and G:F ($P < 0.01$). Pigs fed increasing levels

Table 3. Diet composition (Exp. 2; as-fed basis)

Item	Negative control	L-lysine HCl				Blood meal			Blood cells			Positive control
	0.95% ^a	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.40%	
Corn	58.06	58.06	58.05	58.07	58.06	58.06	58.07	58.07	58.06	58.08	49.61	
Soybean meal (46.5% CP)	26.46	26.46	26.46	26.46	26.46	26.46	26.46	26.46	26.46	26.46	42.09	
Soy oil	2.99	3.09	3.27	3.58	3.43	3.90	4.41	3.43	3.88	4.41	3.93	
Corn starch	8.00	7.51	6.84	5.89	5.57	3.08	0.50	5.76	3.45	0.98	–	
Spray-dried blood meal	–	–	–	–	2.01	4.03	6.04	–	–	–	–	
Spray-dried blood cells	–	–	–	–	–	–	–	1.76	3.53	5.29	–	
Monocalcium P (21% P)	1.68	1.68	1.68	1.68	1.66	1.63	1.60	1.68	1.68	1.68	1.58	
Limestone	0.89	0.98	0.98	0.98	0.85	0.82	0.78	0.92	0.95	0.97	0.81	
Salt	0.43	0.41	0.35	0.28	0.41	0.38	0.36	0.40	0.38	0.35	0.43	
Antibiotic ^b	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Vitamin premix ^c	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Trace mineral premix ^c	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
Calcium chloride	0.08	–	–	–	0.10	0.12	0.15	0.05	0.02	–	0.07	
Sodium bicarbonate	–	0.03	0.12	0.21	–	–	–	–	–	–	–	
L-lysine HCl	–	0.19	0.38	0.57	–	–	–	–	–	–	–	
DL-methionine	0.01	0.08	0.17	0.26	0.04	0.09	0.14	0.05	0.12	0.19	0.07	
L-threonine	–	0.08	0.18	0.28	0.01	0.03	0.05	0.02	0.06	0.10	0.02	
L-isoleucine	–	–	0.02	0.11	–	–	0.04	–	–	0.08	–	
L-tryptophan	–	0.03	0.06	0.09	–	–	–	–	0.01	0.02	–	
L-valine	–	–	0.04	0.14	–	–	–	–	–	–	–	
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Calculated Analysis												
Lysine, %	0.95	1.10	1.25	1.40	1.10	1.25	1.40	1.10	1.25	1.40	1.40	
Met:lysine ratio, %	30	32	36	38	30	32	34	31	34	36	31	
Met & Cys:lysine ratio, %	62	60	60	60	60	60	60	60	60	60	60	
Threonine:lysine ratio, %	69	67	67	67	67	67	67	67	67	67	67	
Isoleucine:lysine ratio, %	77	67	60	60	69	62	60	68	60	60	75	
Tryptophan:lysine ratio, %	22	21	21	21	22	21	21	21	21	21	22	
Sodium, %	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	
Chloride, %	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	
ME, kcal/kg	3,451	3,451	3,451	3,451	3,451	3,451	3,451	3,451	3,451	3,451	3,451	

^aCalculated lysine level.

^bProvided 55 mg of carbadox per kg of complete diet.

^cProvided (per kilogram of complete diet): 11,025 IU of vitamin A; 1,654 IU of vitamin D; 44 IU of vitamin E; 4.4 mg of vitamin K (as menadione); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as d-calcium pantothen); 9.9 mg of riboflavin; 0.044 mg of B₁₂; 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.3 mg of Se; 165.4 mg of Zn; and 0.3 mg of I.

of blood cells tended to have improved ADG (linear, $P < 0.07$) and had increased G:F (linear, $P < 0.01$).

Experiment 2

Pigs fed the positive control diet had improved ADG and G:F ($P < 0.001$) compared to pigs fed the negative control diet (Table 5). Regardless of lysine source, ADG (linear, $P < 0.05$) and G:F (linear, $P < .007$) improved as dietary lysine increased. Pigs fed diets containing blood cells gained faster ($P < 0.02$) and had greater ADFI ($P < 0.01$) than pigs fed blood meal. Average daily feed intake decreased (quadratic, $P < 0.001$) for pigs fed increasing levels of crystalline lysine, while ADFI of pigs fed blood meal tended to decrease (linear, $P < 0.08$) as the level was increased in the diet. However, when comparing different amino acid sources, pigs had greater ADFI when fed diets containing crystalline lysine ($P < 0.001$) and blood cells ($P < 0.01$) compared to diets with blood meal. Gain:feed was improved when pigs consumed blood meal ($P < 0.03$) and was intermedi-

ate for those fed blood cells ($P < 0.14$) when compared to pigs fed diets containing crystalline lysine.

Based on the slope ratio assay, assuming crystalline lysine is 100% bioavailable and with G:F as the response criteria, blood meal and blood cells had similar lysine bioavailabilities compared with crystalline lysine (Figure 1). The regression equations generated for G:F for each source include: $G:F_{\text{lysine}} = 0.3266 \times \text{dietary lysine, \%} + 0.2874$, $G:F_{\text{meal}} = 0.3740 \times \text{dietary lysine, \%} + 0.2458$, and $G:F_{\text{cells}} = 0.3523 \times \text{dietary lysine, \%} + 0.2658$.

Discussion

The inclusion of spray-dried blood meal was advantageous for growth of pigs from d 5 to 12 after weaning. In commercial production, this period shortly after weaning would represent the time when pigs are generally switched from their diet fed immediately after weaning to a less complex diet containing less milk products and specialty protein sources. Our findings

Table 4. Effect of increasing levels of whole blood meal and blood cells on growth performance of the weaning pig (Exp. 1)^{abc}

Item	Blood meal				Blood cells				Probability (<i>P</i> <)								
	2.5%		5.0%		7.5%		5.0%		7.5%		SEM	Control vs others	Meal vs cells	Blood meal ^d		Blood cells ^d	
	Control	2.5%	5.0%	7.5%	2.5%	5.0%	7.5%	Lin	Quad	Lin				Quad	Lin	Quad	
Initial wt, kg	6.53	6.68	6.63	6.50	6.66	6.69	6.61	0.07	0.15	0.41	0.55	0.55	0.55	0.51	0.12		
Day 0 to 7																	
ADG, g	144	159	176	180	162	140	133	11	0.21	0.001	0.005	0.75	0.33	0.15			
ADFI, g	261	264	265	260	268	234	224	13	0.52	0.04	0.91	0.59	0.01	0.45			
Gain:feed	0.54	0.60	0.66	0.69	0.60	0.60	0.58	0.03	0.001	0.001	0.001	0.82	0.34	0.03			
Day 7 to 14																	
ADG, g	277	316	324	333	333	330	363	17	0.001	0.21	0.03	0.23	0.008	0.58			
ADFI, g	419	444	447	440	437	413	433	17	0.38	0.25	0.43	0.42	0.89	0.90			
Gain:feed	0.66	0.72	0.72	0.75	0.75	0.79	0.83	0.03	0.002	0.32	0.07	0.12	0.03	0.24			
Day 0 to 14																	
ADG, g	211	238	250	256	247	235	248	11	0.005	0.60	0.005	0.27	0.07	0.30			
ADFI, g	340	354	356	350	353	323	328	13	0.81	0.09	0.63	0.44	0.24	0.67			
Gain:feed	0.61	0.68	0.70	0.73	0.70	0.72	0.75	0.03	0.001	0.24	0.01	0.17	0.01	0.19			
Final wt, kg	9.56	9.86	10.10	10.05	9.93	10.17	9.86	0.18	0.001	0.94	0.01	0.48	0.44	0.18			

^aA total of 350 pigs (five pigs per pen and 10 pens per treatment) were used with an average initial BW of 6.62 kg at the beginning of the 14-d study. All pigs were fed a starter diet for first 5 d. Thus d 0 of the experiment is actually 5 d after weaning.

^bGrowth performance for the first 5 d after weaning were: ADG = 123 g, ADFI = 109 g, and gain:feed = 1.13.

^cInitial pig weight was used as a covariate adjustment for ADG, ADFI, G:F, and Final wt. in the statistical analysis.

^dLinear and quadratic effects of increasing levels (0 to 7.5%).

Table 5. Effect of source and level of dietary lysine on growth performance in pigs (Exp. 2)^a

Item	Negative control	L-lysine HCl				Blood meal			Blood cells			Positive control
	0.95% ^b	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.10%	1.25%	1.40%	1.40%	
Day 0 to 21												
ADG, g	528	598	599	653	589	611	617	584	642	655	659	
ADFI, g	902	923	854	901	883	846	817	883	896	879	890	
G:F, g/kg	587	650	705	727	672	724	757	666	720	745	745	
Final wt, kg	21.7	23.0	22.3	24.2	22.8	23.3	23.4	22.6	23.9	24.2	24.2	

^aA total of 330 pigs (five pigs per pen and 6 pens per treatment) with an average initial BW of 10.7 kg.

^bCalculated lysine level in the diet.

would be in agreement with Kats et al. (1994), who also reported increased performance in pigs fed blood meal during a similar time period. These authors suggested that 1.9% was the optimum level of blood meal in the diet. In our study, ADG and G:F continued to improve when pigs were fed higher levels (up to 7.5%). One possible explanation for the difference may be that the amino acids isoleucine and threonine may have been limiting in their trial and prevented an increase in growth performance at higher levels of blood meal. Crystalline threonine and isoleucine were added in our diets at increasing amounts to maintain the minimum amino acid ratios relative to lysine as recommended by the NRC (1998).

Interestingly, when pigs were fed spray-dried blood cells in their diet, they responded with increased ADG at the lowest inclusion level (2.5%), but ADG decreased at the highest level (7.5%) during the first week of the experimental period. This was primarily because of a linear decrease in ADFI as the level of blood cells increased in the diet.

Because whole blood contains approximately 20% plasma, this would support our findings that pigs fed spray-dried blood meal had higher ADFI at increasing levels compared to spray-dried blood cells (containing no plasma). Previous research (Hansen et al., 1993; Steidinger et al., 2000) showed increased growth performance in newly weaned pigs fed diets containing spray-dried animal plasma with the response primarily due to increased feed intake. Furthermore, research by Sohn et al. (1991) and de Rodas et al. (1995) demonstrated that both blood meal and animal plasma were superior protein sources to dried skim milk, but pigs fed animal plasma had increased performance compared to those fed blood meal. Their research, as well as ours, confirms the importance of animal plasma in diets for weanling pigs postweaning, regardless of form (separated as plasma or in whole blood).

In our study, the growth response from inclusion of blood meal in the diet deteriorated over time with no differences in ADG and G:F between blood meal and

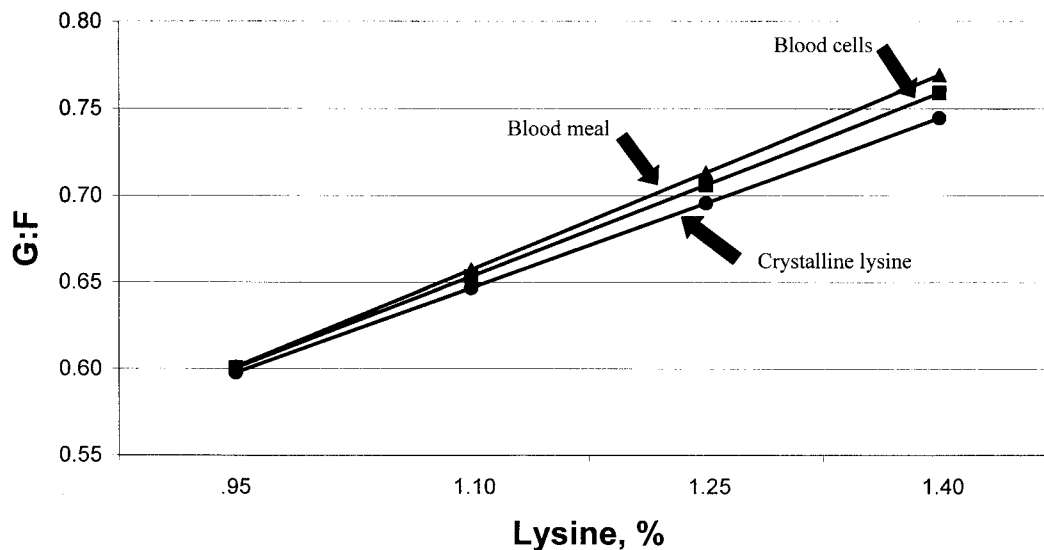


Figure 1. Lysine bioavailabilities of spray-dried blood meal (\blacktriangle), blood cells (\blacksquare), and crystalline lysine (\bullet). Equations for determining lysine bioavailabilities include: Blood meal = $0.3740x + 0.2458$ ($R^2 = 0.71$); Blood cells = $0.3523x + 0.2658$ ($R^2 = 0.69$); and Crystalline lysine = $0.3266x + 0.2874$ ($R^2 = 0.68$).

blood cells for the overall experiment, with only a tendency for improved feed intake for pigs fed blood meal.

A dissimilar response in ADFI to increasing levels of blood meal in diets was demonstrated in our second study. Pigs fed diets with increasing concentrations of crystalline amino acids and blood cells had improved ADFI compared to those fed blood meal. Kats et al. (1994) also reported that pigs fed increasing levels (0.5 to 2.5%) of blood meal in diets fed from 12 to 22 kg had decreased ADG and G:F. This may be an indication that palatability of blood meal in this size and age of pig may be of concern. However, we would not expect an increase in performance in pigs consuming blood products at this given age and weight, as the need for specialty protein sources is much less at this age due to the increased feed intake and increased ability to digest plant proteins. Dritz et al. (1996) reported that diet complexity only improved growth performance in pigs during the early period after weaning (up to 7 kg), which would be in agreement with the responses we observed.

Pigs fed the positive control diet had improved ADG and G:F compared to those fed the low-lysine negative control. This indicates that pigs fed the negative control were deficient in lysine, thus limiting their growth performance. In addition, pigs fed the highest lysine diets, regardless of amino acid source, had equal growth performance over the entire study.

Blood meal varies in feeding value based on the drying procedure, and certain processing methods could have a detrimental effect on the bioavailability of the lysine (Hamm and Searcy, 1976). Conventionally (batch or vat) dried blood meal has been shown to have lysine bioavailabilities of 60 to 64% (Kratzer and Green, 1957) in chicks and poults and 0 to 43% (Waibel et al., 1977) in rat, chick, and turkey assays. Flash or ring-dried blood meal has been reported to have lysine bioavailabilities of 103 and 113% (Batterham et al., 1986) and 71 to 76% (Parsons et al., 1985) in swine assays. Finally, Kratzer and Green (1957) reported lysine bioavailabilities of spray-dried soluble blood meal ranging from 71 to 85% in chick and poult growth experiments.

Because pigs in our study had increased ADG and G:F with increasing amounts of lysine (0.95 to 1.40%) regardless of source (crystalline lysine, blood meal, or blood cells), the slope-ratio assay for determination of lysine bioavailability for the blood products was appropriate. Bioavailability of lysine for spray-dried blood meal in our study was higher than reported for poultry. Species differences may exist in the utilization of lysine from blood meal, or variation in the spray-drying process between lots of blood meal used may contribute to the differences between the studies. The spray-dried soluble blood meal used by Kratzer and Green (1957) was dried at a temperature of 63°C, whereas the blood meal in our study was dried at a temperature of 43°C. The difference in drying temperature may have caused a difference in the overall protein quality of the blood meal, thus explaining the differences seen between

these experiments. Spray-dried blood meal and blood cells had similar bioavailabilities in our study. We feel confident that the additional processing by centrifugation to separate the plasma from the cells does not jeopardize lysine bioavailability. At present, no published literature has established the lysine bioavailability of spray-dried blood cells. In addition, the NRC (1998) does not report amino acid digestibility values for blood cells; however, the ingredient supplier for the blood cells reports the apparent ileal lysine digestibility to be 100% (APC, Inc., unpublished data). More information is available on the apparent ileal lysine digestibility for ring or spray-dried blood meal, as the NRC (1998) and Pearson et al. (1999) reported values of 91 and 90.3%, respectively. Our research supports the work of Batterham et al. (1986), in which the lysine bioavailability of blood meal is equal to or slightly greater than that of crystalline lysine. The fact that both blood products had slightly higher numeric bioavailabilities than crystalline lysine would explain why pigs in our experiments were more efficient when fed diets containing blood products.

Implications

These studies demonstrate that spray-dried blood meal and blood cells can be effective protein sources in diets for nursery pigs to increase daily gain and feed efficiency. Initially, blood meal was more effective than blood cells when fed in the second-diet postweaning. This may be a result of the plasma fraction contained in whole blood meal, whereas the plasma is removed in the production of blood cells. Therefore, these two blood products should not be used interchangeably in diets for nursery pigs without diet formulation adjustments. Furthermore, our data indicate that spray-dried blood cells, spray-dried blood meal, and crystalline lysine have similar lysine bioavailabilities.

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