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A Survey of Added Vitamins and Trace Minerals in Diets Utilized in the U.S. Swine Industry

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Summary

From November 2021 to February 2022, 37 swine nutritionists representing 29 production systems and 8 nutrition supplier companies in the United States were surveyed about added vitamins and trace mineral concentrations in swine diets. Respondents were asked to provide vitamin and trace mineral inclusion rates, weight ranges associated with each dietary phase, and number of sows utilizing their nutritional recommendations. Survey participants represented 4.38 million sows, or 72% of the U.S. industry. Data were compiled into 3 nursery phases (weaning to 15 lb; 15 to 25 lb; and 25 to 50 lb), 3 finishing phases (50 to 120; 120 to 220; and 220 lb to market), gilt development, gestation, lactation, and boar diets. Within each dietary phase, the vitamins and trace minerals of interest included: vitamin A, vitamin D, vitamin E, vitamin K, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, vitamin B₁₂, choline, vitamin C, carnitine, copper, iodine, iron, manganese, selenium, zinc, cobalt, and chromium. Descriptive statistics used included: average, weighted average (determined by the total number of sows), median, minimum, maximum, 25th percentile (lowest quartile), and 75th percentile (highest quartile). In addition, all average vitamin and trace mineral concentrations within each phase of production were compared to the requirement estimates reported in the NRC.² The results of this survey follow similar trends observed in a previous survey in 2016.³ Nutritionists generally supplemented vitamins and trace minerals well above the NRC (2012) requirements. However, greater variation among respondents was observed in all vitamins and trace minerals, particularly in the fat soluble vitamins. Also, the use of alternative sources of vitamin D (25-OH-D₃), E (natural, d-alpha-tocopherol), and organic or chelated minerals like copper, manganese, selenium, and zinc is becoming more frequent. In addition, comparisons to the most recent NRC (2012) requirement estimates highlight the necessity of future research to better understand vitamin and trace mineral requirements in swine diets.

¹ Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

² National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

³ Flohr, J. R., J. M. DeRouchey, J. C. Woodworth, M. D. Tokach, R. D. Goodband, S. S. Dritz. A survey of current feeding regimens for vitamins and trace minerals in the US swine industry. J Swine Health Prod 2016;24(6):290-303.

Introduction

Vitamins and trace minerals are added to swine diets to contribute to good health, performance, and well-being of the animal. Depending on the production phase or stage, pigs require different amounts of each vitamin and trace mineral. Most commercial diets are formulated well above the NRC (2012) requirement estimates for two main reasons. First, nutritionists want to maintain a margin of safety to account for potential reductions in the bioavailability of vitamins resulting from unfavorable storage conditions or excessive storage time. Second, this is an area with traditionally little research, resulting in a lack of knowledge. Six years ago, nutritionists for 2.3 million sows were surveyed and confirmed that, in the U.S., vitamin and trace mineral concentrations are frequently higher than the NRC estimates. Additionally, the survey showed considerable variation in the levels used by different swine operations. This variation might be attributed to differences in health status, vitamin and trace mineral source, feed mill characteristics, or nutritionists' opinions as to a margin of safety. Furthermore, in 2018 there were vitamin shortages that caused some vitamin inclusion rates to be reduced. It is not clear if the resulting supplementation rates remained or were again increased after the vitamin supply became adequate. Because it has been 6 years since the last U.S. survey, and 10 since the previous NRC publication, our goal was to update the vitamin and trace mineral concentrations used, and survey a greater portion of nutritionists in the industry than in 2016.

Procedures

The survey procedures followed the same methods as Flohr et al. (2016). Nutritionists from swine production companies in the top 40 Pork Powerhouses list⁴ and nutrition supplier companies were contacted via email or phone from November 2021 to February 2022.

The survey aimed to identify industry levels of added vitamins and trace minerals in complete diets based on the phase of production. The phases included: 3 nursery phases (weaning to 15 lb; 15 to 25 lb; and 25 to 50 lb), 3 finishing phases (50 to 120; 120 to 220; and 220 lb to market), gilt development, gestation, lactation, and boar diets. Within each dietary phase, the vitamins and trace minerals of interest included: vitamin A, vitamin D, vitamin E, vitamin K (menadione), thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, vitamin B₁₂, choline, vitamin C (ascorbic acid), carnitine, copper, iodine, iron, manganese, selenium, zinc, cobalt, and chromium.

Results were compiled and pooled to determine descriptive statistics in an Excel spreadsheet (Microsoft, Redmond, WA). Descriptive statistics used included: average, weighted average (determined by the total number of sows), median, minimum, maximum, 25th percentile (lowest quartile), and 75th percentile (highest quartile). All values were determined using Excel formula functions, including average, standard deviation (STDEV.S), median, minimum (MIN), maximum (MAX), and 25th and 75th percentiles (QUARTILE.EXC). Weighted averages were calculated using the SUMPRODUCT function of Excel, in which the participant vitamin or trace mineral concentration was multiplied by the number of sows and then divided by the total number of sows for all participants who provided added levels for that nutrient.

⁴ Successful Farmer. 2021. Pork Powerhouses 2021: Pork powerhouses 2021: bouncing back from covid-19. <http://www.agriculture.com>. (Accessed November 7, 2021)

Average vitamin and trace mineral concentrations within each phase of production were compared to NRC (2012) total dietary requirement estimates and to Flohr et al. (2016).

Results and Discussion

In total, 37 U.S. swine production systems and nutrition suppliers participated in the survey totaling approximately 4,382,700 sows. Using the 2022 U.S. Department of Agriculture sow inventory estimate of 6,100,000 (USDA, 2022⁵), this survey sampled approximately 72% of the U.S. swine industry.

Nursery

For nursery diets (weaning to 50 lb), fat soluble vitamins (A, D, E, and K) ranged from 4.3 to 11.8 times the NRC (2012) requirement estimates (Tables 1, 2, and 3), and on average were 99% of the values obtained by Flohr et al. (2016). A major difference was 11 of the 36 respondents used 25-hydroxyvitamin-D₃ as a source of vitamin D (Table 4). Four of the 36 producers specified natural vitamin E as the single source or a percentage of the added vitamin E. Water soluble vitamins (thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, vitamin B₁₂, choline, and vitamin C) ranged from 0.7 to 12.7 times the NRC (2012) requirement estimates and on average were 110% the values obtained by Flohr et al. (2016).

For minerals, nearly all participants reported using pharmacological levels of Zn from weaning to 25 lb (Table 11), and overall mineral concentrations followed the levels observed by Flohr et al. (2016). Approximately half of the respondents reported using some sort of organic mineral source for Cu (12), Mn (11), Se (18), and Zn (9).

Finisher

For finishing (50 lb to market) diets (Tables 5, 6, and 7), fat soluble vitamins ranged from 1.9 to 8.1 times the NRC (2012) requirement estimates, and were on average 98% of the values obtained by Flohr et al. (2016). Three systems reported using 25-hydroxyvitamin-D₃ as a source of vitamin D, and 4 of the 36 producers specified natural vitamin E as the single source or as a percentage of the vitamin E. Water soluble vitamins ranged from 0.8 to 3.7 times the NRC (2012) requirement estimates and on average were 118% of the values obtained by Flohr et al. (2016). Trace minerals ranged from 1.4 to 18.8 times the NRC (2012) requirement estimates and on average were 93% of the values obtained by Flohr et al. (2016). Some respondents reported using some form of organic mineral source for Cu (6), Mn (2), Se (3), and Zn (3).

Breeding herd diets

In gestation (Table 8) and lactation (Table 9) diets, fat soluble vitamins ranged from 1.9 to 7.9 times the NRC (2012) requirement estimates, and on average were 113% of the values obtained by Flohr et al. (2016). Thirteen systems reported using 25-hydroxyvitamin-D₃ as a source of vitamin D, and 8 of the 36 producers specified natural vitamin E as the only source or as a percentage of the vitamin E. Water soluble vitamins ranged from 0.5 to 4.5 times the NRC (2012) requirement estimates and on average were 103% of the values obtained by Flohr et al. (2016). Trace minerals ranged

⁵ U.S. Department of Agriculture. 2022. Quarterly Hogs and Pigs. <http://www.usda.gov> (Accessed June 23, 2022)

from 0.9 to 3.7 times the NRC (2012) requirement estimates and on average were 104% of the values obtained by Flohr et al. (2016). Some respondents reported using a form of organic mineral source for Cu (13), Mn (13), Se (23), and Zn (12).

In gilt development diets (Table 10), fat soluble vitamins ranged from 1.7 to 7.1 times the NRC (2012) requirement estimates, and on average were 112% of the values obtained by Flohr et al. (2016). Thirteen systems reported using 25-hydroxyvitamin-D₃ as a source of vitamin D and 8 of the 36 producers specified natural vitamin E as the only source or as a percentage of the added vitamin E. Water soluble vitamins ranged from 0.4 to 4.2 times the NRC (2012) requirement estimates and on average, 103% the values obtained by Flohr et al. (2016). Trace minerals ranged from 1.2 to 4.3 times the NRC (2012) requirement estimates and on average were 108% of the values obtained by Flohr et al. (2016). Many respondents reported using a form of organic mineral source for Cu (12), Mn (11), Se (22), and Zn (11).

Boar diets (Table 11) were provided by 21 of the producers and fat soluble vitamins ranged from 2.4 to 13.6 times the NRC (2012) requirement estimates, and were on average 123% of the values obtained by Flohr et al. (2016). Eight systems reported using 25-hydroxyvitamin-D₃ as a source of vitamin D, and 5 of the 21 producers specified natural vitamin E as only source or as a percentage of the added vitamin E. Water soluble vitamins ranged from 0.4 to 4.7 times the NRC (2012) requirement estimates and on average were 103% of the values obtained by Flohr et al. (2016). Trace minerals ranged from 1 to 4.6 times the NRC (2012) requirement estimates and on average were 102% of the values obtained by Flohr et al. (2016). Many respondents reported using a form of organic mineral source for Cu (9), Mn (11), Se (17), and Zn (9).

In conclusion, this survey updated the U.S. current inclusion levels of vitamins and trace minerals in pig diets, and it can be used as an industry benchmark. Different herd health status and vitamin and trace mineral sources, and diet formulation philosophy with a margin-of-safety mindset are reflected in the variation found in vitamin and trace mineral concentrations observed in all production phases. Compared to Flohr et al. (2016), this survey captured a larger representation of the U.S. swine industry and the difference in respondents probably reflects many of the changes when comparing both surveys. In addition, comparisons to the most recent NRC (2012) requirement estimates highlight the necessity of future research to better understand vitamin and trace mineral requirements in swine diets.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Added vitamin and trace mineral concentrations in phase 1 nursery diets (weaning to 15 lb)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	10,878	9,418	4.28	2,975	3,750	8,186	9,922	11,999	15,400
D, IU/kg	36	2,397	2,601	11.8	1,605	1,389	1,653	2,094	3,000	10,494
E, IU/kg	36	93.4	78.9	4.93	37.5	20.0	47.4	75.0	101.4	198.3
K, mg/kg	36	3.74	3.88	7.76	2.16	1.25	3.12	3.31	4.40	14.49
Thiamin, mg/kg	24	8.25	7.50	5.00	10.5	0.91	2.17	3.12	6.25	35.0
Riboflavin, mg/kg	36	12.5	10.6	2.65	6.01	5.51	8.27	8.81	9.92	30.1
Niacin, mg/kg	36	50.7	51.6	1.72	13.2	24.8	44.9	49.6	52.5	101.9
Pantothenic acid, mg/kg	36	36.6	34.1	2.84	11.4	22.0	27.5	29.4	36.2	83.0
Pyridoxine, mg/kg	28	7.38	5.75	0.82	5.27	0.20	2.73	4.37	6.69	20.0
B ₁₂ , µg/kg	36	40.8	38.9	1.94	7.70	27.4	33.1	36.9	44.1	55.1
Biotin, mg/kg	28	0.31	0.22	2.72	0.12	0.04	0.11	0.22	0.27	0.65
Folic acid, mg/kg	28	5.32	3.80	12.7	6.01	0.44	1.04	1.32	2.21	20.6
Choline, mg/kg	27	372.3	336.0	0.56	217.5	96.0	178.6	224.0	457.5	919.6
C, ⁴ mg/kg	1	209.5	209.5	---	---	---	---	---	---	---
Carnitine, ⁴ mg/kg	1	9.92	9.92	---	---	---	---	---	---	---
Trace minerals										
Copper, mg/kg	36	99.6	96.5	16.1	80.6	11.6	16.5	98.5	162.7	247.6
Manganese, mg/kg	36	38.1	38.5	9.63	8.15	20.0	33.1	36.8	45.0	55.0
Selenium, mg/kg	36	0.30	0.30	1.00	0.01	0.27	0.30	0.30	0.30	0.30
Zinc, mg/kg	36	2,873	2,798	27.9	792.4	110.1	2,884	2,993	3,080	4,080
Iodine, mg/kg	36	0.59	0.55	3.92	0.27	0.23	0.32	0.50	0.70	1.35
Iron, mg/kg	36	96.9	113.1	1.13	22.9	45.0	100.0	110.1	121.2	165.7
Chromium, ⁴ mg/kg	13	0.20	0.18	---	0.05	0.04	0.20	0.20	0.20	0.21
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,245,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 2. Added vitamin and trace mineral concentrations in phase 2 nursery diets (15 to 25 lb)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	10,305	8,625	3.92	3,234	3,036	5,305	9,369	11,025	15,400
D, IU/kg	36	2,273	2,460	11.2	1,664	551.2	1,653	1,955	2,905	10,494
E, IU/kg	36	85.8	70.6	4.41	34.3	11.0	44.1	66.1	90.9	158.9
K, mg/kg	36	3.55	3.75	7.50	2.15	0.65	2.98	3.31	4.34	14.5
Thiamin, mg/kg	23	3.76	3.94	3.94	2.24	0.91	2.13	3.24	5.86	9.92
Riboflavin, mg/kg	36	8.65	8.20	2.34	1.69	3.31	7.38	8.27	8.87	12.0
Niacin, mg/kg	36	47.5	49.0	1.63	11.9	16.5	42.2	49.6	50.6	82.7
Pantothenic acid, mg/kg	36	34.2	31.7	3.17	10.4	10.7	27.2	27.6	34.7	79.3
Pyridoxine, mg/kg	25	5.55	4.55	0.65	2.17	0.88	2.76	4.32	6.95	8.31
B ₁₂ , µg/kg	36	38.1	36.4	2.08	7.80	16.5	33.1	33.1	39.8	55.1
Biotin, mg/kg	25	0.32	0.22	4.44	0.12	0.06	0.11	0.22	0.28	0.65
Folic acid, mg/kg	25	2.11	1.75	5.83	1.59	0.33	1.00	1.32	1.76	8.27
Choline, mg/kg	22	329.4	283.3	0.57	207.0	41.3	138.1	224.0	364.0	919.6
C, ⁴ mg/kg	1	209.5	209.5	---	---	---	---	---	---	---
Trace minerals										
Copper, mg/kg	36	94.7	90.5	15.1	78.9	6.10	16.5	61.9	160.5	247.6
Manganese, mg/kg	36	36.3	37.0	9.26	8.92	15.3	32.3	34.4	44.1	55.00
Selenium, mg/kg	36	0.30	0.30	0.99	0.01	0.25	0.30	0.30	0.30	0.30
Zinc, mg/kg	36	1,885	2,165	21.6	998.3	108.0	1,995	2,482	2,990	3,110
Iodine, mg/kg	36	0.56	0.52	3.75	0.25	0.23	0.30	0.49	0.70	1.23
Iron, mg/kg	36	94.4	111.5	1.11	22.4	45.0	100.0	110.0	120.0	165.3
Chromium, ⁴ mg/kg	11	0.19	0.18	---	0.05	0.05	0.20	0.20	0.20	0.20
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,245,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 3. Added vitamin and trace mineral concentrations in phase 3 nursery diets (25 to 50 lb)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	6,903	5,951	3.40	2,645	1,951	3,722	5,457	7,788	12,472
D, IU/kg	36	1,608	1,681	8.41	644.3	882.0	1,102	1,653	1,984	4,160
E, IU/kg	36	57.6	44.1	4.01	25.9	11.0	30.0	44.1	48.1	125.0
K, mg/kg	36	3.07	3.14	6.29	1.42	0.53	2.56	3.25	3.53	8.69
Thiamin, mg/kg	11	2.87	2.75	2.75	1.63	0.45	2.07	2.21	3.21	5.79
Riboflavin, mg/kg	36	6.78	6.62	2.21	1.89	3.30	4.9	6.81	8.27	10.8
Niacin, mg/kg	36	36.4	40.2	1.34	10.7	16.5	30.0	42.9	49.6	66.1
Pantothenic acid, mg/kg	36	24.8	23.6	2.62	7.03	10.6	17.9	24.4	27.5	37.4
Pyridoxine, mg/kg	12	4.82	3.42	1.14	2.24	0.88	1.28	3.06	5.00	7.00
B ₁₂ , µg/kg	36	29.6	29.6	1.97	9.10	15.6	22.3	30.4	33.1	50.2
Biotin, mg/kg	13	0.40	0.22	4.33	0.15	0.09	0.11	0.20	0.22	0.65
Folic acid, mg/kg	14	2.53	1.22	4.07	1.23	0.04	0.34	0.75	1.60	4.49
Choline, mg/kg	5	240.5	286.7	0.72	170.4	48.0	220.5	225.0	390.0	550.0
Trace minerals										
Copper, mg/kg	36	95.9	107.5	21.5	86.9	6.10	16.2	125.0	165.2	268.5
Manganese, mg/kg	36	30.7	31.4	10.5	7.03	11.6	29.7	30.0	33.1	55.0
Selenium, mg/kg	36	0.30	0.30	1.19	0.01	0.27	0.30	0.30	0.30	0.31
Zinc, mg/kg	36	290.3	316.6	3.96	445.5	75.0	100.0	110.2	158.2	1,910
Iodine, mg/kg	36	0.44	0.44	3.12	0.23	0.21	0.30	0.33	0.51	1.17
Iron, mg/kg	36	84.5	103.2	1.03	34.9	45.0	79.0	100.0	110.2	238.7
Chromium, ⁴ mg/kg	4	0.20	0.17	---	0.05	0.08	0.17	0.20	0.20	0.20
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,245,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 4. Percentage of participants using alternative vitamin and trace mineral sources

Item	Nursery			Finishing			Gilt development	Breeding herd		
	Wean to 15 lb	15 to 25 lb	25 to 50 lb	50 to 120 lb	120 to 220 lb	220 lb to market		Gestation	Lactation	Boar
Participants	36	36	36	37	37	37	32	36	36	21
Vitamins										
D (25-OH-D ₃)	31%	28%	14%	8%	8%	8%	41%	36%	36%	38%
E (natural, d- α -tocopherol)	6%	8%	11%	11%	11%	11%	25%	22%	22%	24%
Trace minerals ¹										
Copper	43%	40%	37%	25%	22%	19%	47%	39%	39%	56%
Manganese	31%	31%	11%	6%	6%	6%	34%	36%	36%	61%
Selenium	50%	43%	29%	8%	8%	8%	66%	61%	61%	89%
Zinc	26%	23%	11%	8%	8%	8%	34%	33%	33%	50%

¹Percentage of producers and nutrition suppliers that supplement partial or complete trace mineral concentrations from organic or chelated sources.

Table 5. Added vitamin and trace mineral concentrations in early-finishing diets (50 to 120 lb)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	37	4,280	3,981	3.06	1,536	1,951	2,517	3,528	5,292	7,055
D, IU/kg	37	1,167	1,208	8.06	462.5	487.8	992.3	1,087	1,322	2,695
E, IU/kg	37	35.5	29.4	2.68	11.8	11.0	24.2	26.5	33.1	67.5
K, mg/kg	37	1.97	2.17	4.35	1.34	0.51	1.52	1.98	2.57	8.69
Riboflavin, mg/kg	37	5.03	4.92	1.97	0.98	3.30	4.50	4.96	5.44	7.20
Niacin, mg/kg	37	30.1	31.2	1.04	7.08	16.5	27.5	29.9	33.1	49.6
Pantothenic acid, mg/kg	37	18.9	16.9	2.11	3.60	10.6	15.1	16.5	18.9	24.9
B ₁₂ , µg/kg	37	22.8	21.7	2.17	4.20	15.4	19.8	21.6	23.1	33.1
Biotin, mg/kg	1	0.10	0.10	2.00	---	---	---	---	---	---
Thiamin, mg/kg	3	1.30	3.21	3.21	1.65	1.00	2.34	3.68	4.32	4.96
Folic acid, mg/kg	2	0.46	0.26	0.86	0.24	0.02	0.14	0.26	0.38	0.50
Pyridoxine, mg/kg	2	1.99	1.95	1.95	0.05	1.90	1.92	1.95	1.97	2.00
Trace minerals										
Copper, mg/kg	37	76.9	75.0	18.7	67.2	5.00	14.9	16.5	142.5	200.0
Manganese, mg/kg	37	26.0	28.1	14.0	6.70	9.92	25.0	30.0	31.4	40.1
Selenium, mg/kg	37	0.30	0.29	1.45	0.03	0.11	0.30	0.30	0.30	0.31
Zinc, mg/kg	37	106.4	102.2	1.70	19.1	39.9	100.0	102.9	110.1	150.0
Iodine, mg/kg	37	0.46	0.37	2.67	0.20	0.11	0.27	0.30	0.40	1.02
Iron, mg/kg	37	78.9	90.1	1.50	21.6	39.9	75.0	100.0	108.4	134.4
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,382,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 6. Added vitamin and trace mineral concentrations in mid-finisher diets (120 to 220 lb)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	37	3,870	3,394	2.61	1,399	1,500	2,304	2,998	4,116	6,615
D, IU/kg	37	1,061	1,045	6.97	448.6	487.7	826.9	992.3	1,085	2,737
E, IU/kg	37	33.3	25.7	2.34	11.7	5.51	19.8	23.0	30.8	59.8
K, mg/kg	37	1.79	1.89	3.79	1.34	0.51	1.20	1.65	2.06	8.69
Riboflavin, mg/kg	37	4.60	4.22	2.11	0.99	1.65	3.53	4.13	4.95	6.39
Niacin, mg/kg	37	27.7	26.9	0.90	6.61	8.27	22.4	26.9	30.0	44.1
Pantothenic acid, mg/kg	37	16.6	14.4	2.06	3.67	5.37	12.4	13.8	17.6	24.9
B ₁₂ , µg/kg	37	20.9	18.6	3.73	4.55	8.27	15.6	18.2	21.4	29.9
Biotin, mg/kg	1	0.10	0.10	2.00	---	---	---	---	---	---
Thiamin, mg/kg	3	1.20	2.49	2.49	1.13	1.00	1.88	2.76	3.24	3.72
Folic acid, mg/kg	2	0.46	0.26	0.86	0.24	0.02	0.14	0.26	0.38	0.50
Pyridoxine, mg/kg	2	1.98	1.84	1.84	0.16	1.68	1.76	1.84	1.92	2.00
Trace minerals										
Copper, mg/kg	37	50.5	46.5	14.3	58.9	3.05	11.0	13.3	65.0	172.0
Manganese, mg/kg	37	24.0	24.8	12.4	7.19	7.44	22.0	25.3	29.6	40.1
Selenium, mg/kg	37	0.27	0.26	1.71	0.05	0.07	0.22	0.27	0.30	0.30
Zinc, mg/kg	37	98.1	89.1	1.78	20.2	26.6	82.6	90.0	100.0	131.2
Iodine, mg/kg	37	0.43	0.33	2.36	0.21	0.07	0.21	0.25	0.37	1.02
Iron, mg/kg	37	71.7	77.7	1.73	19.2	26.6	66.6	80.0	91.8	110.1
Cobalt, ⁴ mg/kg	1	0.36	0.36	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,382,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 7. Added vitamin and trace mineral concentrations in late-finishing diets (220 lb to market)

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	37	3,378	2,874	2.21	1,314	1,125	1,874	2,480	3,528	6,615
D, IU/kg	37	932.1	893.6	5.96	442.9	344.5	661.5	805.6	997.9	2,778
E, IU/kg	37	29.9	21.8	1.98	11.22	5.51	14.5	19.5	25.8	59.8
K, mg/kg	37	1.60	1.65	3.30	1.37	0.38	0.99	1.32	1.98	8.69
Riboflavin, mg/kg	37	4.06	3.58	1.79	1.10	1.65	2.65	3.31	4.20	6.17
Niacin, mg/kg	37	24.6	22.8	0.76	6.99	8.27	19.8	22.5	27.0	44.1
Pantothenic acid, mg/kg	37	14.7	12.1	1.73	3.75	5.37	9.10	11.0	14.2	24.9
B ₁₂ , µg/kg	37	18.6	15.8	3.17	5.09	8.27	12.5	13.7	19.8	29.9
Biotin, mg/kg	1	0.10	0.10	2.00	---	---	---	---	---	---
Thiamin, mg/kg	3	1.15	2.17	2.17	0.94	1.00	1.60	2.21	2.76	3.31
Folic acid, mg/kg	2	0.46	0.26	0.86	0.24	0.02	0.14	0.26	0.38	0.50
Pyridoxine, mg/kg	2	1.97	1.75	1.75	0.25	1.50	1.62	1.75	1.87	2.00
Trace minerals										
Copper, mg/kg	37	45.3	36.7	12.2	54.5	3.05	8.25	9.01	15.0	172.0
Manganese, mg/kg	37	20.8	20.5	10.2	7.22	6.00	16.5	18.7	25.0	40.0
Selenium, mg/kg	37	0.24	0.21	1.43	0.06	0.05	0.15	0.23	0.27	0.30
Zinc, mg/kg	37	85.3	73.9	1.48	21.1	19.9	57.9	75.0	88.9	120.2
Iodine, mg/kg	37	0.39	0.28	2.02	0.20	0.05	0.17	0.20	0.34	1.00
Iron, mg/kg	37	61.3	64.5	1.61	17.5	19.9	55.0	63.0	77.1	100.0
Cobalt, ⁴ mg/kg	1	0.31	0.31	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,382,700 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 8. Added vitamin and trace mineral concentrations in gestation diets

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	10,511	9,646	2.41	1,549	5,511	8,821	9,920	10,856	12,472
D, IU/kg	36	2,276	2,367	2.96	805.9	1,500	1,733	2,204	2,537	4,499
E, IU/kg	35	95.5	84.4	1.92	22.9	44.1	66.1	79.4	94.5	132.3
K, mg/kg	36	3.87	3.96	7.92	2.10	1.41	3.00	3.75	4.42	14.5
Thiamin, mg/kg	28	2.57	2.74	2.74	1.94	0.25	2.04	2.21	3.00	9.92
Riboflavin, mg/kg	36	9.01	8.58	2.29	1.26	5.51	7.88	8.27	9.92	10.8
Niacin, mg/kg	36	44.9	45.3	4.53	9.34	22.0	39.9	44.1	49.6	82.7
Pantothenic acid, mg/kg	36	31.8	29.8	2.49	5.47	20.0	26.4	28.1	33.0	45.2
Pyridoxine, mg/kg	36	4.08	3.11	3.11	1.65	0.25	1.98	3.31	4.00	8.17
B ₁₂ , µg/kg	36	37.9	36.5	2.44	5.70	20.0	33.1	37.4	39.7	55.1
Biotin, mg/kg	36	0.37	0.29	1.43	0.10	0.09	0.22	0.25	0.33	0.65
Folic acid, mg/kg	35	2.65	2.11	1.62	1.32	0.88	1.32	1.74	2.21	8.27
Choline, mg/kg	33	533.3	576.3	0.46	115.3	300.0	515.0	584.3	661.2	778.4
C, ⁴ mg/kg	1	209.5	209.5	---	---	---	---	---	---	---
Trace minerals										
Copper, mg/kg	36	16.6	17.6	1.76	2.83	11.6	15.0	16.5	20.0	25.0
Manganese, mg/kg	36	42.3	43.4	1.74	9.57	20.0	35.3	50.0	50.0	60.0
Selenium, mg/kg	36	0.30	0.30	2.00	0.01	0.27	0.30	0.30	0.30	0.31
Zinc, mg/kg	36	125.0	127.8	1.28	34.9	60.0	111.9	125.0	125.2	302.0
Iodine, mg/kg	36	0.53	0.52	3.73	0.26	0.23	0.35	0.50	0.63	1.26
Iron, mg/kg	36	94.4	109.7	1.37	20.5	45.0	100.0	105.0	118.5	165.0
Chromium, ⁴ mg/kg	21	0.20	0.19	---	0.03	0.08	0.20	0.20	0.20	0.20
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---
Carnitine, ⁴ mg/kg	1	19.8	19.8	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,370,100 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 9. Added vitamin and trace mineral concentrations in lactation diets

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	36	10,511	9,646	4.82	1,549	5,511	8,821	9,920	10,856	12,472
D, IU/kg	36	2,276	2,367	2.96	805.2	1,500	1,733	2,204	2,537	4,499
E, IU/kg	35	95.5	84.4	1.92	22.9	44.1	66.1	79.4	94.5	132.3
K, mg/kg	36	3.87	3.96	7.91	2.10	1.42	3.00	3.75	4.42	14.5
Thiamin, mg/kg	28	2.57	2.74	2.74	1.94	0.25	2.04	2.21	3.00	9.98
Riboflavin, mg/kg	36	9.01	8.58	2.29	1.26	5.51	7.88	8.27	9.92	10.8
Niacin, mg/kg	36	44.9	45.3	4.53	9.34	22.0	39.9	44.1	49.6	82.7
Pantothenic acid, mg/kg	36	31.8	29.8	2.49	5.47	20.0	26.4	28.1	33.1	45.2
Pyridoxine, mg/kg	36	4.08	3.11	3.11	1.65	0.25	1.98	3.31	4.00	8.17
B ₁₂ , µg/kg	36	37.9	36.5	2.44	5.70	20.0	33.1	37.4	39.7	55.1
Biotin, mg/kg	36	0.37	0.29	1.43	0.10	0.09	0.22	0.25	0.33	0.65
Folic acid, mg/kg	35	2.65	2.11	1.62	1.32	0.88	1.32	1.74	2.21	8.27
Choline, mg/kg	33	523.2	566.1	0.57	115.1	300.0	500.1	550.0	641.8	778.4
C, ⁴ mg/kg	1	209.5	209.5	---	---	---	---	---	---	---
Trace minerals										
Copper, mg/kg	36	16.7	17.6	0.88	2.83	11.6	15.0	16.5	20.0	25.0
Manganese, mg/kg	36	42.1	43.0	1.72	9.38	20.0	35.3	49.7	50.0	60.0
Selenium, mg/kg	36	0.30	0.30	2.00	0.01	0.27	0.30	0.30	0.30	0.31
Zinc, mg/kg	36	124.0	125.3	1.25	24.0	60.0	111.9	125.0	125.2	214.0
Iodine, mg/kg	36	0.53	0.52	3.73	0.26	0.23	0.35	0.50	0.63	1.26
Iron, mg/kg	36	94.5	109.7	1.37	20.5	45.0	100.0	105.0	118.5	165.0
Chromium, ⁴ mg/kg	21	0.20	0.19	---	0.03	0.08	0.20	0.20	0.20	0.20
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---
Carnitine, ⁴ mg/kg	1	19.8	19.8	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,370,100 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 10. Added vitamin and trace mineral concentrations in gilt development diets

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	32	9,481	8,497	2.12	2,243	2,066	7,206	8,352	9,922	12,472
D, IU/kg	32	2,102	2,191	2.74	965.1	688.9	1,653	1,984	2,429	4,499
E, IU/kg	32	88.7	73.3	1.92	26.9	22.0	52.7	67.5	88.0	132.3
K, mg/kg	32	3.54	3.53	7.05	1.75	1.47	2.20	3.30	4.41	11.0
Thiamin, mg/kg	24	2.30	2.31	2.31	1.11	0.40	1.76	2.20	2.69	5.10
Riboflavin, mg/kg	32	8.27	7.72	2.06	1.88	3.86	5.93	7.94	9.92	10.8
Niacin, mg/kg	32	41.6	41.5	4.15	9.60	27.5	34.5	41.9	44.9	78.8
Pantothenic acid, mg/kg	32	28.9	26.5	2.21	6.65	13.9	21.0	26.4	33.0	38.8
Pyridoxine, mg/kg	30	3.68	2.80	2.80	1.38	0.45	1.66	3.03	3.56	5.99
B ₁₂ , µg/kg	32	34.7	32.7	2.18	7.16	16.5	27.6	33.1	37.7	46.3
Biotin, mg/kg	30	0.35	0.26	1.30	0.12	0.07	0.20	0.23	0.33	0.65
Folic acid, mg/kg	30	2.39	1.91	1.47	1.48	0.55	1.16	1.39	1.98	8.27
Choline, mg/kg	27	431.6	446.9	0.36	258.8	100.0	267.8	420.0	550.0	1,471
C, ⁴ mg/kg	1	209.5	209.5	---	---	---	---	---	---	---
Trace minerals										
Copper, mg/kg	32	39.2	42.6	4.26	47.8	11.6	15.0	16.0	58.1	162.0
Manganese, mg/kg	32	38.4	38.3	1.53	11.0	8.27	30.0	40.0	50.0	51.2
Selenium, mg/kg	32	0.28	0.28	1.88	0.03	0.20	0.25	0.30	0.30	0.31
Zinc, mg/kg	32	125.9	125.5	1.25	45.0	60.0	107.2	122.0	125.0	325.0
Iodine, mg/kg	32	0.48	0.48	3.45	0.24	0.21	0.34	0.42	0.56	1.20
Iron, mg/kg	32	85.4	99.1	1.24	21.1	45.0	89.1	100.0	110.0	149.8
Chromium, ⁴ mg/kg	19	0.17	0.15	---	0.05	0.07	0.10	0.20	0.20	0.20
Cobalt, ⁴ mg/kg	1	0.39	0.39	---	---	---	---	---	---	---

¹Respondents who added the nutrient to the diet from the 4,182,600 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.

Table 11. Added vitamin and trace mineral concentrations in boar diets

	Count, n ¹	Weighted average ²	Average	Ratio to NRC ³	Standard deviation	Low	25%	Median	75%	High
Vitamins										
A, IU/kg	21	11,193	10,410	2.60	1,644	5,733	9,458	9,922	12,000	13,230
D, IU/kg	21	2,398	2,710	13.5	885.9	1,653	2,077	2,365	2,873	4,499
E, IU/kg	21	118.4	104.4	2.37	34.6	44.1	77.3	103.4	126.0	173.3
K, mg/kg	21	3.93	4.12	8.25	2.74	1.32	2.20	4.41	4.74	14.5
Thiamin, mg/kg	20	2.58	2.53	2.53	1.50	0.25	2.02	2.21	2.99	5.95
Riboflavin, mg/kg	21	9.25	8.94	2.38	1.36	7.05	7.72	8.82	9.92	12.0
Niacin, mg/kg	21	46.1	46.4	4.65	6.52	39.4	41.9	44.1	49.6	65.0
Pantothenic acid, mg/kg	21	32.9	30.9	2.58	6.18	20.0	27.4	30.3	33.1	45.2
Pyridoxine, mg/kg	21	4.78	4.05	4.05	2.00	0.21	2.76	3.97	4.41	8.85
B ₁₂ , µg/kg	21	40.5	39.6	2.64	11.2	20.0	33.7	38.6	39.7	81.0
Biotin, mg/kg	21	0.47	0.38	1.91	0.14	0.22	0.23	0.36	0.44	0.65
Folic acid, mg/kg	21	3.04	2.47	1.90	1.59	1.10	1.65	1.93	2.43	8.27
Choline, mg/kg	16	455.7	534.0	0.43	155.8	250.0	486.7	523.5	629.3	908.5
C, ⁴ mg/kg	4	192.3	342.3	---	314.3	137.8	137.8	173.6	378.2	884.3
Trace minerals										
Copper, mg/kg	21	17.5	19.5	3.91	6.91	11.6	15.0	17.0	20.0	43.2
Manganese, mg/kg	21	47.9	55.1	2.76	27.9	20.0	40.0	50.0	59.4	153.6
Selenium, mg/kg	21	0.30	0.30	1.00	0.00	0.28	0.30	0.30	0.30	0.30
Zinc, mg/kg	21	138.7	141.8	2.84	39.2	60.0	125.0	125.7	157.8	256.0
Iodine, mg/kg	21	0.59	0.64	4.57	0.25	0.30	0.50	0.50	0.70	1.20
Iron, mg/kg	21	88.2	103.6	1.29	16.9	45.0	100.0	100.0	110.0	140.0
Chromium, ⁴ mg/kg	14	0.20	0.20	---	0.01	0.19	0.20	0.20	0.20	0.20
Carnitine, ⁴ mg/kg	2	220.0	220.0	---	---	220.0	220.0	220.0	220.0	220.0

¹Respondents who added the nutrient to the diet from the 3,236,400 sows surveyed. Reported values are on a complete-feed basis.

²Sum of the products of the inclusion level multiplied by the size of the production (# of sows), divided by the total number of sows from the participants who provided added levels for that nutrient.

³National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>.

⁴NRC does not provide a recommendation for the level of the nutrient.