EFFECT OF COMPOSITE VITAMIN SUPPLEMENTATION ON BROILERS

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Primary Audience: Nutritionists, Live Production Managers, Researchers

SUMMARY

To determine the optimum level of vitamin supplementation of broilers under three levels of environmental and disease stresses, a floor pen trial was conducted. Treatments included five vitamin supplementation levels and three broiler stress conditions. Multi-stress agents included litter age, bird density, coccidiosis challenge, *E. coli* challenge, fat peroxide value, and diet density.

Higher composite vitamin supplementation significantly improved (P<.05) broiler performance and carcass characteristics and broiler profitability. This study confirms that NRC (1984) vitamin supplementation rates may not support maximum commercial broiler performance, that increased stress raises the vitamin supplementation required to maximize broiler performance, and that nutritionists are justified in using higher vitamin supplementation rates to maximize profitability.

Key words: Broiler performance, carcass composition, disease stress, National Research Council, vitamins, vitamin fortification, vitamin requirements

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DESCRIPTION OF PROBLEM

Vitamins are essential nutrients involved in over thirty metabolic reactions in cellular metabolism and are critical to the efficiency of the Krebs/Citric Acid cycle [1]. Vitamins are organic compounds present in most feedstuffs in minute amounts. Typically, vitamins represent only 0.05% of weight and 1.5% of complete feed cost. However, vitamins are essential for normal metabolism. They also cause a specific deficiency disease if absent from the diet and cannot be synthesized by the host animal to meet vitamin requirements [2].

Nutritionists typically provide the minimum vitamin fortification to maximize performance and profitability plus some margin of safety based on field experience. However, a number of factors may affect vitamin requirements. For example, selection for faster growth rate may allow animals to reach much higher weights at much younger ages with less feed consumed. Intensive production growout systems impose higher metabolic stresses which, in turn, may cause increased vitamin deficiencies [3] or increased vitamin requirements. Therefore, nutritionists typically fortify rations with vitamins in accor-

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dance with the following criteria: (a) determining factors in the growout operation which impact vitamin supplementation; (b) determining objectives to accomplish appropriate vitamin nutrition fortification with minimum feed cost; and (c) determining "safety factor" vitamin levels required due to unexpected and varied stress factors among locations and/or within flocks. These factors determine practical vitamin requirements.

Sherwood [4] clearly demonstrated that the broiler chickens fed the 1976 ration achieved a target of 1.8 kg average body weight sooner, averaged more weight at 8 wk of age, and converted feed more efficiently than the birds fed the 1953 ration or the birds receiving either the 1976 or 1953 ration. In all cases, target body weights were achieved with less feed consumed. This lower consumption may affect nutrient requirements. For example, the rapidly-growing broiler chick has been shown to require more niacin due to the faster gains of modern strains of birds as compared to historical populations [5]. Consequently, nutrient requirements may have changed as a result of improved feed utilization (less feed per unit of body weight gain).

Because there are over thirty metabolic reactions involving nine vitamins in the Krebs/Citric Acid cycle alone, the interdependence among most vitamins makes it critical to prevent any vitamin from limiting higher performance. Interactions among vitamins are common and take several forms [6]: (a) B vitamins, as regulators of intermediary metabolism, overlap in several pathways, (b) choline, B_{12}, and folic acid interact directly in the metabolism of methyl groups, and a lack of one can lead to an increased requirement for the others [7], and (c) the relationship between pantothenic acid and B_{12} [8].

Since genetic potential has improved at the rate of 0.8% feed conversion yearly and most of the NRC vitamin requirement data is 20 to 40 years old, vitamin requirements determined several decades ago may not apply to today's poultry [9]. Not only is the vitamin requirement data outdated, but most research leading to establishing requirements is based on the premise that a single vitamin requirement may be measured by maintaining all other vitamins at NRC levels and testing different levels of the vitamin being measured. Therefore, most modern vitamin research does not measure the requirement for a specific vitamin being investigated. Instead, it actually measures the power of the most limiting vitamin(s) in preventing higher performance when animals are reared in typical laboratory non-stress conditions. In these situations, vitamin requirements have not experimentally been shown to change over the last 20 years. Recently, trials conducted to determine vitamin requirements essential to optimize body weight and feed efficiency have also been conducted and suggest that the requirements are higher than those recommended by NRC [10, 11, 12, 13, 14].

In view of the fact that practical industry broiler vitamin feed supplementation is approaching 2 to 10 times NRC (1994) requirements [12, 13, 14], several questions arise: Should research focus on increasing vitamin fortification levels used in practical poultry rations (termed "safety factors") as compared to the reported NRC [11, 13] vitamin requirements? Should research determine the effect of environment, disease, and typical field stress on vitamin requirements? Should studies establish experimentally the link between typical field stress and vitamin requirements?

The objective of the present study was to determine the effect of feeding either NRC vitamin requirements reported in 1984 (at the time of initiation of this research project NRC 1994 had not been published) or various practical industry supplementation rates [12]. Both would be tested when broilers were reared under three different multi-stress regimes. Single one-factor stress treatments, widely used in laboratory research, were dismissed since multiple stressors are generally found under field conditions. Optimum broiler vitamin requirements were established using least-cost or profitability as the primary goal under different field stress regimes in order to prevent either over- or under- vitamin fortification.

Materials and Methods

A group of 11,680 commercial Peterson X Arbor Acres, mixed-sexed broilers placed equally (50:50, males identified by toe-web clipping) was located in a well-insulated and ventilated house. Four hundred broilers from four random hatchery boxes were individually weighed for each sex. The top and bottom 10% were discarded to provide a more uniform statistical evaluation among blocks (pens). The 80% remaining birds were randomly placed at one day of age in 120 experimental floor pens (4.2 ft. x 15.2 ft.) and reared during the period of February to April, 1994. Broilers were replaced when mortality occurred during the first five days of age.

The factorial design consisted of five vitamin supplementation levels (NRC, Low 25%, Average, High 25%, and Highest 5% vitamin usage levels in the poultry industry) and three environmental/disease stress levels (using as stressors floor density, litter *E. coli* challenge, coccidiosis exposure, aflatoxin contamination, fat peroxide, and nutrient density), as shown in Table 1. The dietary nutrient density was also considered a stress factor because a moderately low energy/protein level may decrease growth rate, slow metabolic rate, and presumably decrease stress. Conversely, a very high energy/protein plane of nutrition will accelerate growth rate, increase the metabolic rate, and increase stress.

Used on the floor were 100% new unused pine shavings, or 50% used and 50% new, or 100% used pine shavings to simulate low, moderate, and high stress regimes typically found in the poultry industry. Used pine shavings were obtained from litter having grown five previous broiler flocks. The used litter was first crusted and the top 1–2" removed prior to placing it in the experimental pens.

Recently published industry surveys [12, 14] identified vitamin fortification levels. NRC supplementation was calculated by assaying individual ingredients for vitamins and calculating a vitamin supplementation that when combined with natural vitamins from feed ingredients would meet or exceed 1984 NRC values (Table 2).

Each experimental diet (Tables 3 and 4) for starter (1–21 days), grower (22–42 days), and finisher (43–51 days) rations included a low density, medium density (a typical industry ration), and high density. Table 2 lists vitamin premix and Table 3 details diet composition. Broilers were fed crumbles (0–21 days) and pellets (22–51 days) using a pelleting temperature of 80°C. All feed samples were assayed for proximate analysis, calcium, and phosphorus. All nutrients were found to be in normal range after mixing. Vitamin A, E, and riboflavin were assayed as markers for vitamin supplementation treatments. All vitamin levels were found to be in normal ranges after mixing.

Each treatment was fed to eight replicates containing either 72 (low stress), 88 (moderate stress), or 132 (high stress) equal sexed broilers, providing either 0.092 m^2, 0.066 m^2, or 0.046 m^2 per broiler, respectively.

A Delmarva field strain of *E. coli* (identified and confirmed by the API-20E system) known to create infection (fed orally at 5 days of age) and a combination of coccidia (combination of *E. acervulina*, *E. maxima*, and

TABLE 1. Components of stress treatments

	NONSTRESS	MODERATE	RELATIVELY HIGH
Litter[A]	New	50% old	100% old
Density m^2/bird (ft^2)	0.092 (1.0)	0.066 (0.72)	0.046 (0.5)
Cocci challenge[B], oocysts/bird			
E. acervulina	None	50,000	100,000
E. maxima	None	25,000	50,000
E. tenella	None	5,000	10,000
E. coli challenge, organisms/bird[C]	None	50,000	100,000
Fat peroxide, meq/kg	2.2	33	66
Diet density[D]	moderately low	high (industry)	very high

[A]New = unused pine shavings; Old = pine shavings litter having grown five previous broiler flocks.

[B]Water inoculation at 7 days of age

[C]Litter inoculation at 5 days of age

[D]Details in Table 4

TABLE 2. NRC, Low 25%, Average, High 25%, and High 5% vitamin premixes for vitamin supplementation levels in broiler diets

VITAMINS	GROWER[A]				
	NRC Supplement	Low 25%	Average	High 25%	High 5%
Vitamin A, IU/kg	794	6404	8113	10141	12676
Vitamin D_3, IU/kg	200	2039	2568	3086	3858
Vitamin E, IU/kg	6.28	9.48	15.76	23.89	29.86
Niacin supplement, mg/kg	22.16	26.97	43.54	60.34	75.43
Pantothenic acid, mg/kg	8.82	8.40	10.91	12.47	15.59
Riboflavin, mg/kg	3.42	5.00	6.44	7.71	9.65
Menadione, mg/kg	0.50	0.90	1.63	2.82	3.53
Thiamine, mg/kg	0.22	0.85	1.40	2.19	2.74
Pyridoxine, mg/kg	1.54	0.95	2.25	3.72	4.65
Folic acid, mg/kg	–	0.46	0.75	1.07	1.33
Biotin, mg/kg	0.121	0.024	0.070	0.126	0.157
Vitamin B_{12}, mg/kg	0.010	0.009	0.012	0.017	0.021

[A]NRC Supplement = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

E. tenella oocysts per bird fed via drinking water at 7 days of age) were inoculated.

All broilers were vaccinated for Marek's disease and Newcastle Bronchitis at the hatchery. Salinomycin (66 ppm) was fed as the coccidiostat from days 0–42 and withdrawn through 51 days of age. Bacitracin MD (55 ppm) was fed throughout the study (0–51 days).

Performance was measured at 21, 42, and 51 days of age. Researchers weighed all dead birds and calculated feed efficiency by adding the dead bird weight back into total weight of the pen to calculate pen feed:weight. Carcass

TABLE 3. Basal ration formulation[A]

INGREDIENTS	STARTER	GROWER	FINISHER
Corn	66.712	71.994	77.394
Soybean meal-48	22.437	17.078	11.764
Meat blend-58	8.000	8.000	8.000
Fat	1.087	1.131	1.142
Def. phos. 32-18	0.431	0.372	0.367
Limestone	0.345	0.352	0.338
Lysine Hcl	0.147	0.219	0.289
DL Methionine	0.198	0.202	0.155
Choline chl.-60	0.031	0.027	0.022
Coccidiostat	0.100	0.100	–
Growth promotant	0.050	0.050	0.050
Vitamin premix[B]	0.050	0.050	0.050
Trace mineral premix[C]	0.075	0.075	0.075

[A]High density

[B]See Table 2

[C]Premix supplied the following per kg of diet: Mn, 100 mg; Zn, 80 mg; Cu, 3 mg; I, 0.75 mg; Fe, 20 mg; Se, 0.3 mg.

TABLE 4. Diet densities in low, moderate, and relatively high stress treatments

NUTRIENT	STARTER	GROWER	FINISHER
Low Density Diet			
Energy (kcal/kg)	3064	3119	3174
M+C (%)	0.93	0.88	0.78
Lysine (%)	1.17	1.07	0.98
Protein (%)	21.5	19.5	17.6
Medium Density Diet (Typical Industry Ration)			
Energy (kcal/kg)	3141	3197	3252
M+C (%)	0.95	0.90	0.80
Lysine (%)	1.20	1.10	1.00
Protein (%)	22	20	18
High Density Diet			
Energy (kcal/kg)	3219	3274	3329
M+C (%)	0.97	0.92	0.82
Lysine (%)	1.23	1.13	1.02
Protein (%)	22.5	20.4	18.4

data, obtained at 51 days, included dry yield, breast meat, abdominal fat pad, and total skin tears and scratches. The total skin tears and scratches were measured by simulating field catching conditions and measuring total cuts in external skin areas more than one cm in length.

This study implemented a factorially-arranged randomized complete block design. Statistical examination of the data was performed using the analysis of variance [15], with least significant difference to separate significant differences. All statements of significant differences refer to the 5% level of probability. Data was analyzed as described in published references [15, 16, 17].

RESULTS AND DISCUSSION

PERFORMANCE DATA

Higher levels of vitamin supplementation improved ($P<.05$) broiler average body weight, feed efficiency, and mortality at 21, 42, and 51 days of age (Table 5). When broilers were reared under low stress conditions, both body weights and feed efficiency improved with the average vitamin supplementation treatment at all ages. When broilers were reared under relatively high stress conditions, maximum average body weight ($P<.05$) was achieved by feeding the High 25% vitamin level. Feed efficiency improved by feeding High 5% vitamin level at 21 days of age. Higher average body weight appeared to be partially the result of a carryover effect observed in the first few weeks. However, a carryover effect did not occur with the high stress conditions (Table 6).

The pooled data across stress levels (Table 7) indicate that the highest ($P<.05$) average body weight resulted from feeding the average vitamin supplementation level at 21 and 42 days of age and by feeding the High 25% vitamin supplementation level at 51 days of age. Vitamin supplementation similarly improved ($P<.05$) performance for both males and females. Pooled data across vitamin supplementation treatments (Table 7) indicate that both moderate and high stress regimes depressed ($P<.05$) broiler performance at all growth stages. There were vitamin x stress interactions for body weight and feed efficiency, but not for mortality.

Bird uniformity is becoming more important since it increases processing efficiency and improves the consistency of the final processed product. Using individual body weights, coefficient of variations were measured at 42 and 51 days of age (Table 8) in order to determine body weight uniformity. Higher levels of vitamin supplementation improved ($P<.05$) body weight uniformity. Optimum body weight uniformity resulted from feeding the average vitamin supplemen-

TABLE 5. Effect of vitamin supplementation and stress level on 21, 42, and 51-day broiler performance

VITAMIN LEVEL[A]	NO STRESS			MODERATE STRESS			RELATIVELY HIGH STRESS		
	Body Weight	F/G[B]	Mortality	Body Weight	F/G[B]	Mortality	Body Weight	F/G[B]	Mortality
	g		%	g		%	g		%
21 DAY PERFORMANCE									
NRC	624^{cd}	1.437^{c}	4.79^{b}	550^{i}	1.577^{h}	7.59^{bc}	546^{i}	1.540^{g}	9.38^{d}
Low 25%	655^{b}	1.426^{bc}	2.71^{a}	609^{ef}	1.545^{g}	7.14^{bc}	572^{h}	1.504^{e}	9.38^{d}
Average	686^{a}	1.408^{ab}	1.46^{a}	619^{cde}	1.538^{g}	6.40^{ab}	587^{g}	1.479^{d}	8.37^{cd}
High 25%	682^{a}	1.418^{bc}	1.46^{a}	626^{c}	1.527^{fg}	5.21^{b}	602^{f}	1.470^{d}	8.67^{cd}
High 5%	677^{a}	1.394^{a}	1.88^{a}	625^{c}	1.515^{ef}	5.06^{b}	611^{def}	1.431^{c}	8.27^{cd}
42 DAY PERFORMANCE									
NRC	2002^{d}	1.967^{c}	6.88^{b}	1827^{g}	2.115^{g}	11.61^{f}	1836^{fg}	2.090^{g}	11.29^{f}
Low 25%	2122^{bc}	1.853^{bcd}	3.96^{a}	2036^{d}	1.888^{d}	9.23^{cde}	1871^{ef}	2.040^{f}	10.99^{ef}
Average	2148^{ab}	1.817^{ab}	2.50^{a}	2089^{c}	1.865^{cd}	8.33^{bcd}	1869^{efg}	2.013^{ef}	9.07^{cde}
High 25%	2176^{a}	1.819^{abc}	3.54^{a}	2085^{c}	1.842^{bcd}	7.44^{bc}	1896^{e}	2.018^{f}	9.98^{def}
High 5%	2190^{a}	1.786^{a}	3.33^{a}	2088^{c}	1.833^{bc}	6.99^{b}	1909^{e}	1.996^{ef}	9.88^{def}
51 DAY PERFORMANCE									
NRC	2390^{cd}	2.109^{de}	7.50^{b}	2071^{i}	2.233^{g}	12.95^{g}	2084^{i}	2.196^{f}	12.60^{fg}
Low 25%	2542^{b}	2.013^{c}	4.17^{a}	2419^{ef}	2.013^{c}	9.67^{cd}	2169^{h}	2.113^{e}	12.20^{efg}
Average	2578^{a}	1.946^{ab}	2.71^{a}	2478^{cde}	1.976^{b}	9.38^{bcd}	2237^{g}	2.079^{d}	10.18^{de}
High 25%	2594^{a}	1.936^{a}	4.38^{a}	2480^{c}	1.946^{ab}	7.74^{bc}	2270^{f}	2.099^{de}	10.69^{def}
High 5%	2604^{a}	1.914^{a}	3.54^{a}	2489^{c}	1.930^{a}	7.44^{b}	2281^{def}	2.085^{de}	11.29^{defg}

[A]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

[B]Body weight corrected

[a–i]Means within a column without a common superscript are significantly different ($P < .05$).

tation level when broilers were reared in the low stress condition and by feeding the High 25% vitamin supplementation when broilers were reared under the high stress regime.

CARCASS COMPOSITION DATA

Processing weights, breast meat, and abdominal fat pad data appear in Table 9. Processed body weights were significantly optimized ($P < .05$) under the low stress regime with the average vitamin supplementation level. When broilers were reared in the relatively high stress regime, they benefitted from the High 5% vitamin supplementation.

Total skin tears and scratches were also important since both carcass grading and consumer preference may be impacted. Past research indicates that inadequate vitamin supplementation leads to weak tissue and poor skin integrity and strength during either biotin, pantothenic acid, or vitamin A deficiencies. Vitamin supplementation significantly ($P < .05$) reduced the number of skin tears and scratches in all stress regimes. Even under the low stress condition, skin tears and scratches diminished significantly at the High 5% supplementation level.

PROFITABILITY

Bird performance tends to be measured in terms of weight gain, feed efficiency, and mortality. However, maximum performance may not always be the most profitable strategy. The modern-day poultry industry tends to look for optimum profitability, regardless of live performance. Net income per processed bird

TABLE 6. Effect of vitamin supplementation and stress level on 22–24 and 43–51 day period of broiler performance

VITAMIN LEVEL[A]	NO STRESS			MODERATE STRESS			RELATIVELY HIGH STRESS		
	Body Weight	F/G[B]	Mortality	Body Weight	F/G[B]	Mortality	Body Weight	F/G[B]	Mortality
	g		%	g		%	g		%
22–42 DAY PERFORMANCE									
NRC	1378[d]	2.189[d]	2.18[b]	1277[e]	2.330[f]	4.34[c]	1291[e]	2.322[ef]	2.11[b]
Low 25%	1466[bc]	2.043[c]	1.29[ab]	1427[c]	2.026[bc]	2.25[b]	1299[e]	2.276[ef]	1.77[ab]
Average	1463[bc]	2.009[abc]	1.06[ab]	1469[b]	1.995[abc]	2.07[ab]	1281[e]	2.265[ef]	0.76[ab]
High 25%	1494[ab]	1.995[abc]	2.12[b]	1419[bc]	1.966[ab]	2.36[b]	1294[e]	2.276[ef]	1.43[a]
High 5%	1513[a]	1.957[a]	1.49[ab]	1462[bc]	1.961[ab]	2.03[ab]	1298[e]	2.263[e]	1.78[ab]
43–51 DAY PERFORMANCE									
NRC	388[def]	2.414[abcd]	0.63[abcd]	244[h]	2.311[abc]	1.34[cd]	247[h]	2.446[bcde]	1.31[cd]
Low 25%	420[ab]	2.329[abcd]	0.21[a]	383[def]	2.275[ab]	0.45[abc]	298[g]	2.571[def]	1.21[cd]
Average	429[a]	2.564[cdef]	0.21[a]	389[cdef]	2.745[f]	1.04[abcd]	368[f]	2.684[ef]	1.11[bcd]
High 25%	419[ab]	2.222[ab]	0.83[abcd]	395[bcde]	2.791[f]	0.30[ab]	375[def]	2.580[def]	0.71[abcd]
High 5%	415[abc]	2.173[a]	0.21[a]	401[bcd]	2.587[def]	0.45[abc]	372[ef]	2.378[abcd]	1.41[d]

[A]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

[B]Body weight corrected

[a–f]Means within a column without a common superscript are significantly different ($P < .05$).

is the most accurate index of flock performance. Kennedy *et al.* [18] was one of the first researchers to report net income as a comparative index of broiler performance. He reported that broiler flocks fed a 180 mg/kg vitamin E diet had a 1.3% significantly heavier ($P < .05$) weight per bird and a 0.84% significantly better ($P < .05$) feed efficiency than controls fed 44 mg/kg vitamin E. Net income for the flock on high vitamin E was 2.7% higher than in the control flocks.

In the present study, Dr. Fred Benoff's (University Of Georgia) profitability program calculated profitability per pound and per bird after all production and processing costs were considered. Table 10 details the vitamin supplementation treatment costs. In the grower phase in the present trial, the cost of consecutive vitamin treatments varied from $0.68 to $0.90/ton feed. High 25% vitamin supplementation was $0.90 higher than average, and High 5% was also $0.90 higher than High 25%. Profitability and return on investment were calculated by considering live performance, processing factors, actual feed costs, and average industry growout and processing costs (Table 11). Higher vitamin supplementation levels significantly improved ($P < .05$) profitability. Under moderate stress, profitability was highest ($P < .05$) at High 5% supplementation with a profitability increase of 1.60¢/lb of live weight as compared to Average supplementation. In this study, profitability was directly correlated with vitamin supplementation and bird performance.

TABLE 7. Main effects on 21, 42, and 51-day broiler performance

MAIN EFFECTS	df	BODY WEIGHT	F/G	MORTALITY
		g		%
21 DAYS				
Vitamin Supplement				
NRC		573[c]	1.52[c]	7.25[c]
Low 25%		612[b]	1.49[b]	6.41[b]
Average		631[a]	1.47[a]	5.41[a]
High 25%		636[a]	1.47[a]	5.11[a]
High 5%		637[a]	1.45[a]	5.07[a]
Stress				
Low		665[a]	1.42[a]	2.46[a]
Moderate		606[b]	1.54[b]	6.28[b]
Relatively high		584[c]	1.49[c]	8.81[c]
Source of Variation (Probability > F)				
Vitamin supplement	4	0.0000	0.0000	0.0000
Stress	2	0.0000	0.0000	0.0000
Block	7	0.0979	0.0500	0.1432
Vitamin x stress	8	0.0068	0.0029	0.3466
42 DAYS				
Vitamin Supplement				
NRC		1889[c]	2.06[c]	9.93[c]
Low 25%		2009[bc]	1.93[bc]	8.06[bc]
Average		2035[b]	1.90[b]	6.63[b]
High 25%		2052[ab]	1.89[ab]	6.99[ab]
High 5%		2062[a]	1.87[a]	6.73[a]
Stress				
Low		2127[a]	1.85[a]	4.04[a]
Moderate		2025[b]	1.91[b]	8.72[b]
Relatively high		1876[c]	2.03[c]	10.24[c]
Source of Variation (Probability > F)				
Vitamin supplement	4	0.0000	0.0000	0.0000
Stress	2	0.0000	0.0000	0.0000
Block	7	0.4928	0.8918	0.1191
Vitamin x stress	8	0.0000	0.0000	0.2777
51 DAYS				
Vitamin Supplement				
NRC		2181[d]	2.18[d]	11.02[d]
Low 25%		2377[c]	2.05[c]	8.68[c]
Average		2431[b]	2.00[b]	7.62[b]
High 25%		2448[ab]	1.99[ab]	7.60[ab]
High 5%		2458[a]	1.98[a]	7.42[a]
Stress				
Low		2542[a]	1.98[a]	4.46[a]
Moderate		2388[b]	2.02[b]	9.44[b]
Relatively high		2208[c]	2.11[c]	11.39[c]
Source of Variation (Probability > F)				
Vitamin supplement	4	0.0000	0.0000	0.0000
Stress	2	0.0000	0.0000	0.0000
Block	7	0.1187	0.0362	0.2561
Vitamin x stress	8	0.0000	0.0000	0.0843

TABLE 8. Effect of vitamin fortification and stress level on 51-day broiler individual body weight variation[A]

VITAMIN LEVEL[B]	LOW STRESS	MODERATE STRESS	RELATIVELY HIGH STRESS
NRC	12.14[f]	14.82[h]	16.62[i]
Low 25%	10.40[cd]	12.84[g]	12.96[g]
Average	9.20[ab]	10.32[cd]	13.15[g]
High 25%	10.44[cd]	10.27[c]	10.68[d]
High 5%	9.09[a]	9.52[b]	11.23[e]

[A]Standard deviation of individual body weights

[B]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

[a–i]Means within a column without a common superscript are significantly different (P < .05).

TABLE 9. Effect of vitamin supplementation on carcass composition

VITAMIN LEVEL[A]	DRY YIELD	CARCASS COMPOSITION					
		Live Processing Weight	Hot Processed Weight	Chilled Processed Weight	Breast Meat[B]	Abdominal[B] Fat Pad	Skin Tears[C]
	%	g	g	g	%	%	
NRC	68.53[c]	2248[d]	1541[e]	1671[d]	14.87[d]	2.05	5.4[e]
Low 25%	69.32[b]	2441[c]	1692[d]	1826[e]	14.93[cd]	2.02	4.9[d]
Average	69.89[ab]	2471[c]	1728[c]	1867[b]	15.08[bc]	1.94	4.6[c]
High 25%	70.19[a]	2507[b]	1761[b]	1902[ab]	15.17[ab]	1.87	4.3[b]
High 5%	70.56[a]	2546[a]	1796[a]	1940[a]	15.34[a]	1.85	3.6[a]

[A]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

[B]Expressed as percent of live weight

[C]Total tears and scratches that exceed 1/2 cm

[a–e]Means within a column without a common superscript are significantly different (P < .05).

TABLE 10. Impact of vitamin fortification on broiler vitamin premix cost per ton

VITAMIN LEVEL[A]	STARTER	GROWER	FINISHER
NRC	1.62	1.04	0.60
Low 25%	1.88	1.71	1.09
Average	2.70	2.48	2.15
High 25%	3.69	3.38	3.32
High 5%	4.66	4.27	4.16

[A]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

TABLE 11. Effect of vitamin supplementation on broiler profitability and return on investment per kg of meat

VITAMIN LEVEL[A]	NRC		LOW 25%		AVERAGE		HIGH 25%	
	Profit $	Return x times	Profit $	Return x times	Profit $	Return x times	Profit $	Return x times
Low stress								
Low 25%	0.0517[B]	39						
Average	0.0736	23	0.0219	12				
High 25%	0.0704	13	0.0188	5	0.0020	1		
High 5%	0.0765	10	0.0248	4	0.0029	1	0.0060	3
Moderate Stress								
Low 25%	0.0888	65						
Average	0.1060	38	0.0172	10				
High 25%	0.1201	26	0.0313	9	0.0141	7		
High 5%	0.1220	19	0.0335	7	0.0160	4	0.0018	2
Relatively High Stress								
Low 25%	0.0319	19						
Average	0.0542	13	0.0223	10				
High 25%	0.0565	8	0.0246	4	0.0023	1		
High 5%	0.0697	7	0.0377	5	0.0154	3	0.0131	6

[A]NRC = NRC bioavailable vitamins in feed ingredients used in the broiler diet; Low 25% = the mean for the lowest fifteen vitamin values used in the poultry industry; Average = the mean for sixty-two vitamin values used in the poultry industry; High 25% = the mean for the highest fifteen vitamin values used in the poultry industry; High 5% = the mean for the highest three vitamin values used in the poultry industry.

[B]Increase in profit of $0.0517/kg from NRC to Low 25% under low stress conditions

Conclusions and Applications

1. Increased vitamin supplementation significantly improved ($P<.05$) broiler performance and carcass composition at all stress levels.
2. Under low, moderate, and relatively high stress regimes, broiler performance was optimized at Average, High 25%, and High 5% vitamin supplementation. These data indicate that higher vitamin usage levels may be required under typical field conditions and that NRC (1984) broiler vitamin requirements may be too low for typical industry standards.
3. Stress significantly reduced ($P<.05$) broiler performance and carcass yield.
4. Under the conditions of this trial, higher vitamin fortification reduced the negative impact of stress on broiler performance; however, the vitamin levels did not completely overcome the effect of stress.
5. Highest ($P<.05$) profitability was reached at High 25% supplementation, and, conversely, the lowest ($P<.05$) profitability at NRC (1984) levels.

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