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Effect of Increasing Dietary Iodine on Nursery Pig Growth Performance

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Summary

A total of 720 barrows (DNA 200 × 400, initially 13.8 ± 0.02 lb) were used in a 46-d study to determine the effects of increasing dietary iodine on growth performance of nursery pigs. At weaning, pigs were randomly assigned within six BW blocks to one of six dietary treatments in a generalized randomized block design. There were five pigs per pen and 24 pens per treatment. Experimental diets were corn-soybean meal-based and were fed for the first 39 d (phase 1 from d 0 to 10, phase 2 from d 10 to 24, and phase 3 from d 24 to 39), and then all pigs were fed a common diet for the last week of the study (d 39 to 46). All diets contained a basal level of 0.3 ppm of added iodine from ethylenediamine dihydriodide provided by the trace mineral premix. To create the dietary treatments, a low-iodine control diet (0.3 ppm of added iodine) and a high-iodine diet (30 ppm added iodine from calcium iodate, 63.5% iodine) were manufactured. The four intermediate dietary treatments (6.2, 12.2, 18.1, and 24 ppm of added iodine) were then produced by proportionally blending the low- and high-iodine diets. During the experimental period (d 0 to 39), there was a cubic response ($P \leq 0.023$) for ADG and ADFI where performance increased from 0.3 to 12.2 ppm, was decreased at 24 ppm, and finally increased at 30 ppm. Feed efficiency during the experimental period and overall improved (linear, $P < 0.05$) as added iodine increased. Overall, from d 0 to 46, there was a cubic response ($P \leq 0.023$) for ADG and ADFI resulting in a tendency (cubic, $P = 0.066$) for a final BW response where performance increased from 0.3 to 12.2 ppm, decreased at 24 ppm, and finally increased at 30 ppm. In conclusion, weaned pigs fed 12.2 ppm iodine in the diet had improved overall body weight, ADG, ADFI, and F/G compared with the basal level of 0.3 ppm added iodine.

Introduction

For decades, energy and protein requirements in swine have been determined based on the levels needed to achieve optimal growth and feed efficiency. In contrast, recommendations for vitamins and trace minerals have historically been based on the minimum concentrations required to prevent deficiency symptoms and maintain basic metabolic functions. This fundamental difference in the criteria used for determining nutrient requirements has often led to an underutilization of trace minerals in swine nutrition. However, extensive research over the past 75 years has demonstrated that supple-

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menting trace minerals well above deficiency-prevention levels can enhance growth and reproductive performance in pigs.

Iodine is a trace mineral of particular interest due to its central role in the synthesis of thyroid hormones, which regulate the basal metabolic rate. The NRC (2012) estimates a dietary iodine level of 0.14 ppm for all nursery and growing pig stages, based on data demonstrating the elimination of deficiency symptoms and normalization of thyroid size and growth rate. However, emerging evidence suggests that iodine may play a more dynamic role in swine metabolism than previously recognized. Recent research[2] has shown that feeding dietary iodine at levels up to 100 times the NRC requirement estimate can significantly improve average daily gain (ADG) and increase plasma thyroxine (T4) concentrations in nursery pigs. In that study, dietary iodine levels of 0, 0.14, 1.4, 14, and 140 ppm were evaluated, with pigs fed 14 ppm having the greatest improvements in both ADG and plasma T4. These findings suggest that dietary iodine levels well above current recommendations may enhance growth performance through increased thyroid activity and altered metabolic regulation. This highlights the need for further research to determine the optimal dosage that supports performance without triggering adverse effects linked to excess iodine. Therefore, the objective of this study was to evaluate the effect of increasing dietary iodine on nursery pig performance.

Procedures

The protocol used in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. This study was conducted at the Kansas State University Segregated Early Weaning facility in Manhattan, KS. The facility has two identical barns that are completely enclosed, environmentally controlled, and mechanically ventilated. Each pen contained a 4-hole, dry self-feeder and a cup waterer for ad libitum access to feed and water. Pens (4 × 4 ft) had metal tri-bar floors and allowed approximately 2.7 ft2/pig.

Animals and diets

A total of 720 barrows (DNA 200 × 400; initially 13.8 ± 0.02 lb) were used in a 46-d growth trial. Pigs were weaned at approximately 21 d of age and grouped in six blocks by initial BW. Treatments were assigned in a generalized randomized block design. There were five pigs per pen and 24 replications per treatment, equally distributed across two identical barns (12 replications per barn). Pens of pigs were randomly assigned to one of six dietary treatments with increasing levels of added iodine (0.3, 6.2, 12.2, 18.1, 24, and 30 ppm). Diets were corn-soybean meal-based. The control diet provided 0.3 ppm of added iodine, sourced from ethylenediamine dihydriodide (EDDI) included in the standard trace mineral premix. To ensure accurate inclusion, a custom iodine premix was created by diluting calcium iodate (63.5% iodine) with ground corn at a 1:99 ratio. For each feeding phase, a low-iodine control diet (0.3 ppm of added iodine) and a high-iodine diet (30 ppm of added iodine from the custom calcium iodate premix) were manufactured. The four intermediate dietary treatments (targeting 6.2, 12.2, 18.1, and 24 ppm of added iodine) were then produced by proportionally blending the low- and high-iodine diets. Treatment diets were fed in three phases: phase 1 from d 0 to 10, phase 2 from d 10 to 24, and phase 3 from d 24 to 39. Subsequently, all pigs were fed a common corn-soybean meal-based diet containing 0.3 ppm iodine for the last week of

[2] Dove, R., S. Locke, C. Edmund, M. Sterling, J. Sanvidge, N. Wang, C. A. Lents, and M. Azain. 2024. 273 Effect of dietary iodine supplementation on the growth performance and thyroid hormone concentrations of nursery pigs. J. Anim. Sci. 102(Suppl. 2):162. doi:10.1093/jas/skae102.179.

the trial (d 39 to 46). Treatment diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center in Manhattan, KS, and fed in pellet form for phase 1 and meal form in phases 2 and 3. Pig weights and feed disappearance were measured on d 0, 10, 15, 24, 31, 39, and 46 to determine ADG, ADFI, and feed efficiency (F/G).

Statistical analysis

Data were analyzed as a generalized randomized block design as a one-way ANOVA using the lmer function from the lme4 package in R Studio (Version 3.5.2, R Core Team, Vienna, Austria) with pen serving as the experimental unit, and dietary treatment and weight block as fixed effects. Barn was included in the model as a random effect. Linear, quadratic, and cubic contrasts were tested within increasing levels of dietary iodine. When treatment was a significant source of variation, differences were determined by pairwise comparison using the Tukey-Kramer multiplicity adjustment to control for Type I Error. Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $P \leq 0.10$.

Results and Discussion

From d 0 to 10, a tendency (cubic, $P \leq 0.072$) of treatment response was observed for ADG, F/G, and d 10 BW where performance was improved as iodine increased from 0.3 to 12.2 ppm, then decreased at 24 ppm, followed by another increase at 30 ppm (Table 3).

From d 10 to 24, increasing added iodine increased (linear, $P = 0.009$) ADG, although a tendency for a cubic response was also observed ($P = 0.062$) similar to that described above. Body weight on d 24 also followed the same pattern described (cubic, $P = 0.008$). Average daily feed intake increased (cubic, $P = 0.034$) as iodine increased from 0.3 to 12.2 ppm, then decreased at 24 ppm, followed by another increase at 30 ppm. A marginally significant response (quadratic, $P = 0.086$) was observed for F/G where F/G improved with increasing added iodine up to 24 ppm and then worsened at 30 ppm added iodine.

From d 24 to 39, a marginal response (cubic, $P \leq 0.056$) was observed for ADG and ADFI, where performance improved as iodine increased from 0.3 to 12.2 ppm, then decreased at 24 ppm, followed by another increase at 30 ppm. At d 24 and 39, BW increased (cubic, $P \leq 0.014$) where performance increased from 0.3 to 12.2 ppm, decreased at 24 ppm, and finally increased at 30 ppm.

For the experimental period (d 0 to 39), ADG and ADFI increased (cubic, $P \leq 0.023$) from 0.3 to 12.2 ppm, decreased at 24 ppm, and finally increased at 30 ppm. Feed efficiency improved (linear, $P = 0.018$) with increasing iodine.

Overall (d 0 to 46), ADG and ADFI increased (cubic, $P < 0.023$) resulting in a tendency (cubic, $P = 0.066$) for final BW where performance increased from 0.3 to 12.2 ppm, decreased at 24 ppm, and finally increased at 30 ppm. Feed efficiency improved (linear, $P = 0.019$) as dietary iodine increased.

For the experimental period (d 0 to 39) dose response models, linear, quadratic, cubic, and broken-line linear models were evaluated, and model selection was based on the lowest BIC value. For ADG (Figure 1), cubic and broken-line linear models were best fitting. For the cubic model, the maximum ADG was predicted at a local maxima

of 10.2 ppm iodine. For the broken-line linear model, no further improvement was observed beyond a breakpoint of 12.2 ppm added iodine. For F/G (Figure 2), quadratic and broken-line linear models were best fitting. For the quadratic model, the best F/G was predicted at 20.4 ppm added iodine. For the broken-line linear model, no further improvement in F/G was observed beyond the breakpoint of 9.3 ppm added iodine.

In summary, increasing added iodine in the diets consistently improved growth performance and feed efficiency in nursery pigs compared with the control diet formulated with levels of added iodine similar to those used in commercial production. Based on the dose-response models, formulating diets to contain between 9.3 and 12.2 ppm of added iodine optimized ADG and F/G. These results suggest that feeding iodine well above the NRC (2012) requirement estimate can yield significant performance benefits.

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Table 1. Diet composition (as-fed basis)1

	Phase 1		Phase 2		Phase 3	
Item Added iodine, ppm	0.3	30.0	0.3	30.0	0.3	30.0
Ingredient, %						
Corn	45.50	45.03	60.80	60.30	65.55	65.08
Soybean meal, 47.7% CP	22.09	22.09	22.90	22.90	30.54	30.54
Whey powder	12.50	12.50	7.00	7.00	---	---
Whey permeate, 80% lactose	7.50	7.50	---	---	---	---
Soy protein concentrate2	7.50	7.50	5.00	5.00	---	---
Soybean oil	1.00	1.00	---	---	---	---
Calcium carbonate	0.58	0.58	0.70	0.70	0.75	0.75
Monocalcium phosphate, 21.5% P	1.10	1.10	1.10	1.10	1.05	1.05
Sodium chloride	0.50	0.50	0.70	0.70	0.60	0.60
L-Lys-HCl	0.36	0.36	0.50	0.50	0.48	0.48
DL-Met	0.23	0.23	0.20	0.20	0.20	0.20
L-Thr	0.19	0.19	0.20	0.20	0.22	0.22
L-Trp	0.03	0.03	0.05	0.05	0.05	0.05
L-Val	0.09	0.09	0.10	0.10	0.12	0.12
Trace mineral premix	0.15	0.15	0.20	0.20	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Phytase3	0.06	0.06	0.06	0.06	0.06	0.06
Zinc oxide	0.40	0.40	0.30	0.30	---	---
Iodine premix, 0.635% I4	---	0.47	---	0.47	---	0.47
Calculated analysis						
SID AA %						
Lys, %	1.40	1.40	1.35	1.35	1.30	1.30
Ile:Lys	60	60	57	57	56	56
Leu:Lys	116	116	116	116	117	117
Met:Lys	37	37	37	37	37	37
Met and Cys:Lys	58	58	58	58	58	58
Thr:Lys	65	65	65	65	65	65
Trp:Lys	20	20	20	20	20	20
Val:Lys	70	70	70	70	70	70
His:Lys	36	36	36	36	37	37
SID Lys:Net energy, g/Mcal	5.57	5.57	5.52	5.52	5.36	5.36
Net energy, kcal/lb	1,140	1,140	1,109	1,109	1,101	1,101
CP, %	21.7	21.7	21.0	21.0	20.8	20.8
Ca, %	0.72	0.72	0.72	0.72	0.68	0.68
P, %	0.68	0.68	0.65	0.65	0.61	0.61
STTD P, %5	0.58	0.58	0.53	0.53	0.48	0.48
Iodine added, ppm	0.30	30.00	0.30	30.00	0.30	30.00

[1] Phases 1, 2, and 3 were fed from d 0 to 10, 10 to 24, and 24 to 39, respectively. The low added iodine phase 3 diet was fed as a common phase to all pigs from d 39 to 46.

[2] PurePro Soy (Bunge; Chesterfield, MO).

[3] HiPhorius 2400 (Novonesis, Kongens Lyngby, Denmark) provided at 654 FTU/lb of feed in all phases, with an assumed release of 0.12% STTD P.

[4] Iodine premix was formulated to be 99 parts corn and 1 part CaI (63.5% Iodine). The premix was added at the expense of corn.

[5] Standardized total tract digestible.

Table 2. Chemical analysis of experimental diets (as-fed basis)1

	Added iodine, ppm					
Item	0.3	6.2	12.2	18.1	24.0	30.0
Analyzed iodine levels, ppm						
Phase 1	3.04	5.32	10.02	12.97	18.59	21.54
Phase 2	2.94	5.99	11.07	15.08	19.96	24.16
Phase 3	1.25	4.86	7.95	12.56	16.77	24.43

[1] Representative samples of treatment diets were taken from the feed mill. Two samples per treatment were submitted to Michigan State University Veterinary Diagnostic Laboratory (East Lansing, MI) for iodine analysis and were analyzed in duplicate.

Table 3. Effect of increasing dietary iodine on nursery pig growth performance1										
	Added iodine, ppm							P =		
Item	0.3	6.2	12.2	18.1	24	30	SEM	Linear	Quadratic	Cubic
BW, lb										
d 0	13.8	13.8	13.8	13.8	13.8	13.8	0.02	0.747	0.992	0.950
d 10	18.2	18.2	18.5	18.3	18.0	18.6	0.16	0.429	0.504	0.064
d 24	31.5	32.1	32.6	32.1	31.7	32.8	0.31	0.079	0.625	0.008
d 39	49.9b	50.3ab	51.9a	51.0ab	49.8b	51.6ab	0.46	0.119	0.289	0.014
d 46	60.0	60.2	62.4	60.7	60.0	61.4	0.62	0.377	0.310	0.066
d 0 to 10										
ADG, lb	0.44	0.44	0.46	0.45	0.42	0.48	0.017	0.410	0.507	0.067
ADFI, lb	0.44	0.43	0.45	0.43	0.42	0.46	0.014	0.828	0.248	0.279
F/G	1.01	0.99	0.97	0.97	1.01	0.95	0.019	0.122	0.694	0.072
d 10 to 24										
ADG, lb	0.93b	0.97ab	1.01a	0.99ab	0.97ab	1.01a	0.017	0.009	0.230	0.062
ADFI, lb	1.32	1.33	1.34	1.34	1.32	1.40	0.022	0.091	0.868	0.034
F/G	1.42	1.38	1.39	1.37	1.36	1.39	0.014	0.060	0.086	0.762
d 24 to 39										
ADG, lb	1.23ab	1.23ab	1.28a	1.23ab	1.21b	1.25ab	0.017	0.845	0.546	0.056
ADFI, lb	1.89ab	1.88ab	1.94a	1.88ab	1.84b	1.91ab	0.024	0.596	0.904	0.054
F/G	1.54	1.53	1.51	1.52	1.52	1.53	0.013	0.330	0.193	0.967
Experimental period (d 0 to 39)										
ADG, lb	0.92c	0.93abc	0.97a	0.94abc	0.92bc	0.97ab	0.013	0.057	0.440	0.010
ADFI, lb	1.31ab	1.31ab	1.36a	1.32ab	1.28b	1.35ab	0.018	0.406	0.913	0.023
F/G	1.43	1.41	1.40	1.40	1.40	1.40	0.009	0.018	0.058	0.600
Common phase (d 39 to 46)										
ADG, lb	1.53	1.54	1.54	1.53	1.55	1.55	0.027	0.730	0.892	0.807
ADFI, lb	2.42	2.43	2.47	2.42	2.40	2.44	0.027	0.908	0.752	0.211
F/G	1.59	1.59	1.60	1.59	1.57	1.58	0.023	0.530	0.650	0.455
Overall (d 0 to 46)										
ADG, lb	1.00b	1.01ab	1.05a	1.02ab	1.00ab	1.05ab	0.012	0.055	0.506	0.015
ADFI, lb	1.46ab	1.45ab	1.51a	1.46ab	1.43b	1.50ab	0.018	0.435	0.970	0.023
F/G	1.46	1.44	1.44	1.43	1.43	1.43	0.008	0.019	0.137	0.869

[1] A total of 720 pigs (Line 200 × 400, DNA, Columbus, NE; initially 13.8 ± 0.02 lb) were used in a 46-d growth study with five pigs per pen and 24 pens per treatment.

[abc] Within a row, means without a common superscript differ ($P < 0.05$).

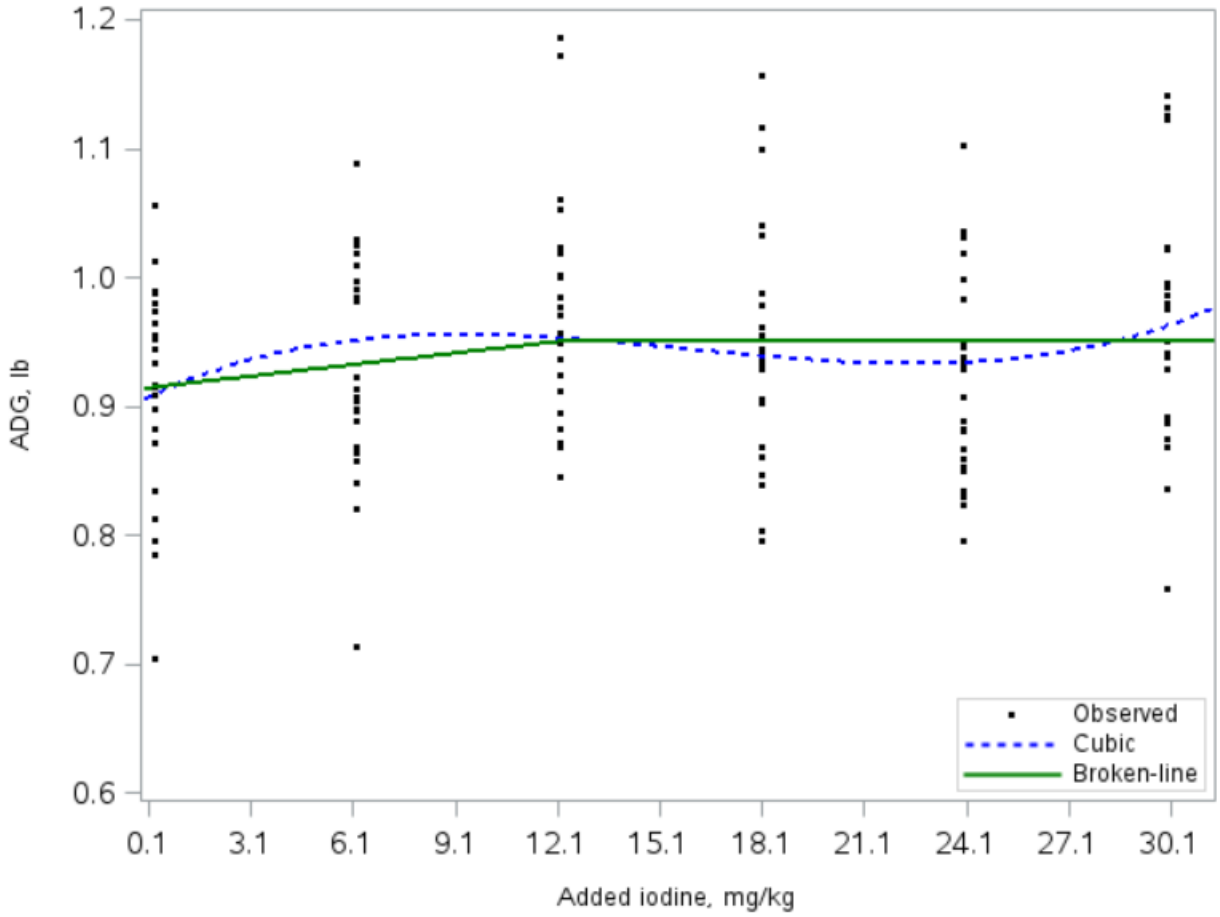


Figure 1. Estimation of added iodine requirements to maximize ADG for 13.8- to 50.8-lb DNA 200 × 400 pigs.

A total of 720 barrows (DNA 200 × 400; initially 13.8 ± 0.2 lb) were used in a 46-d trial. Cubic, broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate the added iodine level required to maximize ADG during the 39-d experimental period. The BLL and cubic models resulted in the best fit based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit (BIC = -346.7 vs. -348.16, BLL vs. cubic, respectively). The BLL model predicted no further improvement beyond 12.2 ppm added iodine. The cubic model predicted 95 and 100% of maximum ADG at greater than 5.2 and 10.15 ppm added iodine, respectively. The developed cubic model equation for ADG was: ADG, lb = $0.000020 \times (\text{Added Iodine, ppm})^3 - 0.00093 \times (\text{Added Iodine, ppm})^2 + 0.01228 \times (\text{Added Iodine, ppm}) + 0.9061$.

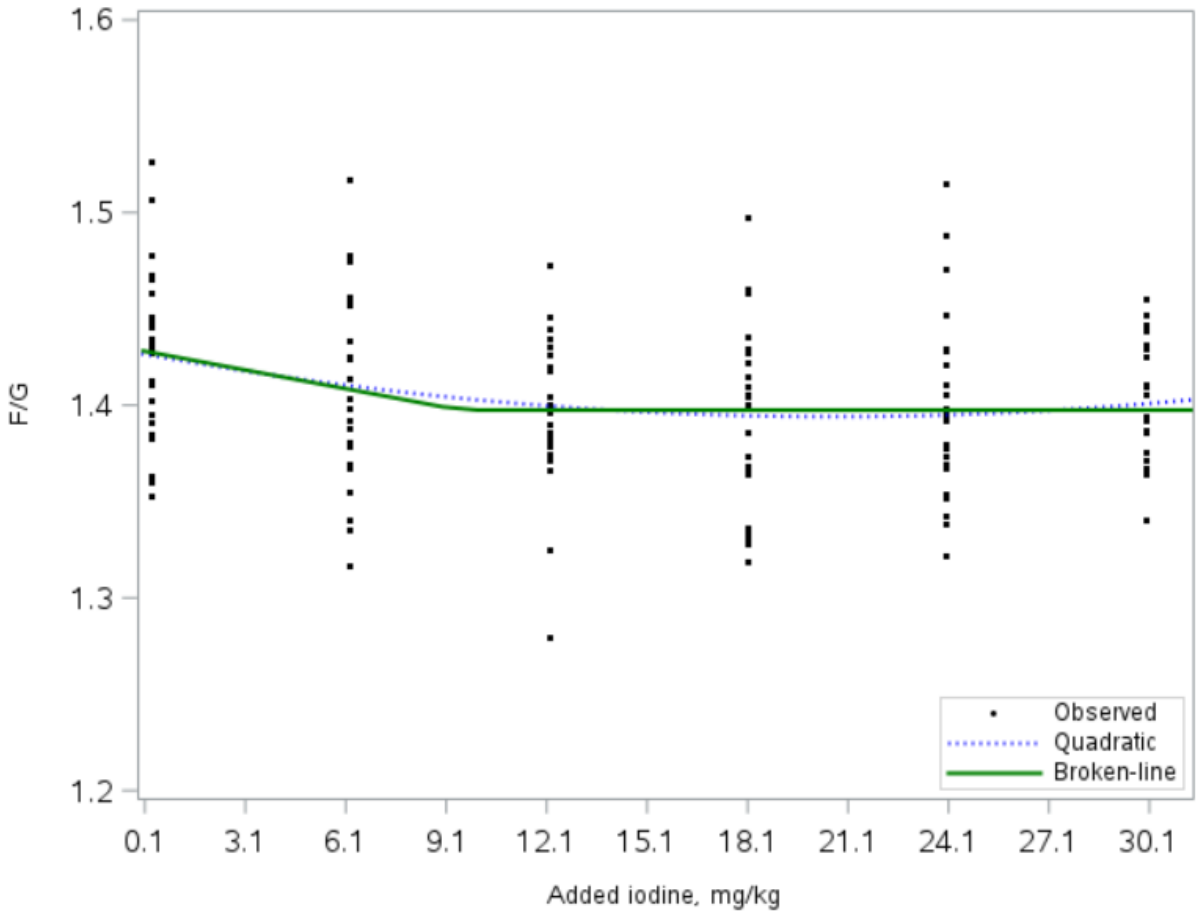


Figure 2. Estimation of added iodine requirements to minimize F/G for 13.8 to 50.8-lb DNA 200 × 400 pigs.

A total of 720 barrows (DNA 200 × 400; initially 13.8 ± 0.2 lb) were used in a 46-d trial. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate the added iodine level required to minimize F/G during the 39-d experimental period. The BLL and QP models resulted in the best fit based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit (BIC = -483.3 vs. -483.1, BLL vs. QP, respectively). The BLL model predicted no further improvement beyond 9.5 ppm added iodine. The QP model predicted 95 and 100% of minimum F/G at greater than 16.0 and 20.6 ppm added iodine, respectively. The developed QP model equation for F/G was F/G = 0.000077 × (Added Iodine, ppm)^2 – 0.00317 × (Added Iodine, ppm) + 1.4268.