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Effects of Monosodium Glutamate and AminoGut on Nursery Pig Performance

Abstract

A total of 1,134 nursery pigs (PIC 359 × 1050, 10.9 ± 0.46 lb BW) were used in a 42-d growth study to determine the effects of monosodium glutamate (MSG), AminoGut, and glutamine (Ajinomoto Heartland, LLC, Chicago, IL) on growth performance. Pigs were fed 1 of 6 dietary treatments. Treatments were fed in 2 phases from d 0 to 7 and 7 to 21. The dietary treatments contained 0, 0.5, 1.0, or 1.5% MSG fed in both phases, 0.8 and 0.6% AminoGut fed in phase 1 and 2, respectively, or a combination of 1.0% MSG and 0.4% glutamine fed in both phases. A common post-treatment diet was fed from d 21 to 42. Phase 1 was in pellet form and the subsequent phases were in meal form. Pigs were randomly allotted to pens at weaning and pens were then allotted to treatment according to BW in a randomized complete block design with 7 replications per treatment. During phase 1 (d 0 to 7), there was no evidence for difference ($P > 0.553$) for ADG, ADFI, or F/G with the addition of MSG, AminoGut, or MSG+Gln. In phase 2 (d 7 to 21), the addition of MSG did not impact ADG or ADFI ($P > 0.163$), but resulted in a marginal improvement (linear, $P = 0.097$) in F/G. Pigs fed AminoGut demonstrated improved ADG ($P < 0.05$) compared to all other treatments and increased ($P < 0.05$) ADFI compared to pigs fed 0.5, 1.0, or 1.5% MSG. There was no evidence for difference ($P > 0.105$) during the common post-treatment period, overall period, or in final BW. Results from this study indicate that feeding MSG alone or with Gln does not result in improved post-weaning growth performance. AminoGut provided a growth and intake response from d 7 to 21 post-weaning. While the increase in BW for pigs fed AminoGut was maintained through the common phase, the response was no longer significant. Further investigation is required to determine the appropriate timing and feeding duration of AminoGut in the nursery.

Keywords

AminoGut, glutamate, glutamine, monosodium glutamate, nursery pig

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Cover Page Footnote

Appreciation is expressed to Ajinomoto Heartland, LLC, Chicago, IL, for funding and New Horizon Farms (Pipestone, MN) for providing the animals, research facilities, and technical support.

Authors

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K-STATE Research and Extension

Swine Day 2017

Effects of Monosodium Glutamate and AminoGut on Nursery Pig Performance[1]

A.B. Clark, M.D. Tokach, J.M. DeRouchey, S.S. Dritz,[2] J.C. Woodworth, R.D. Goodband, and K.J. Touchette[3]

Summary

A total of 1,134 nursery pigs (PIC 359 × 1050, 10.9 ± 0.46 lb BW) were used in a 42-d growth study to determine the effects of monosodium glutamate (MSG), AminoGut, and glutamine (Ajinomoto Heartland, LLC, Chicago, IL) on growth performance. Pigs were fed 1 of 6 dietary treatments. Treatments were fed in 2 phases from d 0 to 7 and 7 to 21. The dietary treatments contained 0, 0.5, 1.0, or 1.5% MSG fed in both phases, 0.8 and 0.6% AminoGut fed in phase 1 and 2, respectively, or a combination of 1.0% MSG and 0.4% glutamine fed in both phases. A common post-treatment diet was fed from d 21 to 42. Phase 1 was in pellet form and the subsequent phases were in meal form. Pigs were randomly allotted to pens at weaning and pens were then allotted to treatment according to BW in a randomized complete block design with 7 replications per treatment. During phase 1 (d 0 to 7), there was no evidence for difference ($P > 0.553$) for ADG, ADFI, or F/G with the addition of MSG, AminoGut, or MSG+Gln. In phase 2 (d 7 to 21), the addition of MSG did not impact ADG or ADFI ($P > 0.163$), but resulted in a marginal improvement (linear, $P = 0.097$) in F/G. Pigs fed AminoGut demonstrated improved ADG ($P < 0.05$) compared to all other treatments and increased ($P < 0.05$) ADFI compared to pigs fed 0.5, 1.0, or 1.5% MSG. There was no evidence for difference ($P > 0.105$) during the common post-treatment period, overall period, or in final BW. Results from this study indicate that feeding MSG alone or with Gln does not result in improved post-weaning growth performance. AminoGut provided a growth and intake response from d 7 to 21 post-weaning. While the increase in BW for pigs fed AminoGut was maintained through the common phase, the response was no longer significant. Further investigation is required to determine the appropriate timing and feeding duration of AminoGut in the nursery.

Introduction

Glutamine (Glu) and glutamate (Gln), though both considered non-essential amino acids, are highly important fuel sources for the small intestine. These amino acids may be limited during the post-weaning period as pigs transition from sow's milk (a good

[1] Appreciation is expressed to Ajinomoto Heartland, LLC, Chicago, IL, for funding and New Horizon Farms (Pipestone, MN) for providing the animals, research facilities, and technical support.

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[3] Ajinomoto Heartland, Inc. (Chicago, IL).

source of these amino acids) to dry diets. Furthermore, with the gastrointestinal stress associated with weaning, dietary supplementation of Glu and Gln may prove beneficial to help the pig maintain intestinal health and function. Previous studies conducted at Kansas State University[4] evaluated the effects of monosodium glutamate on nursery pig performance with and without balancing for Na and Cl content. When Na was not controlled, increasing MSG decreased nursery pig performance, whereas, performance was maintained when Na was balanced. Furthermore, Gonçalves et al.[5] investigated the effects of AminoGut (Ajinomoto Heartland, Inc., Chicago, IL), a combination of glutamate and glutamine, and reported improvements in ADG and F/G when feeding from d 10 to 24 post-weaning. Therefore, the objective of this study was to evaluate the effects of MSG during the post-weaning period and its combination with Gln, as well as AminoGut on performance of pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The trial was conducted at a commercial nursery research facility in southwest Minnesota. The barn was mechanically ventilated and had completely slatted flooring and deep pits for manure storage. Each pen was equipped with a 6-hole, stainless-steel, dry self-feeder and a pan waterer allowing ad libitum access to feed and water. Diets were manufactured at two commercial feed mills (Hubbard, Mankato, MN, for phase 1; and New Horizon Farms, Pipestone, MN, for phases 2 and 3). Feed additions to each individual pen were delivered and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN). Samples of each diet were analyzed for proximate analysis as well as Na, Cl, and salt content (Ward Laboratory, Kearney, NE).

A total of 1,134 nursery pigs (PIC 280 × 1050, initially 10.9 ± 0.46 lb BW) were used in a 42-d growth trial with 27 pigs per pen and 7 replications per treatment. Pigs were weaned at approximately 16 d of age and were randomly allotted to pens upon arrival to the nursery. Pens were then blocked by BW within weaning day and allotted to one of 6 dietary treatments fed in 2 phases from d 0 to 7 and 7 to 21. The dietary treatments contained 0, 0.5, 1.0, or 1.5% MSG fed in both phases, 0.8 and 0.6% AminoGut fed in phases 1 and 2, respectively, or a combination of 1.0% MSG and 0.4% glutamine fed in both phases. All phases were formulated to balance for Na and Cl content while meeting the Na and Cl requirements for each phase. With increasing MSG, Na and Cl were balanced by the addition of sodium bicarbonate or potassium chloride, with salt removed as needed. A common post-treatment diet was fed from d 21 to 42. Phase 1 diets were fed in pelleted form. Phase 2 diets and the common diet were fed in meal form with the 0 and 1.5% MSG diets blended in the robotic feeding system to create the 2 intermediate MSG treatments. Pens were weighed and feed disappearance was measured on d 0, 7, 14, 21, 28, 35, and 42 to determine ADG, ADFI, and F/G.

[4] Clark, A.B. 2016. Dose-responses to lysine, valine, and isoleucine and the effects of monosodium glutamate on nursery pigs. M.S. Thesis. Kansas State University, Manhattan, KS.

[5] Gonçalves, M. A.; Tokach, M. D.; Dritz, S. S.; Touchette, K.; DeRouchey, J. M.; Woodworth, J. C.; and Goodband, R. D. 2016. "Effects of AminoGut and Diet Formulation Approach on Growth Performance and Economic Return in Nursery Pigs," Kansas Agricultural Experiment Station Research Reports: Vol. 2: Iss. 8. https://doi.org/10.4148/2378-5977.1290

Data were analyzed using the PROC GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen considered the experimental unit. Linear and quadratic contrasts were applied for the MSG treatments. LSMEANS was used for mean separation. Results were considered significant at $P \leq 0.05$ and tendencies between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Dietary treatment analysis generally matched formulated nutrient levels. Sodium concentration was variable across treatments although within analytical variation (Tables 3 and 4). The MSG utilized was the same product used in previous MSG studies and contained 19.2% Na.

During phase 1 (d 0 to 7), there was no evidence for difference ($P > 0.552$) for ADG, ADFI, or F/G with the addition MSG, AminoGut, or MSG+Gln (Table 7). In phase 2 (d 7 to 21), the addition of MSG did not result in evidence for differences ($P > 0.163$) in ADG or ADFI, but resulted in a marginal improvement (linear, $P = 0.097$) in F/G. Pigs fed AminoGut demonstrated improved ($P < 0.05$) ADG compared to all other treatments. In addition, pigs fed AminoGut had improved ($P < 0.05$) ADFI compared to pigs fed 0.5, 1, or 1.5% MSG and similar intake (($P > 0.05$) to those fed 0% MSG or MSG+Gln. There was no evidence for difference ($P > 0.105$) during the common post-treatment period or the overall period. Furthermore, no evidence for difference ($P > 0.906$) was observed in BW until d 21 where pigs fed increasing AminoGut had increased BW compared to MSG fed pigs, with MSG+Gln fed pigs having intermediate BW. There was no evidence for difference ($P = 0.200$) in final BW. However, the advantage in BW on d 21 of 0.9 lb per pig for pigs fed AminoGut compared to the control was 1.1 lb per pig on d 42.

Results from this study suggest that increasing MSG from 0 to 1.5% did not improve nursery growth performance. This response is similar to results by Clark et al.[6] in which MSG did not elicit evidence for differences when diets were balanced for Na and Cl. Feeding AminoGut resulted in improved growth and feed intake in phase 2, similar to the response of Gonçalves et al.[5] Further research should evaluate feeding duration and the amount of AminoGut added to the diet during the post-weaning period.

[6] A.B. Clark, M.D. Tokach, J.M. DeRouchey, S.S. Dritz, J.C. Woodworth, R.D. Goodband, and K.J. Touchette. 2017. Effects of Monosodium Glutamate on 14 to 56 lb Nursery Pigs *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7. http://newprairiepress.org/kaesrr/vol3/iss7/.

Table 1. Phase 1 diet composition (as-fed basis)[1]

	Monosodium glutamate,[2] %					
Ingredient, %	0	0.5	1.0	1.5	AminoGut	MSG + Gln
Corn	34.00	33.83	33.67	33.40	33.14	33.24
Soybean meal (48% CP)	26.13	26.14	26.15	26.17	26.19	26.18
Dried distillers grains with solubles	5.00	5.00	5.00	5.00	5.00	5.00
Fish meal	4.50	4.50	4.50	4.50	4.50	4.50
HP 300[3]	2.50	2.50	2.50	2.50	2.50	2.50
Lactose	20.00	20.00	20.00	20.00	20.00	20.00
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	0.80	0.80	0.80	0.80	0.80	0.80
Limestone	0.60	0.60	0.60	0.60	0.60	0.60
Sodium bicarbonate	0.98	0.63	0.28	0.00	0.98	0.28
Sodium chloride	0.30	0.30	0.30	0.25	0.30	0.30
L-Lys-HCl	0.48	0.48	0.48	0.48	0.48	0.48
L-Thr	0.25	0.25	0.25	0.25	0.25	0.25
L-Trp	0.07	0.07	0.07	0.07	0.07	0.07
L-Val	0.10	0.10	0.10	0.10	0.10	0.10
Methionine hydroxy analog	0.28	0.28	0.28	0.28	0.28	0.28
Choline chloride, 60%	0.04	0.04	0.04	0.04	0.04	0.04
Axtra PHY[4]	0.02	0.02	0.02	0.02	0.02	0.02
Zinc oxide	0.40	0.40	0.40	0.40	0.40	0.40
Potassium chloride	0.34	0.34	0.34	0.42	0.34	0.34
Vitamin E, 200,000 IU	0.01	0.01	0.01	0.01	0.01	0.01
Selenium, 0.06%	0.05	0.05	0.05	0.05	0.05	0.05
Trace mineral premix[5]	0.13	0.13	0.13	0.13	0.13	0.13
Vitamin premix[6]	0.05	0.05	0.05	0.05	0.05	0.05
Monosodium glutamate	---	0.50	1.00	1.50	---	1.00
AminoGut[2]	---	---	---	---	0.80	---
Glutamine	---	---	---	---	---	0.40
Total	100	100	100	100	100	100

continued

Table 1, *continued*. Phase 1 diet composition (as-fed basis)[1]

	Monosodium glutamate,[2] %					
Ingredient, %	0	0.5	1.0	1.5	AminoGut	MSG + Gln
Calculated analysis						
Standardized ileal digestibility (SID) amino acids, %						
Lys	1.40	1.40	1.40	1.40	1.40	1.40
Ile:Lys	55	55	55	55	55	55
Leu:Lys	108	108	108	108	108	108
Met:Lys	39	39	39	39	39	39
Met and Cys:Lys	57	57	57	57	57	57
Thr:Lys	65	65	65	65	65	65
Trp:Lys	20.2	20.2	20.2	20.2	20.2	20.2
Val:Lys	67	67	67	67	67	67
Total Lys, %	1.56	1.56	1.56	1.56	1.56	1.56
ME, kcal/lb	1,565	1,563	1,561	1,557	1,553	1,561
NE, kcal/lb	1,174	1,172	1,170	1,167	1,164	1,170
SID Lys:ME, g/Mcal	4.06	4.06	4.07	4.08	4.09	4.07
CP, %	21.8	21.8	21.8	21.8	21.7	22.2
Ca, %	0.69	0.69	0.69	0.69	0.69	0.69
P, %	0.63	0.63	0.63	0.63	0.63	0.63
Available P, %	0.49	0.49	0.49	0.49	0.49	0.49
Na, %	0.43	0.43	0.43	0.43	0.43	0.43
Cl, %	0.52	0.52	0.52	0.52	0.52	0.52

[1] Phase 1 was fed from d 0 to 7 post-weaning.

[2] Monosodium glutamate and AminoGut (Ajinomoto Heartland, LLC, Chicago, IL).

[3] HP 300 (Hamlet Protein, Findlay, OH).

[4] AxtraPHY (Dupont, Wilmington, DE) containing 454,000 FTU/lb of premix.

[5] Provided per lb of premix: 24 g Mn, 60 g Fe, 73 g Zn, 6 g Cu, and 621 mg I.

[6] Provided per lb of premix: 11,000 IU vitamin A; 2,000 IU vitamin D_3; 60,000 IU vitamin E; 6,000 mg vitamin K; 8,000 mg riboflavin; 41,000 mg pantothenic acid; 45,000 mg niacin; 50 mg vitamin B_{12}, 1,200 mg folic acid; 908 mg thiamin; 2,500 mg pyridoxine; and 200 mg biotin.

Table 2. Phases 2 and 3 diet composition (as-fed basis)[1]

	Monosodium glutamate,[2] %				Common
Ingredient, %	0	1.5	AminoGut[2]	MSG + Gln	phase 3[3]
Corn	47.27	46.16	46.58	46.29	61.53
Soybean meal (48% CP)	27.48	27.55	27.52	27.54	28.63
Dried distillers grains with solubles	5.00	5.00	5.00	5.00	5.00
Fish meal	5.00	5.00	5.00	5.00	---
Lactose	10.00	10.00	10.00	10.00	---
Tallow	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	0.53	0.56	0.56	0.53	0.88
Limestone	0.88	0.88	0.88	0.88	1.15
Sodium bicarbonate	0.60	0.00	0.60	0.08	---
Sodium chloride	0.36	0.03	0.36	0.23	0.58
L-Lys-HCl	0.40	0.40	0.40	0.40	0.45
DL-Met	0.18	0.18	0.18	0.18	0.15
L-Thr	0.18	0.18	0.18	0.18	0.18
L-Trp	0.03	0.03	0.03	0.03	0.02
L-Val	0.04	0.05	0.05	0.05	0.04
L-Ile	0.00	0.00	0.00	0.00	---
Optiphos 2000[4]	0.01	0.01	0.01	0.01	0.01
Zinc oxide	0.25	0.25	0.25	0.25	0.25
Potassium chloride	0.26	0.69	0.26	0.43	---
Vitamin and mineral premix[5]	0.15	0.15	0.15	0.15	0.15
Denagard 10[6]	0.18	0.18	0.18	0.18	---[8]
Aureomycin 90[7]	0.23	0.23	0.23	0.23	---[8]
Monosodium glutamate	---	1.50	---	1.00	---
AminoGut	---	---	0.60	---	---
Glutamine	---	---	---	0.40	---
Total	100	100	100	100	100

continued

Table 2, *continued*. Phases 2 and 3 diet composition (as-fed basis)[1]

	Monosodium glutamate,[2] %				
Ingredient, %	0	1.5	AminoGut[2]	MSG + Gln	Common phase 3[3]
Calculated analysis					
Standardized ileal digestibility (SID) amino acids, %					
Lys	1.35	1.35	1.35	1.35	1.25
Ile:Lys	58	58	58	58	58
Leu:Lys	118	117	118	117	125
Met:Lys	38	38	38	38	35
Met and Cys:Lys	58	58	58	58	57
Thr:Lys	63	63	63	63	63
Trp:Lys	18.0	18.0	18.0	18.0	18.3
Val:Lys	67	67	67	67	67
Total Lys, %	1.52	1.52	1.52	1.52	1.40
ME, kcal/lb	1,508	1,492	1,498	1,501	1,505
NE, kcal/lb	1,117	1,104	1,109	1,111	1,114
SID Lys:ME, g/Mcal	4.06	4.10	4.09	4.08	3.77
CP, %	22.2	22.2	22.2	22.6	20.8
Ca, %	0.75	0.75	0.75	0.75	0.70
P, %	0.61	0.61	0.61	0.61	0.58
Available P, %	0.45	0.46	0.46	0.45	0.39
Na, %	0.35	0.35	0.35	0.35	0.28
Cl, %	0.50	0.50	0.50	0.50	0.53

[1] Phase 2 was fed from d 7 to 21 post-weaning.

[2] Monosodium glutamate and Aminogut (Ajinomoto Heartland, LLC, Chicago, IL).

[3] Common phase diet was fed from d 21 to 42 post-weaning.

[4] Optiphos 2000, (Huvepharma Inc., Peachtree City, GA) provided 227 phytase units (FTU)/lb of diet, for an estimated release of 0.14% available P.

[5] Each lb of premix contained 33 ppm Fe from ferrous sulfate, 37 Zn from zinc oxide, 13 Mn ppm from manganous oxide, 5 ppm Cu from copper sulfate, 0.23 ppm I from calcium iodate, 0.1 ppm Se, 2,425 IU vitamin A, 45,455 IU vitamin E, 9,697 micrograms vitamin B_{12}, 1,818 mg riboflavin, 6,907 mg pantothenic acid, 13,182 mg niacin, 303 mg folic acid, 545 mg vitamin B_6, 31 mg biotin, 607 IU vitamin D_3, and 424 mg thiamine.

[6] Denegard 10 (Elanco Animal Health, Greenfield, IN) providing tiamulin at 10 g/lb.

[7] Aureomycin 90 (Zoetis, Florham Park, NJ) providing tetracycline at 90 g/lb.

[8] Antibiotics were pulsed during the common phase with no medication fed from d 21 to 28 and antibiotics included during d 28 to 42.

Table 3. Chemical analysis of phase 1 diets (as-fed basis)[1]

	Monosodium glutamate,[2] %					
Item, %	0	0.5	1.0	1.5	AminoGut[2]	MSG + Gln
DM	92.01	91.7	92.2	91.95	92.28	92.16
CP	22.5	22.3	22.5	24	22.6	22.1
ADF	3.9	3.1	4.0	3.2	4.1	3.4
NDF	5.6	6.3	5.7	6.6	6.5	5.9
Crude fiber	1.6	2.0	1.9	2.1	2.0	1.8
Ca	0.88	0.79	0.79	0.85	0.77	0.79
P	0.62	0.57	0.62	0.65	0.59	0.61
Ether extract	4.7	5.3	5.2	4.9	4.9	5.4
Sodium	0.53	0.47	0.40	0.35	0.38	0.43
Chloride	0.63	0.61	0.63	0.52	0.59	0.59

[1] Phase 1 was fed from d 0 to 7 in pelleted form.

[2] Monosodium glutamate and AminoGut (Ajinomoto Heartland, LLC, Chicago, IL).

Table 4. Chemical analysis of phase 2 diets (as-fed basis)[1]

	Monosodium glutamate,[2] %					
Item, %	0	0.5	1.0	1.5	AminoGut[2]	MSG + Gln
DM	89.69	89.47	89.6	89.63	89.86	89.54
CP	22.2	22.7	20.6	22.6	21.2	21.7
ADF	3.7	3.5	3.0	3.4	3.6	3.2
NDF	8.5	7.2	6.6	7.2	7.8	8.3
Crude fiber	2.1	2.3	2.3	2.4	2.6	2.4
Ca	0.84	0.93	1.02	0.88	0.86	0.98
P	0.55	0.59	0.61	0.57	0.66	0.61
Ether extract	3.9	3.7	3.3	3.7	3.9	3.7
Sodium	0.41	0.34	0.27	0.33	0.29	0.33
Chloride	0.43	0.59	0.59	0.6	0.53	0.59

[1] Phase 2 was fed from d 7 to 21 in pelleted form.

[2] Monosodium glutamate and AminoGut (Ajinomoto Heartland, LLC, Chicago, IL).

Table 5. Effects of monosodium glutamate, AminoGut, and glutamine on nursery pig performance[1]

	Monosodium glutamate,[2] %							Probability, $P <$		
						MSG +		MSG		
	0.0	0.5	1.0	1.5	AminoGut[3]	Gln[4]	SEM	Linear	Quadratic	Overall
Phase 1 (d 0 to 7)										
ADG, lb	0.07	0.04	0.05	0.06	0.05	0.07	0.018	0.542	0.220	0.553
ADFI, lb	0.40	0.43	0.42	0.42	0.42	0.43	0.012	0.492	0.260	0.727
F/G	7.89	5.69	10.21	8.12	7.70	8.38	3.391	0.723	0.986	0.961
Phase 2 (d 7 to 21)										
ADG, lb	0.58^{b,c}	0.55^{c}	0.58^{b,c}	0.58^{b,c}	0.65^{a}	0.60^{b}	0.017	0.575	0.334	0.001
ADFI, lb	0.88^{a,b}	0.82^{c}	0.86^{b,c}	0.85^{b,c}	0.92^{a}	0.88^{a,b}	0.021	0.510	0.163	0.014
F/G	1.52^{a}	1.48^{a}	1.48^{a}	1.46^{a,b}	1.41^{b}	1.48^{a}	0.026	0.097	0.553	0.041
Common phase (d 21 to 42)										
ADG, lb	1.21	1.21	1.17	1.19	1.22	1.19	0.023	0.253	0.424	0.325
ADFI, lb	1.75	1.73	1.71	1.74	1.79	1.73	0.038	0.777	0.518	0.586
F/G	1.44	1.43	1.47	1.46	1.46	1.46	0.014	0.170	0.875	0.437
Overall (d 0 to 48)										
ADG, lb	0.80	0.79	0.78	0.80	0.83	0.80	0.017	0.660	0.239	0.105
ADFI, lb	1.22	1.20	1.20	1.22	1.26	1.22	0.024	0.912	0.406	0.260
F/G	1.53	1.53	1.55	1.53	1.52	1.53	0.015	0.535	0.537	0.830
BW, lb										
d 0	10.9	10.9	10.9	10.9	10.9	10.9	0.19	0.778	1.000	1.000
d 7	11.4	11.2	11.2	11.3	11.2	11.4	0.26	0.609	0.525	0.906
d 21	19.5^{b}	19.1^{b}	19.4^{b}	19.4^{b}	20.4^{a}	19.8^{a,b}	0.40	0.976	0.423	0.060
d 42	45.0	44.5	43.9	44.5	46.1	44.7	0.80	0.468	0.379	0.200

[1] A total of 1,134 nursery pigs (initially 10.9 lb BW) were used in a three-phase nursery study with 27 pigs per pen and 7 replications per treatment.

[2] Treatments were determined according to increasing levels of monosodium glutamate, glutamine, or Aminogut.

[3] AminoGut (Ajinomoto Heartland, Inc., Chicago, IL) contains both glutamine and glutamate. AminoGut was fed at 0.8 or 0.6% of the diet in phases 1 and 2, respectively.

[4] The combination treatment included MSG at 1.0% and Gln at 0.4% in both phases 1 and 2.

[a,b,c] Treatments with differing superscripts differ $P < 0.05$.