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EFFECTS OF REPLACING WHEY PROTEIN CONCENTRATE WITH CRYSTALLINE AMINO ACIDS ON WEANLING PIG PERFORMANCE

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Authors:

J. Chung, S.D. Carter,C.V. Maxwell and B.W. Senne

Story in Brief

A total of 84 weanling pigs were allotted to six dietary treatments to evaluate the efficacy of replacing whey protein concentrate (WPC) with crystalline amino acids (AA) on growth performance and plasma urea N (PUN). The control diet (1.65% Lys) contained 9.6% WPC. In Diet 2, WPC was replaced with an ideal mixture of essential AA. Diets 3 to 6 were 3) as Diet 2 + Leu, Ile, Val; 4) as Diet 2 + Phe, Tyr, Trp; 5) as Diet 2 + His, Arg, Pro; and 6) as Diet 2 + AA added to Diets 3, 4, and 5. Crystalline amino acids were added to Diets 3 to 5 to approximate ratios to Lys in the control diet. Experimental diets were fed during Phase 1 (d 0-14), then all pigs were fed a common Phase 2 (1.35% Lys, d 14-28) and 3 diet (1.15% Lys, d 28-35). During Phase 1, pigs fed the control diet grew faster and were more efficient than pigs fed Diet 2. Addition of AA to Diet 2 tended to improve ADG and G:F, with the greatest improvement from the addition of Phe, Tyr, and Trp. On d 14, PUN was markedly lower in pigs fed Diet 2 as compared with pigs fed the control diet. In general, addition of AA to Diet 2 increased PUN with the greatest increase from the addition of Leu, Ile, and Val. For the 35-d test, pigs fed the control diet during Phase 1 grew faster and were more efficient than pigs fed Diet 2 during Phase 1. Among the AA additions to Diet 2 during Phase 1, the addition of Phe, Tyr, and Trp to Diet 2 elicited the greatest improvement in ADG and G:F over the 35-d experiment. These results suggest that replacing WPC with an ideal blend of AA during Phase 1 reduced pig performance; however, the addition of specific AA to an ideal mixture of AA improved growth performance.

Key Words: Amino Acid, Early-Weaned Pig, Growth Performance

Introduction

The amino acid requirements of swine can be supplied by natural intact protein sources or furnished by crystalline amino acids. Crystalline amino acids have been added to low protein swine diets to overcome potential amino acid deficiencies (Tuitoek et al., 1997) and to improve amino acid balance in the diet in order to optimize swine performance. In addition, the supplementation of crystalline amino acids to low protein diets is one method to decrease nitrogen excretion (Carter et al., 1996).

Recent studies have evaluated the effects of amino acid supplementation of low protein diets on growth performance of weanling pigs. Davis et al. (1997) and de Rodas et al. (1997) reported that in weanling pigs, the replacement of whey protein concentrate with an ideal mixture of crystalline amino acids resulted in reduced growth performance. The poorer performance of pigs fed the crystalline AA diet may have been due to an AA imbalance or limited nitrogen for synthesis of dispensable amino acids. Therefore, the objectives of this study were to 1) evaluate the efficacy of replacing whey protein concentrate (WPC, 77% CP) with crystalline amino acids in weanling pig diets on growth performance and plasma urea nitrogen (PUN), and 2) evaluate the specific additions of essential and non-essential amino acids to a low protein, amino acid supplemented diet for weanling pigs.

Materials and Methods

A total of 84 pigs (20 d of age and 12.2 lb initial BW) were sorted by weight and divided into four groups (blocks). The first two weight groups contained 24 pigs and the next two weight groups included 18 pigs, respectively. Pigs within each weight group were allotted randomly to six equal subgroups (three or four pigs/pen) with stratification based on sex and litter. The pens within each of the four weight groups were randomly assigned to six dietary treatments (four pens/treatment, Table 1). The control diet was a fortified corn-soybean meal-dried whey diet containing 9.6% whey protein concentrate (WPC) as the natural amino acid source. Diets 2 to 6 were formulated to evaluate the effects of replacing WPC with crystalline amino acids. Diets 2 to 6 were: 2) in Diet 2 the WPC component in Diet 1 was replaced with an ideal mixture of crystalline amino acids (Chung and Baker, 1992), 3) as Diet 2 with crystalline leucine, isoleucine, and valine added to approximate ratios to lysine in control diet, 4) as Diet 2 with crystalline phenylalanine, tyrosine, and tryptophan added to approximate ratios to lysine in the control diet, 5) as Diet 2 with crystalline histidine, arginine, and proline added to approximate ratios to lysine in control diet, and 6) as Diet 2 with crystalline amino acids added to Diets 3, 4, and 5. Calculated chemical compositions of the six experimental diets during Phase 1 are shown in Table 2.

All experimental diets were formulated to contain 1.65% total lysine (1.44% digestible lysine), 33.08% corn, 20% dried whey, 10% dehulled oats, 6.57% menhaden fish meal, 3.5% spray dried plasma protein (AP 920), 2.81% soy protein concentrate, and 1.50% spray dried blood meal (AP 301G). All experimental diets except the control diet contained glycine, aspartate, and glutamine as dispensable nitrogen sources. Potassium bicarbonate was added to Diets 2 to 6 to approximate the electrolyte balance in control diet. Pigs were fed six experimental diets from d 0 to 14 postweaning (Phase 1). Upon completion of Phase 1, pigs were fed a common Phase 2 diet (1.35% lysine) from d 14 to 28 and a Phase 3 diet (1.15% lysine) from d 28 to 35 postweaning.

Pigs were housed in an environmentally controlled off-site nursery in elevated pens (5□ x 3□ 7") with woven wire flooring. The initial temperature of 88°F was subsequently decreased 2°F per week. Pigs in each pen had ad libitum access to one nipple waterer and a three-hole feeder. Pig body weight and feed intake were determined weekly to evaluate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (G:F). Blood samples were taken via anterior vena cava at the end of Phase 1 (d 14) of the experiment and plasma was analyzed for urea N concentration using The Roche® Reagent for PUN.

Performance data and plasma urea nitrogen data were analyzed according to a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performed using the GLM procedures of SAS (1988). Pre-planned non-orthogonal contrasts were used to compare treatment means.

Results and Discussion

From d 0 to 7 postweaning, pigs fed the control diet had numerically higher daily gain compared with the low protein, AA diets; however, this increase in ADG was greater ($P<.10$) only compared with pigs fed Diets 3 and 6. Average daily feed intake and gain:feed were not affected ($P>.10$) by dietary treatment. From d 7 to 14 postweaning, pigs fed the control diet containing 9.6% WPC as the natural intact amino acid source had greater ($P<.05$) ADG and G:F than the pigs fed Diet 2 which contained an ideal blend of amino acids. Addition of AA to Diet 2 tended to improve ADG and G:F with greatest improvement for pigs fed Diet 6. However, ADFI was not affected ($P<.10$) by dietary treatment. From d 0 to 14 postweaning (Phase 1), pigs fed the control diet containing 9.6% WPC as the natural intact amino acid source grew 21% faster and gained 12% more efficiently (P<.05) than pigs fed Diet 2 which contained an ideal blend of crystalline amino acids (Table 3). During Phase 1, addition of crystalline amino acids to Diet 2 containing an ideal mixture of crystalline amino acids tended to improve ADG and G:F with the greatest improvement from the addition of Phe, Tyr, and Trp. Average daily feed intake was not significantly affected (P>.10) by the addition of crystalline amino acids.

At the end of Phase 1, plasma urea nitrogen (PUN) was markedly lower (P<.01) in pigs fed Diet 2 containing an ideal blend of amino acids as compared with those fed the control diet containing 9.6% WPC. In general, the addition of crystalline amino acids to Diet 2 increased (P<.01) PUN, with the greatest increase (P<.01) occurring when Leu, Ile, and Val were added.

From d 14 to 35 postweaning, there were only small differences in growth performance among dietary treatments. For the entire 35-d experimental period, pigs fed the control diet containing 9.6% WPC during Phase 1 grew faster and gained more efficiently (P<.10) than those fed Diet 2. Among the addition of crystalline amino acids to the ideal blend during Phase 1, the addition of Phe, Tyr, and Trp to Diet 2 elicited the greatest improvement in ADG and G:F over the 35-d experimental period.

In the present study, pigs fed the WPC diet grew faster and were more efficient than pigs fed an ideal blend of crystalline amino acids and the supplementation of specific crystalline amino acids to an ideal mixture tended to enhance growth performance during Phase 1 (from d 0 to 14). Similar to our results, de Rodas et al. (1997) suggested that in segregated early weaned pigs, replacement of WPC by an ideal mixture of crystalline essential amino acids resulted in reduced growth performance. Davis et al. (1997) also observed that in conventionally weaned pigs, substitution of WPC with crystalline amino acids resulted in depressed ADG and feed efficiency during Phase 1 (from d 0 to 14). In addition, Fickler et al. (1994) reported that growth rate and nitrogen retention decreased and percentage of nitrogen utilized increased in pigs fed crystalline amino acids and a mixture of non-essential amino acids (including alanine, aspartic acid, glutamic acid, glycine, proline, and serine) as compared with a control diet containing grains, soybean meal, fish meal, and skim milk. In the same study, the authors suggested that, in order to increase growth rate and nitrogen retention, the amount of dispensable amino acids in chemically defined diets should be increased and the pattern of indispensable amino acids should be improved in order to attain an ideal protein. In conclusion, the results of the present study indicate that replacing WPC with an ideal blend of amino acids during Phase 1 (from d 0 to 14) reduced pig performance and the ideal amino acid pattern used in this experiment was not adequate to support normal growth performance of weanling pigs.

Implications

Replacement of whey protein concentrate with crystalline amino acids reduced growth performance of weanling pigs. Addition of specific amino acids to an ideal blend of amino acids tended to improve growth performance. The reduction in growth performance of pigs fed low protein, amino acid supplemented diets suggests that the ideal amino acid pattern utilized in the current experiment may not be adequate to maximize growth performance in weanling pigs.

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Table 1. Composition of experimental diets (Phase 1).

	Diet					
	1	2	3	4	5	6
	Amino acid source[a]					
			CAA+	CAA+	CAA+	
	WPC	CAA	LIV	PTT	HAP	All AA
Fixed ingredients[b]	77.46	77.46	77.46	77.46	77.46	77.46
Lactose	3.29	4.65	4.65	4.65	4.65	4.65
WPC, 77%	9.60	-	-	-	-	-
$Ca_2H_2(PO_4)_2$	1.04	1.04	1.04	1.04	1.04	1.04
Limestone	.04	.06	.06	.06	.06	.06
L-Lysine HCl	-	.54	.54	.54	.54	.54
DL-Methionine	.08	.34	.34	.34	.34	.34
L-Threonine	-	.29	.29	.29	.29	.31
L-Tryptophan	-	.10	.10	.10	.10	.10
L-Valine	-	.14	.14	.14	.14	.14
L-Isoleucine	-	.30	.30	.30	.30	.30
Glycine	-	1.08	1.67	1.33	1.17	2.17
Aspartic acid	-	1.08	1.67	1.33	1.17	2.17
Glutamic acid	-	1.08	1.67	1.33	1.17	2.17
L-Leucine	-	-	.60	-	-	.60
L-Valine	-	-	.19	-	-	.19
L-Isoleucine	-	-	.03	-	-	.03
L-Phenylalanine	-	-	-	.135	-	.135
L-Tyrosine	-	-	-	.135	-	.135
L-Tryptophan	-	-	-	.040	-	.040
L-Proline	-	-	-	-	.30	.30
L-Histidine	-	-	-	-	.15	.15
L-Arginine	-	-	-	-	.13	.13

Other[c]	4.38	4.08	4.28	4.38	4.28	4.93
Sucrose	2.06	3.60	2.12	2.57	2.84	-
Corn starch	2.06	3.60	2.31	3.26	3.26	1.30
$KHCO_3$[d]	-	.19	.19	.19	.25	.26

[a]WPC, Basal + whey protein concentrate (Control); CAA, Basal + crystalline essential and non-essential AA; CAA+LIV, as Diet 2 + Leu, Ile, Val; CAA+TPT, as Diet 2 + Phe, Tyr, Trp; CAA+HAP, as Diet 2 + His, Arg, Pro; All AA, as Diet 2 + AA added to Diets 3, 4, and 5.

[b]Contained 33.08% corn, 20% dried whey, 10% dehulled oats, 6.57% menhaden fish meal, 3.5% spray dried plasma protein (AP 920), 2.81% soy protein concentrate, and 1.50% spray dried blood meal (AP 301G). [c]Contained .10% flavor, .03% ethoxyquin, 2.15-3.00% soybean oil, .20% salt, .30% trace minerals and vitamins, .30% zinc oxide, 1.00 neo-terramycin.

[d]Added to approximate (Na+K)-Cl balance in control diet.

Table 2. Chemical composition of diets (Phase 1).

	Diet					
	1	2	3	4	5	6
	Amino acid source[a]					
			CAA+	CAA+	CAA+	
Ingredient	WPC	CAA	LIV	PTT	HAP	All AA
ME, Kcal/lb	1,500	1,500	1,500	1,501	1,500	1,500
CP, %	24.5	21.2	22.7	21.8	21.4	24.0
Total AA, %						
Lysine	1.65	1.62	1.62	1.62	1.62	1.62
Threonine	1.20	1.10	1.10	1.10	1.10	1.12
Methionine	.51	.65	.65	.65	.65	.65
Cystine	.51	.33	.33	.33	.33	.33
Met. + Cys	1.01	.98	.98	.98	.98	.98
Tryptophan	.35	.29	.29	.33	.29	.33
Digestible AA, %						
Lysine	1.44	1.44	1.44	1.44	1.44	1.44
Threonine	.96	.93	.93	.93	.93	.95

Methionine	.44	.60	.60	.60	.60	.60
Tryptophan	.30	.26	.26	.30	.26	.30
AA ratios (% of digestible lysine)						
Lysine	100	100	100	100	100	100
Threonine	66	65	65	65	65	66
Methionine	31	42	42	42	42	42
Met. + Cys.	60	60	60	60	60	60
Tryptophan	21	18	18	21	18	21
Isoleucine	62	60	62	60	60	62
Leucine	145	104	145	104	104	145
Valine	81	68	81	68	68	81
Histidine	43	33	33	33	43	43
Arginine	68	58	58	58	68	68
Phe. + Tyr.	112	93	93	112	93	112
Ca, %	.91	.91	.91	.91	.91	.91
P, %	.80	.80	.80	.80	.80	.80

[a]WPC, Basal + whey protein concentrate (Control); CAA, Basal + crystalline essential and non-essential AA; CAA+LIV, as Diet 2 + Leu, Ile, Val; CAA+TPT, as Diet 2 + Phe, Tyr, Trp; CAA+HAP, as Diet 2 + His, Arg, Pro; All AA, as Diet 2 + AA added to Diets 3, 4, and 5.

Table 3. The effects of crystalline amino acid additions to low crude protein diets for weanling pigs[a].

	Diet						
	1	2	3	4	5	6	
	Amino acid source[b]						
			CAA+	CAA+	CAA+		
	WPC	CAA	LIV	PTT	HAP	All AA	SE
Day 0 to 7							

ADG, lb	.489[c]	.417[cd]	.398[d]	.469[cd]	.458[cd]	.387[d]	.036
ADFI, lb	.438	.406	.369	.420	.425	.366	.034
Gain:feed	1.091	.995	1.058	1.112	1.082	1.059	.054
Day 7 to 14							
ADG, lb	.850[c]	.689[d]	.777[cd]	.834[cd]	.788[cd]	.851[c]	.048
ADFI, lb	.861[cd]	.785[c]	.838[cd]	.872[cd]	.919[d]	.857[cd]	.051
Gain:feed	.986[cd]	.870[cd]	.927[cd]	.954[cd]	.858[c]	.994[d]	.050
Day 0 to 14							
ADG, lb	.670[c]	.553[d]	.587[cd]	.652[cd]	.624[cd]	.619[cd]	.037
ADFI, lb	.650	.596	.604	.646	.672	.611	.038
Gain:feed	1.029[c]	.921[d]	.973[cd]	1.011[cd]	.929[cd]	1.012[cd]	.037
Day 14 to 35							
ADG, lb	1.140[cd]	1.072[d]	1.175[c]	1.170[cd]	1.111[cd]	1.189[c]	.040
ADFI, lb	1.647	1.660	1.696	1.651	1.644	1.698	.048
Gain:feed	.690[cd]	.642[c]	.689[cd]	.707[d]	.676[cd]	.701[cd]	.055
Day 0 to 35							
ADG, lb	.951[c]	.864[d]	.940[cd]	.962[c]	.916[cd]	.961[c]	.033
ADFI, lb	1.248	1.234	1.259	1.249	1.255	1.263	.039
Gain:feed	.761[cd]	.697[c]	.745[cd]	.769[d]	.730[cd]	.762[cd]	.045
PUN, mg/dL							
Day 14	7.134[e]	2.878[f]	6.661[e]	4.405[f]	3.883[f]	8.595[e]	.479

[a]Least squares means for four pens (3 to 4 pigs/pen) per treatment. Pigs averaged 12.2 and 44.8 lb at trial initiation and termination, respectively.

[b]WPC, Basal + whey protein concentrate (Control); CAA, Basal + crystalline essential and non-essential AA; CAA+LIV, as Diet 2 + Leu, Ile, Val; CAA+TPT, as Diet 2 + Phe, Tyr, Trp; CAA+HAP, as Diet 2 + His, Arg, Pro; All AA, as Diet 2 + AA added to Diets 3, 4, and 5.

[c,d]Means within same row with different superscripts differ ($P<.10$).

[e,f]Means within same row with different superscripts differ ($P<.01$).

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