

CHAPTER 7

Vitamin and Trace Mineral Supplementation for Poultry and Swine

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INTRODUCTION

The vitamin and trace mineral requirements of poultry and swine are difficult to estimate because there are a large number of variables that can influence experimental results, including feed intake, genetics, physiological state, stress, and health challenges.

In this chapter, supplementation of vitamin and trace mineral levels in poultry and swine diets is suggested, not nutritional requirements. Some articles used here present optimal levels of supplementation based on the animal's health (immunity, antioxidant capacity, etc.), which indirectly affects performance. Vitamin and trace mineral supplementation levels in IU or mg/kg of feed were based on articles, breeding company manuals, and industry recommendations.

Taking into account the improved efficiency for production (meat, piglets, eggs, etc.) of current genetics lines, it is highlighted that feed intake capacity may be limiting the production potential. This fact draws attention to the need to adjust the levels of vitamins and trace minerals so that poultry and swine express their maximum genetic potential. Furthermore, variations in ingredient concentration, bioavailability, and the degradation of vitamins and trace minerals resulting from storage or feed manufacturing conditions, among others, must be considered in each production system.

With the advancement of knowledge about minerals from organic sources and the availability of new supplements for animals, nutritionists have the possibility of choosing to use inorganic or organic sources of trace minerals. An average equivalency factor, calculated from published papers, was used to calculate organic mineral supplementation in mg/kg of weight gain.

The recommendation of vitamins and trace minerals (IU or mg/kg) supplementation to broiler chicken diets, in the different growing phases was made using a proportion ratio, considering the level of growing phase I (17 to 27 days) = 1.0, with the proportion of the pre-starter phase being 1.3 and that of the finisher phase being 0.7. The recommended amount, in IU or mg/kg of

feed, for each phase was calculated with the aim of keeping the intake of vitamins and minerals per kg of weight gain constant.

The amount of trace minerals for laying birds and broiler breeders was calculated as 1.1 and 1.2 times (ratio), respectively, to that recommended for replacement pullet birds in the breeding phase.

A ratio was also established in the recommendations for vitamins and trace minerals, in IU or mg/kg of feed, for growing swine. Grower phase I (63 to 91 days) was used as a reference = 1, while for the other phases, ratios ranging from 1.6 for the pre-starter phase and up to 0.6 for the finisher phase II were stipulated. The recommended proportion in each phase aims to maintain a constant intake of vitamins and minerals per kg of weight gain.

For breeding swine, the trace mineral recommendation was calculated following the ratio of 1.3 to that used for growing swine phase I.

The content and relative bioavailability of inorganic and organic sources of trace minerals for poultry and swine are presented in Table 7.08. A literature review was carried out for each mineral, from which the average bioavailability was obtained, presented as a percentage relative to the standard source. In theory, organic trace minerals are more available to the animal than inorganic ones. However, it should be noted that there are several types of organic trace minerals, some with greater bioavailability than others, depending on the Chelation Index (Q_i) and the Stability Constant (K_s) between the mineral and the ligand. Trace minerals with high Q_i and K_s have high bioavailability coefficients and performance.

Table 7.01 - Vitamin Supplementation Levels for Broilers

Phase	Pre Starter	Starter	Grower I & II		Finisher I & II	
Age (days)	0-8	8-17	17-27	27-35	35-43	43-49
Weight Range (kg)	0.05-0.24	0.24-0.68	0.68-1.49	1.49-2.29	2.29-3.11	3.11-3.70
Weight Gain (g/day)	19.4	50	86.3	104.4	103.7	93.8
Feed Intake (g/day)	23.2	64.6	131.5	185.1	203.9	197.9
Vitamins	UI or mg/kg of Gain	UI or mg/day				
Vitamin A, UI	16493	320	825	1423	1722	1710
Vitamin D3, UI	4039	78	202	349	422	419
Vitamin E, UI	61.9	1.201	3.094	5.341	6.461	6.417
Vitamin K3, mg	3.48	0.068	0.174	0.300	0.364	0.361
Vitamin B1, mg	4.10	0.080	0.205	0.354	0.428	0.425
Vitamin B2, mg	10.2	0.198	0.510	0.880	1.065	1.058
Vitamin B6, mg	5.73	0.111	0.287	0.495	0.599	0.595
Vitamin B12, mg	0.026	0.0005	0.0013	0.0022	0.0027	0.0024
Pantothenic Acid, mg	21.5	0.417	1.075	1.855	2.245	2.230
Nicotinic Acid, mg	68.3	1.325	3.416	5.896	7.132	7.084
Folic Acid, mg	1.66	0.032	0.083	0.143	0.173	0.172
Biotin, mg	0.159	0.0031	0.0079	0.0137	0.0166	0.0165
Choline, mg	713	13.83	35.65	61.53	74.44	73.94
UI or mg/kg Feed						
Vitamin A, UI	13791	12765	10824	9302	8388	7817
Vitamin D3, UI	3378	3126	2651	2278	2054	1915
Vitamin E, UI	51.7	47.9	40.6	34.9	31.5	29.3
Vitamin K3, mg	2.91	2.69	2.29	1.96	1.77	1.65
Vitamin B1, mg	3.43	3.17	2.69	2.31	2.09	1.94
Vitamin B2, mg	8.53	7.90	6.70	5.75	5.19	4.84
Vitamin B6, mg	4.79	4.44	3.76	3.23	2.92	2.72
Vitamin B12, mg	0.0217	0.0201	0.0171	0.0147	0.0132	0.0123
Pantothenic Acid, mg	17.98	16.64	14.11	12.13	10.93	10.19
Nicotinic Acid, mg	57.1	52.9	44.8	38.5	34.7	32.4
Folic Acid, mg	1.389	1.286	1.090	0.937	0.845	0.787
Biotin, mg	0.1327	0.1228	0.1041	0.0895	0.0807	0.0752
Choline, mg	596	552	468	402	363	338
Ratio	1.27	1.18	1.00	0.86	0.77	0.72

Table 7.02 - Vitamin Supplementation Levels for Replacement Pullets, Layers, and Breeders

Type Phase	Replacement Pullets		Layers	Breeders
	Starter ¹	Grower ¹		
Egg Mass (g/day)	-	-	60	-
Feed Intake (g/day)	-	-	100	-
Vitamins	UI or mg/kg Egg Mass		UI or mg/day	
Vitamin A, UI	15571		934	
Vitamin D3, UI	4167		250	
Vitamin E, UI	21.2		1.270	
Vitamin K3, mg	3.76		0.226	
Vitamin B1, mg	3.15		0.189	
Vitamin B2, mg	8.00		0.480	
Vitamin B6, mg	3.66		0.220	
Vitamin B12, mg	0.0283		0.0017	
Pantothenic Acid, mg	19.2		1.150	
Nicotinic Acid, mg	50.0		3.000	
Folic Acid, mg	1.10		0.066	
Biotin, mg	0.1000		0.0060	
Choline, mg	473		28.4	
	UI or mg/kg Feed			
Vitamin A, UI	12765	10824	9343	11500
Vitamin D3, UI	3126	2651	2500	3150
Vitamin E, UI	47.9	40.6	13	55.0
Vitamin K3, mg	2.69	2.29	2.26	3.20
Vitamin B1, mg	3.17	2.69	1.89	2.80
Vitamin B2, mg	7.90	6.70	4.80	8.50
Vitamin B6, mg	4.44	3.76	2.20	3.00
Vitamin B12, mg	0.0201	0.0171	0.0170	0.0270
Pantothenic Acid, mg	16.64	14.11	11.50	15.00
Nicotinic Acid, mg	52.9	44.8	30.0	35.0
Folic Acid, mg	1.286	1.090	0.660	1.100
Biotin, mg	0.123	0.104	0.060	0.120
Choline, mg	552	468	284	450
Ratio	1.18	1.00	-	-

¹For replacement pullets, vitamin supplementation levels are the same as broilers in the starter and grower I phases (Table 7.01).

Table 7.03 - Trace Mineral Supplementation Levels for Broilers

Phase		Pre Starter	Starter	Grower I & II		Finisher I & II	
Age (days)		0-8	8-17	17-27	27-35	35-43	43-49
Weight Range (kg)		0.05-0.24	0.24-0.68	0.68-1.49	1.49-2.29	2.29-3.11	3.11-3.70
Weight Gain (g/day)		19.4	50	86.3	104.4	103.7	93.8
Feed Intake (g/day)		23.2	64.6	131.5	185.1	203.9	197.9
Trace Minerals	mg/kg of Gain	mg/day					
Inorganic							
Copper	14.45	0.280	0.722	1.247	1.508	1.498	1.355
Iron	69.20	1.342	3.460	5.972	7.224	7.176	6.491
Manganese	101.3	1.965	5.064	8.741	10.574	10.503	9.500
Selenium	0.437	0.008	0.022	0.038	0.046	0.045	0.041
Zinc	94.96	1.842	4.748	8.195	9.914	9.848	8.908
Iodine	1.470	0.029	0.073	0.127	0.153	0.152	0.138
Organic							
Copper	6.50	0.126	0.325	0.561	0.679	0.674	0.610
Iron	31.1	0.604	1.557	2.687	3.251	3.229	2.921
Manganese	45.6	0.884	2.279	3.933	4.758	4.726	4.275
Selenium	0.196	0.004	0.010	0.017	0.021	0.020	0.018
Zinc	42.7	0.829	2.137	3.688	4.461	4.431	4.008
mg/kg Feed							
Inorganic							
Copper		12.08	11.18	9.48	8.15	7.35	6.85
Iron		57.87	53.56	45.41	39.03	35.19	32.80
Manganese		84.69	78.39	66.47	57.13	51.51	48.01
Selenium		0.365	0.338	0.287	0.246	0.222	0.207
Zinc		79.41	73.50	62.32	53.56	48.30	45.01
Iodine		1.229	1.138	0.965	0.829	0.747	0.697
Organic							
Copper		5.44	5.03	4.27	3.67	3.31	3.08
Iron		26.04	24.10	20.44	17.56	15.84	14.76
Manganese		38.11	35.28	29.91	25.71	23.18	21.60
Selenium		0.164	0.152	0.129	0.111	0.100	0.093
Zinc		35.73	33.08	28.05	24.10	21.73	20.25
Ratio		1.27	1.18	1.00	0.86	0.77	0.72

Table 7.04 - Trace Mineral Supplementation Levels for Replacement Pullets, Layers, and Breeders

Type Phase	Replacement Pullets		Layers	Breeders
	Starter ¹	Grower ¹		
Egg mass (g/day)	-	-	60	-
Feed Intake (g/day)	-	-	100	-
Trace Minerals		mg/kg feed		
Inorganic				
Copper	11.18	9.48	10.43	11.38
Iron	53.56	45.41	49.96	54.50
Manganese	78.39	66.47	73.12	79.76
Selenium	0.338	0.287	0.315	0.344
Zinc	73.50	62.32	68.55	74.79
Iodine	1.138	0.965	1.061	1.157
Organic				
Copper	5.03	4.27	4.69	5.12
Iron	24.10	20.44	22.48	24.52
Manganese	35.28	29.91	32.90	35.89
Selenium	0.152	0.129	0.142	0.155
Zinc	33.08	28.05	30.85	33.65
Ratio	1.18	1.00	1.10	1.20

¹For replacement pullets, trace mineral supplementation levels are the same as broilers in the starter and grower I phases, respectively (Table 7.03).

Table 7.05 - Vitamin Supplementation Levels for Growing Swine

Phase	Pre Starter I & II		Starter	Grower I & II		Finisher I & II	
Age (days)	21 - 35	35 - 49	49 - 63	63 - 91	91 - 119	119 - 147	147 - 175
Weight Range (kg)	6.2 - 8.4	8.4 - 17.9	16 - 26	26 - 47	47 - 74	74 - 103	103 - 131
Average Weight (kg)	8.4	14.2	21.3	36.0	60.9	89.1	117.3
Weight Gain (g/day)	309	454	564	762	953	1024	987
Feed Intake(g/day)	388	631	939	1500	2331	3007	3364

Vitamins	UI or mg/kg of Gain	UI or mg/day					
		Pre Starter I & II	Starter	Grower I & II	Grower I & II	Finisher I & II	Finisher I & II
Vitamin A, UI	14298	4418	6492	8064	10895	13626	14642
Vitamin D3, UI	3498	1081	1588	1973	2665	3333	3582
Vitamin E, UI	93.4	28.9	42.4	52.7	71.2	89.0	95.6
Vitamin K3, mg	6.81	2.10	3.09	3.84	5.19	6.49	6.97
Vitamin B1, mg	2.27	0.70	1.03	1.28	1.73	2.16	2.32
Vitamin B2, mg	8.67	2.68	3.93	4.88	6.60	8.26	8.87
Vitamin B6, mg	4.54	1.40	2.06	2.56	3.46	4.32	4.65
Vitamin B12, mg	0.051	0.016	0.023	0.029	0.039	0.049	0.052
Pantothenic Acid, mg	34.0	10.5	15.5	19.2	25.9	32.4	34.8
Nicotinic Acid, mg	65.0	20.1	29.5	36.7	49.5	61.9	66.6
Folic Acid, mg	0.743	0.230	0.337	0.419	0.566	0.708	0.761
Biotin, mg	0.247	0.076	0.112	0.139	0.188	0.235	0.253
Choline, mg	454	140.2	206.0	256.0	345.8	432.5	464.7

UI or mg/kg Feed							
Vitamin A, UI	11387	10288	8588	7264	5846	4869	4195
Vitamin D3, UI	2786	2517	2101	1777	1430	1191	1026
Vitamin E, UI	74.4	67.2	56.1	47.4	38.2	31.8	27.4
Vitamin K3, mg	5.42	4.89	4.09	3.46	2.78	2.32	1.99
Vitamin B1, mg	1.808	1.633	1.364	1.153	0.928	0.773	0.666
Vitamin B2, mg	6.90	6.23	5.20	4.40	3.54	2.95	2.54
Vitamin B6, mg	3.61	3.26	2.73	2.30	1.85	1.54	1.33
Vitamin B12, mg	0.041	0.037	0.031	0.026	0.021	0.017	0.015
Pantothenic Acid, mg	27.1	24.5	20.4	17.3	13.9	11.6	10.0
Nicotinic Acid, mg	51.8	46.8	39.0	33.0	26.6	22.1	19.1
Folic Acid, mg	0.592	0.535	0.446	0.378	0.304	0.253	0.218
Biotin, mg	0.196	0.178	0.148	0.125	0.101	0.084	0.072
Choline, mg	361.4	326.5	272.6	230.5	185.5	154.5	133.2
Ratio	1.57	1.42	1.18	1.00	0.80	0.67	0.58

Table 7.06 - Trace Mineral Supplementation Levels for Growing Swine

Phase	Pre Starter I & II		Starter	Grower I & II		Finisher I & II		
Age (days)	21 - 35	35- 49	49 - 63	63 - 91	91 - 119	119 - 147	147 - 175	
Weight Range (kg)	6.2 - 8.4	8.4 - 17.9	16 - 26	26 - 47	47 - 74	74 - 103	103 - 131	
Average Weight (kg)	8.4	14.2	21.3	36.0	60.9	89.1	117.3	
Weight Gain (g/day)	309	454	564	762	953	1024	987	
Feed Intake (g/day)	388	631	939	1500	2331	3007	3364	
Trace Minerals	mg / kg of Gain	mg/day						
Inorganic								
Copper	23.0	7.11	10.44	12.97	17.53	21.92	23.55	22.70
Iron	146	45.1	66.3	82.3	111.3	139.1	149.5	144.1
Manganese	70.0	21.6	31.8	39.5	53.3	66.7	71.7	69.1
Selenium	0.630	0.195	0.286	0.355	0.480	0.600	0.645	0.622
Zinc	208	64.3	94.4	117.3	158.5	198.2	213.0	205.3
Iodine	1.73	0.535	0.785	0.976	1.318	1.649	1.772	1.708
Organic								
Copper	10.3	3.20	4.70	5.84	7.89	9.86	10.60	10.22
Iron	65.7	20.3	29.8	37.1	50.1	62.6	67.3	64.8
Manganese	31.5	9.73	14.30	17.77	24.00	30.02	32.26	31.09
Selenium	0.284	0.088	0.129	0.160	0.216	0.270	0.290	0.280
Zinc	93.6	28.9	42.5	52.8	71.3	89.2	95.8	92.4
mg/kg Feed								
Inorganic								
Copper	18.32	16.55	13.81	11.68	9.40	7.83	6.75	
Iron	116.3	105.0	87.7	74.2	59.7	49.7	42.8	
Manganese	55.7	50.4	42.0	35.6	28.6	23.8	20.5	
Selenium	0.502	0.453	0.378	0.320	0.258	0.215	0.185	
Zinc	165.6	149.7	124.9	105.7	85.0	70.8	61.0	
Iodine	1.378	1.245	1.039	0.879	0.707	0.589	0.508	
Organic								
Copper	8.24	7.45	6.22	5.26	4.23	3.52	3.04	
Iron	52.3	47.3	39.5	33.4	26.9	22.4	19.3	
Manganese	25.09	22.66	18.92	16.00	12.88	10.73	9.24	
Selenium	0.226	0.204	0.170	0.144	0.116	0.097	0.083	
Zinc	74.5	67.3	56.2	47.5	38.3	31.9	27.5	
Ratio	1.57	1.42	1.18	1.00	0.80	0.67	0.58	

Table 7.07 - Vitamin and Trace Mineral Supplementation Levels for Swine Breeders

Phase	Swine Breeders
Vitamins	UI or mg/kg Feed
Vitamin A, UI	9927
Vitamin D3, UI	1660
Vitamin E, UI	61.5
Vitamin K3, mg	2.70
Vitamin B1, mg	1.38
Vitamin B2, mg	5.50
Vitamin B6, mg	2.10
Vitamin B12, mg	0.028
Pantothenic Acid, mg	21.8
Nicotinic Acid, mg	31.2
Folic Acid, mg	1.36
Biotin, mg	0.340
Choline, mg	750
Trace Minerals ¹	mg/kg Feed
Inorganic	
Copper	15.2
Iron	96.4
Manganese	46.2
Selenium	0.416
Zinc	137.4
Iodine	1.142
Organic	
Copper	6.84
Iron	43.4
Manganese	20.8
Selenium	0.187
Zinc	61.8
Ratio¹	1.30

¹ Trace minerals recommended ratio of 1.3 relative to the grower phase I - 26 a 47 kg (Table 7.06).

Table 7.08 - Trace Mineral Content and Relative Bioavailability of Inorganic and Organic Sources for Poultry and Swine

Sources	Cu (%)	Relative Bioavailability (%)	
		Broilers (n¹)	Swine (n¹)
Inorganic			
Copper sulfate pentahydrate	25.2	100	100
Copper carbonate	54.6	77 (3)	62 (1)
Copper chloride	64.2	120 (3)	-
Tribasic copper chloride	54.7	100 (3)	97 (1)
Copper hydroxychloride	54.0	112 (3)	-
Copper oxide I	88.8	95 (2)	21 (2)
Copper sulfate monohydrate	34.5	-	-
Organic			
Copper lysine FG²	7.6	99 (1)	-
Lysine copper complex	10.4	117 (4)	112 (1)
Copper methionine complex	20.9	92 (2)	107 (1)
Copper glycinate	24.0	-	146 (1)
Copper propionate	29.0	-	-
Copper proteinate	10.0	101 (4)	114 (1)
Chelate copper amino acid	8.9	109 (2)	-
Chelate copper MHA³	15.0	112 (1)	145 (1)
Sources Fe (%)			
Inorganic			
Ferrous sulfate monohydrate	30.0	100	100
Iron carbonate	43.0	3 (4)	18 (2)
Ferric chloride hexahydrate	20.7	103 (1)	-
Ferric oxide	69.9	10 (2)	-
Ferrous oxide	77.8	-	12 (1)
Ferrous sulfate heptahydrate	20.0	-	-
Organic			
Iron citrate	19.0	86 (2)	183 (5)
Iron amino acid complex	11.1	-	-
Lysine iron complex	11.1	-	-
Iron methionine complex	13.1	104 (2)	168 (2)
Iron - EDTA	13.0	99 (1)	90 (1)
Iron fumarate	32.5	96 (2)	-
Iron glycinate	21.0	-	130 (3)
ferrous gluconate	2.0	94 (2)	-
iron proteinate	13.4	110 (17)	132 (2)
Sources Mn (%)			
Inorganic			
Manganese sulfate monohydrate	30.3	100	100
Manganese carbonate	46.7	34 (2)	-
manganese dioxide	63.1	70 (1)	-
Manganese hydroxychloride	44.0	106 (3)	-
Manganese oxide	56.9	82 (9)	96 (1)
Manganese oxide FG²	58.5	69 (6)	-
Manganese sulfate pentahydrate	22.7	-	-
Organic			
Amino acid manganese chelate	8.1	120 (16)	-
Manganese methionine complex	8.3	107 (8)	-
Manganese glycinate	21.0	125 (1)	124 (1)
Amino acid manganese	7.7	-	-
Manganese methionine FG²	15.7	120 (2)	-
Amino acid manganese chelate	8.1	84 (1)	-
MHA³ manganese chelate	13.0	116 (1)	158 (1)
Manganese propionate	12.0	139 (1)	-
Manganese proteinate	15.5	110 (6)	-

¹ Literature consulted to obtain the average bioavailability value. ² Feed Grade; ³ Methionine hydroxy analogue.

Table 7.08 - Trace Mineral Content and Relative Bioavailability of Inorganic and Organic Sources for Poultry and Swine (cont.)

Sources	I (%)	Relative Bioavailability (%)	
		Broilers (n ¹)	Swine (n ¹)
Inorganic			
Calcium iodate	62.8	-	-
Potassium iodate	59.2	-	-
Copper iodide	66.3	-	-
Potassium iodide	76.0	-	-
Organic			
Ethylenediamine hydroiodide	79.5	-	-
Sources Se (%)			
Inorganic			
Sodium Selenite	45.0	100	100
Sodium selenate	42.0	114 (5)	-
Sodium selenate decahydrate	21.4	-	-
Selenium metal	99.9	83 (4)	-
Calcium selenite	41.4	102 (4)	101 (2)
Organic			
Selenium yeast	0.1-0.3	190 (4)	214 (6)
L-Selenium methionine	4.0	119 (3)	147 (2)
Selenium MHA	2.0	270 (2)	415 (2)
Sources Zn (%)			
Inorganic			
Zinc sulfate heptahydrate	22.2	100	100
Zinc carbonate	54.0	107 (1)	98 (1)
Basic zinc carbonate	58.5	77 (1)	-
Zinc chloride	54.8	-	-
Tetrabasic zinc chloride	62.2	107 (2)	-
Zinc hydroxychloride	54.0	120 (3)	125 (1)
Zinc oxide	72.5	72 (4)	55 (3)
Zinc oxide FG ²	73.4	58 (18)	74 (3)
Zinc Metallic Dust	98.3	67 (1)	-
Zinc sulfate monohydrate	35.0	-	-
Zinc sulfate monohydrate FG ²	35.6	87 (1)	-
Zinc sulfate heptahydrate FG ²	22.0	-	-
Organic			
Zinc amino acid complex	12.0	122 (3)	-
Zinc lysine complex	7.2	106 (1)	60 (4)
Zinc methionine complex	21.9	169 (3)	92 (5)
Zinc amino acid chelate	9.4	108 (1)	-
Zinc MHA ³ chelate	16.0	-	125 (1)
Zinc propionate	27.0	117 (3)	-
Zinc proteinate	14.8	121 (13)	-
Zinc glycinate	26.0	-	124 (1)
Zinc polysaccharide	19.0	94 (1)	-

¹ Literature consulted to obtain the average bioavailability value. ² Feed Grade; ³ Methionine hydroxy analogue.

