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Effects of Monosodium Glutamate on 11- to 50-lb Nursery Pigs

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Abstract
A total of 1,134 nursery pigs (PIC 280 × 1050, 11.2 lb BW) were used in a 48-d growth study to determine the effects of monosodium glutamate (MSG; Ajinomoto Heartland, LLC, Chicago, IL) on growth performance. Pigs were fed 1 of 6 dietary treatments: 0, 0.5, 1.0, 1.5, or 2.0% MSG, or a high salt treatment formulated to match the sodium content of the 1.0% MSG treatment. Experimental diets were fed in 3 phases from d 0 to 12, d 12 to 26, and d 26 to 48. Phase 1 was in pellet form and phases 2 and 3 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 12), no significant differences were detected among MSG treatments, but pigs fed the high salt diet tended ($P < 0.053$) to have poorer F/G than pigs fed the 1% MSG treatment. In phase 2 (d 12 to 26), increasing MSG decreased (linear, $P = 0.045$) ADG, ADFI, and worsened F/G while pigs fed the high salt diet had decreased ($P < 0.001$) ADG and poorer ($P < 0.001$) F/G than pigs fed the 1% MSG diet. In phase 3 (d 26 to 48), no significant differences were detected among the MSG treatments however pigs fed the high salt diet had decreased ($P < 0.028$) ADG and ADFI compared with those fed the 1% MSG diet. Pig BW was reduced (linear, $P < 0.016$) on d 26 and 48 for pigs fed the MSG diets and pigs fed the high salt treatment had decreased ($P < 0.001$) BW compared to pigs fed 1% MSG. For the overall nursery period (d 0 to 48), increasing MSG decreased (linear, $P = 0.033$) ADG and tended (linear, $P = 0.095$) to decrease ADFI. Furthermore, pigs fed the high salt treatment had decreased ($P < 0.009$) ADG and ADFI and poorer ($P < 0.001$) F/G compared to their 1% MSG counterparts. Results from this study indicate that feeding MSG may have had a negative impact on ADFI and therefore, subsequent BW and ADG. In addition, the high salt treatment formulated to match the sodium content of the 1% MSG diet had consistently poorer performance than the 1% MSG treatment, suggesting that high salt content may negatively affect pig growth. Further research is warranted to determine the effects of feeding monosodium glutamate to nursery pigs in diets balanced for sodium content.

Keywords
monosodium glutamate, nursery pig, growth

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.

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K-STATE Research and Extension

Swine Day 2017

Effects of Monosodium Glutamate on 11- to 50-lb Nursery Pigs[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 280 × 1050, 11.2 lb BW) were used in a 48-d growth study to determine the effects of monosodium glutamate (MSG; Ajinomoto Heartland, LLC, Chicago, IL) on growth performance. Pigs were fed 1 of 6 dietary treatments: 0, 0.5, 1.0, 1.5, or 2.0% MSG, or a high salt treatment formulated to match the sodium content of the 1.0% MSG treatment. Experimental diets were fed in 3 phases from d 0 to 12, d 12 to 26, and d 26 to 48. Phase 1 was in pellet form and phases 2 and 3 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 12), no significant differences were detected among MSG treatments, but pigs fed the high salt diet tended ($P < 0.053$) to have poorer F/G than pigs fed the 1% MSG treatment. In phase 2 (d 12 to 26), increasing MSG decreased (linear, $P = 0.045$) ADG, ADFI, and worsened F/G while pigs fed the high salt diet had decreased ($P < 0.001$) ADG and poorer ($P < 0.001$) F/G than pigs fed the 1% MSG diet. In phase 3 (d 26 to 48), no significant differences were detected among the MSG treatments however pigs fed the high salt diet had decreased ($P < 0.028$) ADG and ADFI compared with those fed the 1% MSG diet. Pig BW was reduced (linear, $P < 0.016$) on d 26 and 48 for pigs fed the MSG diets and pigs fed the high salt treatment had decreased ($P < 0.001$) BW compared to pigs fed 1% MSG. For the overall nursery period (d 0 to 48), increasing MSG decreased (linear, $P = 0.033$) ADG and tended (linear, $P = 0.095$) to decrease ADFI. Furthermore, pigs fed the high salt treatment had decreased ($P < 0.009$) ADG and ADFI and poorer ($P < 0.001$) F/G compared to their 1% MSG counterparts. Results from this study indicate that feeding MSG may have had a negative impact on ADFI and therefore, subsequent BW and ADG. In addition, the high salt treatment formulated to match the sodium content of the 1% MSG diet had consistently poorer performance than the 1% MSG treatment, suggesting that high salt content may negatively affect pig growth. Further research is warranted to determine the effects of feeding monosodium glutamate to nursery pigs in diets balanced for sodium content.

[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).

Introduction

Glutamate serves many roles in cellular processes and is particularly important for intestinal tract function and gut development. While it is considered a non-essential amino acid, glutamate significantly contributes to the energy supply for intestinal cells.[4] The suckling pig receives abundant glutamate from the sow's milk;[5] however, due to decreased feed intake typically seen after weaning, nursery pigs are often limited in glutamate intake. This may exacerbate common post-weaning issues, such as impaired growth performance and diarrhea due to damaged intestinal villi. Rezaei et. al[6] observed that supplementing up to 4% dietary monosodium glutamate (MSG) improved nursery growth performance. Therefore, the objective of this study was to identify the effects of increasing monosodium glutamate on nursery pig performance and determine if the response can be attributed to increasing sodium content or glutamate.

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 phase 2 and 3). Feed additions to each individual pen were delivered and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, 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 11.2 lb BW) were used in a 48-d growth trial with 27 pigs per pen and 7 replications per treatment. Pigs were weaned at approximately 17 d of age and were randomly allotted to pens upon weaning. Pens were then blocked by BW and allotted to one of 6 dietary treatments. The dietary treatments were diets containing 0, 0.5, 1.0, 1.5, and 2.0% MSG, or a high salt diet. The high salt treatment was formulated to contain the equivalent amount of sodium as the 1% MSG treatment: 0.58, 0.50, and 0.42% Na in phases 1, 2, and 3, respectively. Pigs were fed in 3 phases from d 0 to 12, 12 to 26, and 26 to 48. Phase 1 was fed in pelleted form. Phases 2 and 3 were fed in meal form with the 0 and 2.0% MSG diets blended in the robotic feeding system to create the 3 intermediate MSG treatments. Pens were weighed and feed disappearance was measured on d 0, 6, 12, 19, 26, 34, 41, and 48 to determine ADG, ADFI, and F/G.

[4] Watford M. 2008. Glutamine metabolism and function in relation to proline synthesis and the safety of glutamine and proline supplementation. J Nutr. 138:2003–7.
[5] Haynes, T.E., Li, P., Li, X., Shimotori, K., Sato, H., Flynn, N. E., Wang, J., Knabe, D. A., Wu, G. 2009. L-Glutamine or L-alanyl-L- glutamine prevents oxidant- or endotoxin-induced death of neonatal enterocytes. Amino Acids. 37:131–142.
[6] Rezaei, R., Knabe, D.A., Tekwe, C.D., Dahanayaka, S., Ficken, M.D., Fielder, S.E., Eide, S.J., Lovering, S.L., Wu G. 2013. Dietary supplementation with monosodium glutamate is safe and improves growth performance in postweaning pigs. Amino Acids. 44:911–923.

Data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) with pen considered the experimental unit. Linear and quadratic contrasts were applied for the MSG treatments. A single degree of freedom contrast was used to compare the high salt treatment to the 1% MSG treatment. 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, with some variability exhibited in the sodium concentration, particularly in the phase 1 pelleted diets (Table 3, 4, and 5).

During phase 1 (d 0 to 12), adding MSG to the diet did not impact pig performance; however, pigs fed the high salt treatment tended ($P = 0.053$) to have poorer F/G than pigs fed 1.0% MSG (Table 6). In phase 2 (d 12 to 26), increasing MSG decreased (linear, $P < 0.045$) ADG, ADFI, and worsened F/G. Additionally, pigs fed the high salt treatment had poorer ($P < 0.001$) ADG and F/G than pigs fed 1.0% MSG. In phase 3 (d 26 to 48), no significant differences were detected among the MSG treatments. Pigs fed the high salt treatment had decreased ($P < 0.028$) ADG and ADFI compared with those fed 1% MSG. No significant differences were observed in BW until d 26 and 48, where increasing MSG decreased (linear, $P < 0.016$) BW and pigs fed the high salt diets had decreased ($P < 0.001$) BW compared to pigs fed 1.0% MSG. For the overall nursery period (d 0 to 48), increasing MSG decreased (linear, $P = 0.033$) ADG and tended to decrease (linear, $P = 0.095$) ADFI. Furthermore, pigs fed the high salt treatment had decreased ($P < 0.009$) ADG and ADFI and poorer ($P < 0.001$) F/G compared to their 1.0% MSG counterparts.

Results from this study suggest that increasing MSG from 0 to 2.0% did not improve nursery growth performance and had a negative impact on ADFI and, therefore, ADG and subsequent BW. In addition, pigs fed the high salt treatment consistently had poorer performance than pigs fed the same sodium content with 1.0% MSG, suggesting that very high salt concentrations negatively affect pig growth. Therefore, pig responses to glutamate should be evaluated independently from sodium. Further research is required to determine the optimal feeding level and duration of monosodium glutamate for nursery pigs and its role in mediating the post-weaning growth lag in diets without excess sodium.

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

	Monosodium glutamate,[2] %					
Ingredient, %	0	0.5	1.0	1.5	2.0	High salt
Corn	39.37	38.84	38.30	37.76	37.22	38.86
Soybean meal (48% CP)	17.65	17.69	17.73	17.77	17.80	17.69
Corn DDGS,[3] 6-9% oil	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[4]	2.50	2.50	2.50	2.50	2.50	2.50
Dried whey	25.00	25.00	25.00	25.00	25.00	25.00
Choice white grease	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium P (22% P)	0.40	0.40	0.40	0.40	0.40	0.40
Limestone	0.50	0.50	0.50	0.50	0.50	0.50
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.78
L-Lys HCl	0.48	0.48	0.48	0.48	0.48	0.48
L-Thr	0.18	0.18	0.18	0.18	0.18	0.18
L-Trp	0.05	0.05	0.05	0.05	0.05	0.05
L-Val	0.10	0.10	0.10	0.10	0.10	0.10
Methionine hydroxy analog	0.24	0.24	0.24	0.24	0.24	0.24
Choline chloride, 60%	0.04	0.04	0.04	0.04	0.04	0.04
Phytase[5]	0.04	0.04	0.04	0.04	0.04	0.04
Zinc oxide	0.39	0.39	0.39	0.39	0.39	0.39
Vitamin E, 20,000 IU	0.05	0.05	0.05	0.05	0.05	0.05
Selenium, 0.06%	0.05	0.05	0.05	0.05	0.05	0.05
Trace mineral premix	0.13	0.13	0.13	0.13	0.13	0.13
Vitamin premix	0.05	0.05	0.05	0.05	0.05	0.05
MSG[2]	--	0.50	1.00	1.50	2.00	--
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	2.0	High salt
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	111	111	111	111	110	111
Met:Lys	36	36	36	36	36	36
Met and Cys:Lys	56	56	56	56	56	56
Thr:Lys	62	62	62	62	62	62
Trp:Lys	19.1	19.1	19.1	19.1	19.1	19.1
Val:Lys	67	67	67	67	66	67
Total Lys, %	1.55	1.55	1.55	1.55	1.55	1.55
ME, kcal/lb	1,580	1,572	1,565	1,557	1,549	1,573
NE, kcal/lb	1,193	1,186	1,180	1,174	1,168	1,187
SID Lys:ME, g/Mcal	4.02	4.04	4.06	4.08	4.10	4.04
CP, %	21.0	21.0	20.9	20.9	20.9	21.0
Ca, %	0.71	0.71	0.71	0.71	0.71	0.71
P, %	0.67	0.67	0.67	0.66	0.66	0.67
Available P, %	0.59	0.59	0.59	0.59	0.59	0.59
Na, %	0.39	0.49	0.58	0.68	0.78	0.58
Cl, %	0.78	0.78	0.78	0.78	0.78	1.06

[1] Phase 1 was fed from d 0 to 12.

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

[3] DDGS = distillers dried grains with solubles.

[4] HP 300 (Hamlet Proteins).

[5] Quantum Blue 5G (AB Vista, Plantation, FL) provided 907 phytase units (FTU)/lb of diet, for an estimated release of 0.15% available P.

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

	Phase 2			Phase 3		
	MSG,[2] %			MSG, %		
Ingredient, %	0	2.0	High salt	0	2.0	High salt
Corn	43.49	41.34	42.97	50.37	48.22	49.84
Soybean meal (48% CP)	22.42	22.57	22.45	24.79	24.94	24.83
Distillers dried grains with solubles	15.00	15.00	15.00	20.00	20.00	20.00
Fish meal	5.00	5.00	5.00	--	--	--
Dried whey	10.00	10.00	10.00	--	--	--
Corn oil	1.00	1.00	1.00	1.00	1.00	1.00
Calcium carbonate	0.85	0.85	0.85	1.10	1.10	1.10
Monocalcium phosphate (22% P)	0.30	0.30	0.30	0.70	0.70	0.70
Sodium chloride	0.35	0.35	0.84	0.35	0.35	0.84
L-Lys HCl	0.40	0.40	0.40	0.50	0.50	0.50
DL-Met	0.14	0.14	0.14	0.13	0.13	0.13
L-Thr	0.13	0.13	0.13	0.15	0.15	0.15
L-Trp	0.03	0.03	0.03	0.03	0.03	0.03
Phytase[3]	0.03	0.03	0.03	0.03	0.03	0.03
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
MSG	--	2.00	--	--	2.00	--
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix	0.13	0.13	0.13	0.13	0.13	0.13
Denagard 10	0.18	0.18	0.18	0.18	0.18	0.18
Aureo 90	0.22	0.22	0.22	0.22	0.22	0.22
Total	100	100	100	100	100	100

continued

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

	Phase 2			Phase 3		
	MSG,[2] %			MSG, %		
Ingredient, %	0	2.0	High salt	0	2.0	High salt
Calculated analysis						
Standardized ileal digestibility (SID) amino acids, %						
Lys	1.35	1.35	1.35	1.25	1.25	1.25
Ile:Lys	60	60	60	60	60	60
Leu:Lys	132	131	132	141	139	140
Met:Lys	37	37	37	35	35	35
Met and Cys:Lys	58	58	58	58	58	58
Thr:Lys	63	63	63	63	63	63
Trp:Lys	18.1	18.1	18.1	18.1	18.1	18.1
Val:Lys	68	67	68	68	67	68
Total Lys, %	1.54	1.54	1.54	1.43	1.43	1.43
ME, kcal/lb	1,524	1,493	1,516	1,509	1,478	1,502
NE, kcal/lb	1,120	1,095	1,114	1,104	1,080	1,098
SID Lys:ME, g/Mcal	4.02	4.10	4.04	3.76	3.84	3.78
CP, %	23.3	23.2	23.3	22.1	22.0	22.1
Ca, %	0.75	0.75	0.75	0.65	0.65	0.65
P, %	0.64	0.64	0.64	0.58	0.57	0.58
Available P, %	0.52	0.52	0.52	0.44	0.44	0.44
Na, %	0.31	0.69	0.50	0.23	0.61	0.42
Cl, %	0.62	0.62	0.91	0.54	0.54	0.83

[1] Phase 2 diets were fed from d 12 to 26 and phase 3 diets were fed from d 26 to 48.

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

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

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

	Monosodium glutamate,[2] %					
Item	0	0.5	1.0	1.5	2.0	High salt
Moisture	7.73	7.43	7.76	7.45	7.66	7.23
DM	92.28	92.57	92.25	92.55	92.35	92.77
CP	21.00	21.45	20.50	21.20	21.40	20.50
ADF	2.65	2.75	2.10	2.50	3.50	3.25
NDF	10.80	9.55	10.30	11.15	12.20	11.90
Crude fiber	2.10	1.70	1.80	1.90	2.05	1.90
Ca	0.90	0.93	0.77	0.83	0.75	0.80
P	0.72	0.73	0.67	0.68	0.66	0.69
Ether extract	5.95	5.90	6.30	6.05	6.30	6.25
Starch	24.70	23.10	25.25	25.05	24.30	25.25
Sodium	0.43	0.54	0.44	0.47	0.52	0.47
Chloride	0.74	0.80	0.68	0.69	0.74	0.99
Salt	1.22	1.31	1.13	1.13	1.21	1.63

[1] Phase 1 was fed from d 0 to 12 in pelleted form.

[2] MSG (Monosodium glutamate, 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	2.0	High salt
Moisture	10.12	10.92	10.25	10.55	10.07	10.36
DM	89.88	89.09	89.76	89.46	89.94	89.65
CP	22.55	21.85	22.55	22.30	22.65	20.15
ADF	4.10	4.05	4.75	4.50	4.45	4.90
NDF	12.50	12.70	13.45	12.40	12.20	15.60
Crude fiber	2.80	2.70	3.25	3.00	3.30	3.55
Ca	1.07	1.04	0.93	0.96	0.87	0.97
P	0.73	0.73	0.74	0.77	0.76	0.77
Ether extract	4.50	4.90	4.65	4.70	4.90	5.45
Starch	27.40	27.30	27.05	26.25	25.15	26.60
Sodium	0.29	0.38	0.42	0.43	0.56	0.50
Chloride	0.53	0.63	0.62	0.61	0.65	0.90
Salt	0.86	1.04	1.03	1.00	1.08	1.48

[1] Phase 2 was fed from d 12 to 26 in meal form. Diets with 0 and 2.0% MSG were manufactured and then blended to create the intermediate MSG treatments using a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN).

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

Table 5. Chemical analysis of phase 3 diets, % (as-fed basis)[1]

	Monosodium glutamate,[2] %					
Item	0	0.5	1.0	1.5	2.0	High salt
Moisture	11.36	11.39	11.42	10.49	10.75	10.77
DM	88.64	88.62	88.59	89.51	89.25	89.24
CP	20.85	21.55	22.60	23.15	22.40	22.70
ADF	4.55	4.75	5.05	5.25	4.55	4.90
NDF	13.75	14.00	15.80	14.30	14.00	14.50
Crude fiber	3.05	3.30	3.30	3.45	3.10	3.25
Ca	0.78	0.76	0.77	0.69	0.89	0.81
P	0.62	0.63	0.67	0.64	0.67	0.68
Ether extract	4.10	4.20	4.25	4.25	4.05	3.70
Starch	31.90	31.45	29.85	31.25	30.35	29.95
Sodium	0.22	0.31	0.33	0.38	0.39	0.35
Chloride	0.44	0.47	0.55	0.44	0.36	0.67
Salt	0.72	0.78	0.91	0.71	0.59	1.09

[1] Phase 3 was fed from d 26 to 48 in meal form. Diets with 0 and 2.0% MSG were manufactured and then blended to create the intermediate MSG treatments using a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN).

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

Table 6. Effects of monosodium glutamate on nursery pig performance[1]

	Monosodium glutamate,[2] %					High		MSG, *P* <		High salt vs. 1% MSG
Item	0.0	0.5	1.0	1.5	2.0	salt[3]	SEM	Linear	Quadratic	*P* <
Phase 1 (d 0 to 12)										
ADG, lb	0.26	0.28	0.28	0.28	0.29	0.26	0.014	0.163	0.537	0.103
ADFI, lb	0.48	0.48	0.49	0.49	0.49	0.49	0.009	0.203	0.943	0.620
F/G	1.87	1.73	1.77	1.80	1.73	1.97	0.083	0.386	0.635	0.053
Phase 2 (d 12 to 26)										
ADG, lb	0.75	0.69	0.70	0.66	0.65	0.56	0.025	0.001	0.448	0.001
ADFI, lb	1.12	1.01	1.04	1.06	1.01	0.98	0.035	0.045	0.221	0.123
F/G	1.50	1.47	1.49	1.60	1.55	1.75	0.036	0.038	0.671	0.001
Phase 3 (d 26 to 48)										
ADG, lb	1.27	1.20	1.24	1.21	1.21	1.16	0.022	0.173	0.347	0.028
ADFI, lb	1.91	1.81	1.88	1.81	1.83	1.76	0.038	0.176	0.403	0.022
F/G	1.51	1.51	1.52	1.50	1.51	1.51	0.019	0.949	0.875	0.814
Overall (d 0 to 48)										
ADG, lb	0.86	0.82	0.83	0.81	0.82	0.75	0.018	0.033	0.340	0.001
ADFI, lb	1.31	1.24	1.27	1.26	1.25	1.20	0.027	0.095	0.210	0.009
F/G	1.53	1.51	1.53	1.55	1.54	1.60	0.011	0.144	0.633	0.001
BW, lb										
d 0	11.2	11.2	11.2	11.2	11.2	11.2	0.146	1.000	0.817	0.647
d 12	14.3	14.6	14.6	14.5	14.6	14.3	0.202	0.145	0.440	0.121
d 26	25.0	24.3	24.5	23.8	23.8	22.3	0.488	0.001	0.574	0.001
d 48	52.3	50.3	51.3	49.9	50.0	47.6	0.961	0.016	0.405	0.001

[1] A total of 1,134 nursery pigs (initially 11.2 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 (MSG, Ajinomoto Heartland, Inc., Chicago, IL).

[3] High salt treatment was formulated to match the sodium content of the 1% MSG treatment.