Determination of the Minimum Crude Protein Requirements of Broiler Starters and Finishers in the Tropics

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SUMMARY

THREE experiments were conducted with broiler chicks to determine the minimum crude protein levels in the diets of broiler starters and finishers reared in a tropical environment. The first two trials covered both the starter and finisher periods of 12 weeks while the third experiment covered only the finishing period. The calculated dietary crude protein levels used in the first trial were 14,16 18, 20, 22 and 24%; in the second trial, 20, 22, 24 and 26% and in the third trial, 14, 16, 18 and 20% on afr dry basis. Results showed the 24% crude protein (trial 1) and 26% crude protein (trial 2) diets promoted highly significantly better liveweight gains than all the other rations during the starter period while during the finishing period, there were no significant differences in the liveweight gains on the diets containing 18, 20, 22, 24 and 26% although growth was always better on the higher protein diets. Diets containing 14, 16 and 18% crude protein were grossly inadequate for the broiler starters while during the finishing period, if all the birds were on adequate broiler starter diets before being put on finisher diets, all these diets promoted growth almost equally well, there being no significant differences among growth rates. The feed/gain ratios followed the same trends as obtained for growth rates, the ratios becoming significantly better for higher protein diets. Mortality was highest for the lowest protein diets and lowest for the highest protein diets, while the percent nitrogen retained tended to be better, through not significantly so, for the higher protein diets.

On the basis of these studies, it is recommended that the diets of broiler starter chicks in the tropics should not contain less than 24% crude protein, while those of the finishers should not contain less than 18% crude protein on air dry basis for optimal results.

INTRODUCTION

FOR a long time now, there has been no information on the minimal or optimal nutrient requirements of the domestic animals and poultry reared in the tropics. A tremendous amount of this exists for the animals reared in the temperate environments and the temptation has always existed for the animal nutritionists and feed manufacturers in the tropical developing world, to use the same standards which have been determined in the temperate environment on those animals being reared in the tropics. While this practice is not necessarily wrong, there is a definite need to determine the minimum nutrient requirements of the tropical animals if it is realized that the two environments are very radically different. While the animals reared in the temperate environment may benefit from high calorie diets because of the low ambient temperatures, for instance, those reared in the tropical environment perpetually faced with high ambient temperatures, may not benefit from the consumption of such calorie-loaded diets.

The determination of the minimum crude protein requirement of the domestic fowl has been done by a number of workers in the temperate world (Norris, 1951; Hill, Norris, Henser and Scott, 1951; Hill, 1949; Hill, Norris, Scott and Henser 1954; Nesheim and Scott, 1962 and Scott, 1963). All these workers recommended about 20% crude protein diet for broiler starters and about 16% for broiler finishers. Also, the Agricultural Research Council (1963), the National Research Council, Washington (1971) and Bolton, (1963) made similar recommendations. Attempts by various feed manufacturers to introduce diets containing these recommended protein levels to commercial farmers in Nigeria have not worked well and the studies reported here were under-

taken primarily to determine what the minimum levels of crude protein should be in the diets of broiler starters and finishers reared in the tropics and compiled from locally-produced feeding stuffs.

MATERIALS AND METHODS

Three trials were carried out, two on broiler starters and finishers, and the third on broiler finishers.

Experiment 1

This trial involved 720 day old broiler chicks of the White Rocks breed which were specially bought from a commercial poultry farm in the neighbourhood. These were given a 24% protein diet for a week after which they were randomly divided into six equal groups of 120, and these 120 were further subdivided into three subgroups of 40, representing three replicates. The six groups were fed each of the six diets formulated to contain 14, 16, 18, 20, 22 and 24% crude protein on air dry basis. The diets were formulated from the locally available ingredients almost exclusively except for the vitamin — mineral premix which was imported. The composition of these diets appears in table 1 (rations 1 to 6). In balancing these diets, attempts were made to maintain a balanced proportion of the various protein concentrates, groundnut cake, fishmeal and blood meal, and the calculated amino acid contents and the amino acids expressed as percentages of calculated crude protein appear in tables 3 and 4 respectively (rations 1 to 6). There were thus six main treatment groups replicated three times. The chicks were all housed in floor brooder pens of the same dimensions, sufficiently large to prevent overcrowding. Both the feeding and watering were done *ad libitum*, and

TABLE 1

Composition of Rations used in Experiments I / II

Ingredients (%)	*Rations* 1	2	3	4	5	6	7
Yellow maize	75.15	69.65	65.15	60.15	54.65	49.15	43.65
Groundnut meal	10.00	14.00	17.00	20.50	24.50	28.50	32.50
Fish meal	2.00	3.00	4.00	5.00	6.00	7.00	7.50
Blood meal	1.00	1.50	2.00	2.50	3.00	3.50	4.50
Rice bran	2.0	2.00	2.00	2.00	2.00	2.00	2.00
Brewer's dried yeast	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Palm oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00
A-D-Vit. (For broilers)	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
TOTALS	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Composition (%)							
Calculated crude protein	14.00	16.00	18.00	20.00	22.00	24.00	26.00
Crude protein (determined)	13.87	16.35	17.90	20.41	22.20	24.50	26.25
Crude fibre (determined)	3.48	3.81	3.89	3.86	3.56	3.63	3.70
Ether extract (determined)	10.17	10.23	10.69	10.33	10.62	10.69	10.78
Metabolizable energy (kcal/kg) calculated	3.321	3.275	3.238	3.188	3.151	3.105	3.050

A Pfizer Livestock Feeds Products, supplying the following nutrients per kg of ration: Vitamin A., 11,785.5 IU; D, 1964.3 ICU; Riboflavin, 5.40mg; Pantothenic acid 9.82mg; Nicotinic acid, 24.55mg; Folic acid, 0.98mg; Choline Chloride, 147.32gm; Vitamin E,4.91 units; Vitamin K, 2.20mg; Vitamin B12, 0.01mg; Methionine, 245.53 mg; Cobalt, 1.23mg; Iodine, 0.98mg; Copper, 9.82mg; Manganese, 55.00mg; Zinc, 49.11 mg and Iron 19.64mg.

TABLE 2

Ingredients (%)	Rations 1	2	3	4
Yellow maize	77.25	72.25	67.25	62.25
Groundnut meal	10.00	15.00	17.00	20.00
Fish meal	2.00	3.00	4.00	5.00
Blood meal	1.00	1.50	2.00	2.50
Rice bran	2.50	2.50	2.50	2.50
Brewer's dried yeast	1.00	1.00	1.00	1.00
Dicalcium phosphate	2.50	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50	0.50
Palm oil	2.50	2.50	2.50	2.50
A-D-Vit-Fee (broilers)	0.50	0.50	0.50	0.50
Salt	0.25	0.25	0.25	0.25
TOTALS	100.00	100.00	100.00	100.00
Composition (%)				
Crude protein (determined)	13.93	16.40	18.02	20.12
Crude fibre (determined)	3.50	3.90	3.97	3.89
Ether extract (determined)	8.76	8.80	8.71	8.57
Metabolisable energy (kcal/kg) (calculated)	3 226	3,184	3.147	3..02

1) Pfizer Livestock Feeds product, containing the same ingredients as specified under table 1

TABLE 3

Calculated amino acid Composition of experimental diets as percentages of final diet [Expts. I / II]

Amino acids	Rations 1	2	3	4	5	6	7
Arginine	1.21	1.51	1.74	2.01	2.31	2.62	3.01
Histidine	0.44	0.54	0.60	0.68	0.77	0.87	0.95
Isoleucine	0.56	0.61	0.72	0.80	0.87	0.96	1.04
Leucine	1.59	1.77	1.92	2.09	2.27	2.46	2.62
Lysine	0.71	0.87	1.00	1.15	1.30	1.45	1.61
Methionine	0.25	0.28	0.34	0.34	0.36	0.41	0.43
Methionine + Cystine	0.58	0.64	0.72	0.79	0.86	0.93	0.99
Phenylalanine	0.81	0.95	1.07	1.20	1.35	1.47	1.66
Phenylalanine + tyrosine	1.51	1.75	1.95	2.18	2.41	2.62	2.90
Threonine	0.63	0.71	0.78	0.86	0.96	1.03	1.12
Tryptophan	0.15	0.18	0.21	0.24	0.27	0.30	0.32
Valine	0.77	0.90	1.01	1.14	1.25	1.37	1.54

TABLE 4

Calculated amino acid Composition of experimental diets as percentages of calculated crude protein [Expts. I / II]

Amino acids	Rations 1	2	3	4	5	6	7
Arginine	8.64	9.44	9.66	10.05	10.50	10.88	11.12
Histidine	3.14	3.34	3.33	3.45	3.50	3.63	3.65
Isoleucine	4.00	4.00	4.00	4.00	3.95	4.00	4.00
Leucine	11.36	11.06	10.66	10.45	10.22	10.21	10.08
Lysine	5.07	5.44	5.56	5.75	5.91	6.04	6.19
Methionine	1.78	1.75	1.72	1.70	1.73	1.71	1.65
Methionine + Cystine	4.14	4.00	4.00	3.95	3.91	3.88	3.81
Phenylalanine	5.79	5.94	5.94	6.00	6.14	6.13	6.35
Phenylalanine + tyrosine	10.79	10.94	10.83	10.90	10.95	10.92	11.15
Threonine	4.50	4.44	4.33	4.30	4.27	4.29	4.31
Tryptophan	1.07	1.13	1.17	1.20	1.23	1.25	1.23
Valine	5.50	5.63	5.61	5.70	5.68	5.71	5.92

records of feed consumption and live-weight gains were taken daily and weekly respectively.

After four weeks, three birds from each of the replicates for all the treatments were randomly selected and kept in the metabolism cages, where the nitrogen retention studies were carried out. Collection of faecal droppings covered six days after the first five days of adjustment period. The droppings were daily weighed, sprayed with some boric acid, and then stored in refrigerated room maintained at -5°C. The analyses for moisture and nitrogen contents on the stored, bulked samples were done according to the AOAC methods of analysis (1970).

This trial lasted 12 weeks, and the chicks were on the same diets throughout although after the entire trial period, the results were analysed on the basis of the performances during the first six weeks, last six weeks, and the entire 12 weeks.

Experiment 2

This trial involved 600 day old White Rocks chicks hatched on the campus of the University and were of completely different strain and genetic priority from those used in experiment 1. The 600 chicks were also reared for the first week on a 24% crude protein diet, and later divided in four groups of 150 birds, each group being subdivided into three equal replicates of 50 birds. The four diets used contained 20, 22, 24 and 26% crude protein on air dry basis, and the feeding, management, housing and record keeping were similar to those described above for experiment 1. Nitrogen metabolism studies were not carried out on these birds. The dietary composition are represented under rations 4, 5, 6 and 7 of table 1, while their amino acid composition and proportions are represented in tables 3 and 4 respectively under rations 4, 5, 6 and 7. This trial also lasted for 12 weeks.

Experiment 3

The White Rocks broiler chicks used here were all reared on 24% protein diet for the first six weeks after which 600 of them were randomly selected and randomly allocated into four equal groups of 150. Each group was also randomly subdivided into three equal replicates of 50 birds, and were housed in floor brooder house covered with wood shavings. The four diets fed were formulated to contain 14, 16, 18 and 20% protein on the same principles as experiments 1 and 2, using the same types of locally available ingredients (Table 2). The calculated amino acids contents and proportions as percentages of calculated crude protein levels are represented under rations 1, 2, 3 and 4 of tables 3 and 4 respectively. Feeding, watering and other management practices were similar to those carried out on birds in experiments 1 and 2. Nitrogen retention studies were also not carried out on these birds, and the trial lasted 6 weeks only.

All the data collected were subjected to the analysis of variance, followed by the Duncan's Multiple Range test whenever significant differences were indicated (Steel and Torrie, 1960).

RESULTS

Average Weekly Body Weights and Daily Live-weight Gains

The summarises of the weekly body weights and average daily live-weight gains appear in tables 5, 6 and 7 for experiments 1, 2 and 3 respectively. Graphical representations of the average weekly liveweight gains and the cummulative weekly live-weight gains according to treatments are further illustrated in Figs. 1 and 2 respectively for experiment 1 only.

In experiment 1, (table 5), diet 6 (24% crude Protein) promoted the best gains throughout. In the first six weeks, the average daily gain (ADG) of birds on diet 6 was significantly better than those of the birds on all other diets ($P<0.01$). The ADG of the birds on the 20 and 22% crude protein diets (rations 4 and 5) were not significantly different from each other, but birds on diet 5 had significantly better ADG than those on diets 1, 2 and 3 ($P<0.01$). Diets 1 and 2 containing 14% and 16% crude protein respectively, produced the poorest gains, highly significantly poorer than the gains on other diets ($P<0.01$). In the second period

TABLE 5

Average Weekly Body Weights [g] of Broiler Starters on Different levels of Dietary Protein: Experiment 1

Weeks	Diets 1	2	3	4	5	6
1	61.4	70.7	75.2	78.9	83.5	91.0
2	78.3	97.7	109.9	128.6	144.8	165.8
3	98.6	129.8	153.1	168.3	201.7	248.5
4	113.8	136.5	189.2	235.6	275.2	338.6
5	123.4	168.1	240.9	325.8	376.7	460.7
6	156.6	221.3	279.0	408.5	583.4	717.2
7	181.3	291.7	575.0	689.2	800.5	970.2
8	228.0	407.6	841.7	964.9	1068.1	1290.9
9	305.7	558.5	1105.7	1265.0	1374.5	1581.5
10	410.5	759.6	1391.6	1532.4	1661.3	1829.9
11	537.6	964.7	1631.0	1809.4	1933.6	2123.9
12	659.3	1171.8	1900.2	2058.2	2112.6	2401.6

Summary of Average Daily Weight gains [g]

Periods	Rations 1	2	3	4	5	6	SE means
0 - 6 weeks	2.55n	4.17	7.86b	10.75bc	12.77c	15.96d	0.721 **
7 - 12 "	11.97a	22.67b	16.93c	16.94c	16.44c	17.72c	1.564 **
0 - 12 "	7.28a	13.40a	23.40b	23.85b	24.60b	26.84b	1.09 **

** = Highly significant differences among treatment means ($P < 0.01$)

a,b,c,d. Treatment means not followed by the same superscripts are significantly different from one another ($P < 0.05$ or $P < 0.01$)

(weeks 7 to 12) diets 1 and 2 also produced the worst gains which were significantly lower than those on all other diets ($P<0.01$). However, there were no significant differences in the ADG figures of birds consuming diets 3 to 6. Considering the entire 12 weeks duration, the ADG figures of birds consuming diets 3 to 6 were fairly close and not significantly different from one another ($P>0.05$), but they were significantly better than the ADG of birds consuming diets 1 and 2 ($P<0.01$).

In experiment 2 (Table 6) diet 4 containing 26% crude protein produced the best ADG in the first 6 weeks, significantly better than those on all other diets ($P<0.05$). The ADG on other diets, 1, 2 and 3, were close and not significantly different from one another ($P>0.05$). In the periods 7-12 weeks and 0-12 weeks, the ADG figures were all close and not significantly different from one another ($P>0.05$) although the 26% protein diet was the best throughout.

In trial 3, although there were progressive increases in both the weekly body weights and the ADG figures (table 7) as protein levels increased from 14 to 20%, the differences among treatment means were not significant ($P<0.05$).

Average Weekly and Daily Feed Consumption Rates

In experiment 1, there were progressive increases in the feed consumption rates as the dietary protein levels increased (table 8). Within the first 6 weeks, the average daily feed (ADF) consumed by birds on diet 6 was significantly higher than the figures obtained for all other diets ($P<0.01$). The birds on diets 4 and 5 consumed at rates not significantly different from each other, but significantly

FIG. 1.

WEEKLY WEIGHT OF BROILER CHICKS ON DIFFERENT PROTEIN DIETS. (EXPERIMENT I).

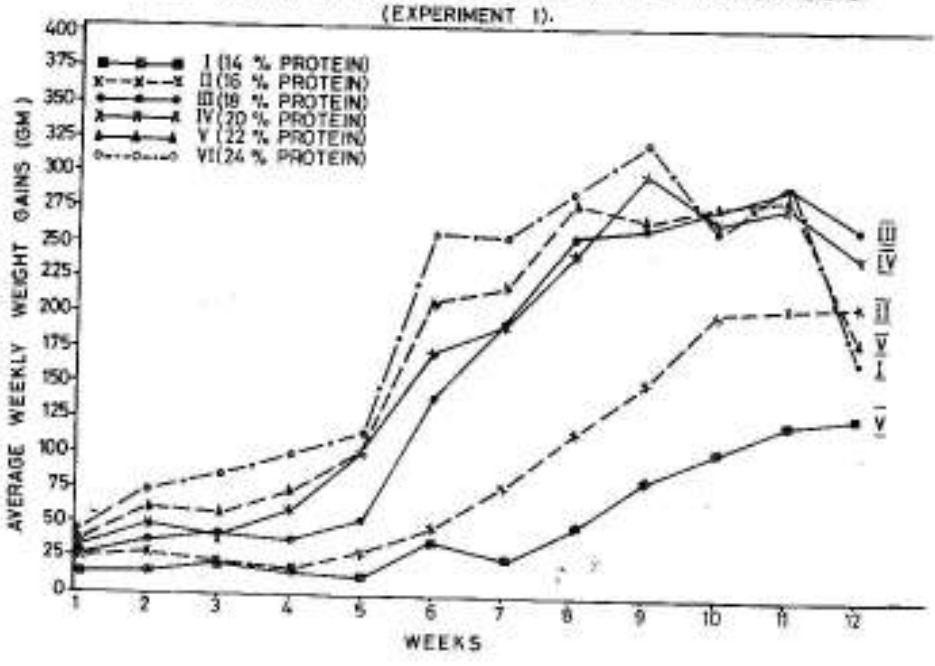

FIG. 2.

CUMULATIVE AVERAGE WEEKLY WEIGHT GAINS OF BROILER CHICKS ON DIETS CONTAINING GRADED LEVELS OF PROTEIN. (EXPERIMENT I).

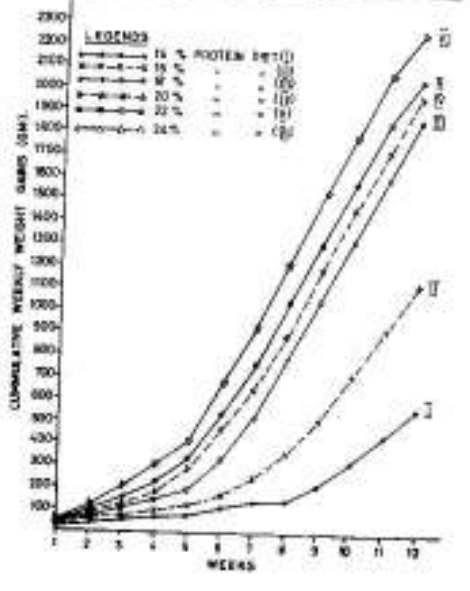

TABLE 6

Average Weekly Body Weights [g] of Broiler Starters fed Diets containing Graded Protein Levels: Experiment 2

	Diets			
Weeks	1	2	3	4
1	93.5	91.4	94.9	91.0
2	153.4	165.2	161.5	160.0
3	223.5	241.7	235.6	236.0
4	288.8	308.8	312.4	346.7
5	383.6	406.5	410.9	462.3
6	508.1	524.1	548.9	615.6
7	659.0	674.4	710.4	791.6
8	818.8	801.7	865.1	943.6
9	950.3	938.0	1027.4	1105.7
10	1079.9	1079.5	1145.2	1243.2
11	1206.9	1208.5	1292.0	1387.7
12	1324.3	1414.4	1394.7	1483.5

Summary of Average Daily Weight Gains [g]

	Diets				*SE Means*
Periods	1	2	3	4	
0 - 6 Weeks	10.89a	11.27a	11.84a	13.43b	0.307*
0 - 12 „	19.43	18.80	20.67	20.66	0.961 (NS)
0 - 12 „	15.16	15.03	16.25	17.05	0.560 (NS)

* = Highly significant treatment differences ($P < 0.05$)
NS = No significant treatment differences ($P > 0.05$)
a,b,c,d. Treatment means not followed by the same superscripts are significantly different ($P < 0.05$ or $P < 0.01$)

TABLE 7

Average Weekly Body Weights [gm] of Broiler Finishers given Diets containing Graded Levels of Protein: Experiment 3.

	Diets			
Weeks.	1	2	3	4
7	847.5	902.2	896.6	893.8
8	1028.8	1076.5	1007.1	1113.7
9	1106.8	1165.1	1180.3	1282.7
10	1237.7	1304.0	1383.0	1485.8
11	1469.4	1586.0	1648.0	1713.0
12	1600.0	1697.1	1719.9	1780.5
	Average Daily Gain (g)			*SE Means*
7 - 12 Weeks	21.08	22.76	23.00	24.42	1.95(NS)

NS = No significant differences among treatment means.

higher than the rates obtained for birds on diets 1, 2 and 3 on lower protein diets ($P<0.01$). There were also no significant differences in the feed consumption rates of birds on diets 1 and 2. ($P>0.05$). In the second period (7-12 weeks), the ADF figures for birds on diets 3, 4, 5 and 6 were close and not significantly different from one another ($P>0.05$) but they were significantly higher than the rates on diets 1 and 2 ($P<0.01$). The trends in the feed consumption figures for the entire period were the same as for second period.

TABLE 8

Average Weekly Feed Consumption Figures [gm] for Broiler Starter Chicks Fed Graded Levels of Protein in the Tropics : Expt. 1

Weeks.	*Diets* 1	2	3	4	5	6
1	56.7	58.4	60.1	65.1	65.5	61.9
2	61.6	76.1	92.7	103.9	106.1	116.8
3	55.7	84.9	120.1	139.1	152.4	180.4
4	69.8	91.6	123.2	174.1	191.6	224.1
5	98.1	109.1	164.3	239.3	259.0	303.5
6	87.2	110.2	238.7	298.7	365.1	425.3
7	128.7	199.1	410.9	435.0	485.6	498.0
8	191.0	416.0	590.0	642.0	657.3	712.6
9	214.0	288.1	568.6	690.1	699.0	771.9
10	285.3	365.8	757.0	821.1	823.2	829.1
11	390.7	506.1	848.7	889.7	898.8	937.7

Summary of Average Daily Feed Consumption [g]

Period	*Diets* 1	2	3	4	5	6	*SE Means*
0 - 6 weeks	9.50	12.62a	19.80b	24.29c	27.1bc	31.19d	0.879**
7 - 12 ,,	37.84	64.59b	100.42a	109.8c	105.50c	113.84c	5.49**
0 - 12 ,,	23.67a	38.60b	59.83c	64.09c	66.33	72.51c	3.16**

** — Highly significant differences among treatment means ($P < 0.01$)

TABLE 9

Average Weekly Feed consumption Figures [gm] for Broiler Starter Chicks Fed Diets containing Graded Levels of Protein:

Experiment 2

Weeks	*Diets* 1	2	3	4
1	71.2	75.0	70.0	62.1
2	122.5	134.2	122.3	131.5
3	109.5	112.9	139.0	99.7
4	188.5	175.7	166.5	179.3
5	144.2	172.6	210.7	247.6
6	301.1	298.6	298.7	231.0
7	495.7	476.9	457.6	484.4
8	534.3	490.4	479.3	483.1
9	529.3	468.2	493.0	481.6
10	485.8	456.4	458.1	498.2
11	534.7	506.2	501.8	501.9
12	537.6	506.1	502.1	501.3

Summary of Average Daily Feed Consumed (gm)

Period	*Diets* 1	2	3	4	*SE Means*
0 - 6 Wks	23.32	23.07	23.26	24.98	1.076(NS)
7 - 12 Wks	74.38	65.76	68.85	70.25	4.544(NS)
0 - 12 Wks	48.27	44.43	46.07	47.62	2.801(NS)

NS — No significant difference among treatment means ($P < 0.05$)

TABLE 10

Average Weekly Feed Consumption Figures [gm] for Broiler Finisher Chicks Fed Graded Levels of Protein Expt. 3

	Diets			
Weeks	1	2	3	4
7	487.4	477.1	428.1	479.2
8	541.2	519.8	474.4	522.0
9	651.3	625.1	601.6	668.6
10	693.3	562.7	617.3	732.5
11	388.6	374.4	387.1	429.1
12	626.0	609.7	616.1	563.0

Summary of Average Daily Feed consumed [gm] and Feed/gain Ratio

	Diets				SE Means
	1	2	3	4	
Overall average daily feed consumed (g)	78.72	75.56	74.50	82.46	3.49(NS)
Overall Feed/Gain Ratio	3.39	3.41	3.24	3.38	0.22(NS)

NS = No significant differences among treatment means.

TABLE 11

Average Weekly Feed/Gain Ratio of Broiler Starter chicks fed Diets containing Graded Levels of Protein Expt. 1

	Diets					
Weeks	1	2	3	4	5	6
1	4.40	2.37	2.26	2.06	1.78	1.43
2	5.99	2.45	2.96	2.44	1.75	1.57
3	2.79	3.80	3.03	2.66	2.69	1.16
4	3.26	3.01	3.62	3.07	2.68	2.36
5	7.27	4.01	3.52	2.41	2.83	2.24
6	2.64	3.88	1.77	1.78	1.78	1.65
7	5.45	2.27	3.14	2.31	3.25	1.99
8	5.43	2.76	2.56	2.59	2.28	2.60
9	2.87	2.68	2.60	2.84	2.61	2.44
10	2.84	2.84	2.76	3.11	2.27	3.31
11	3.31	2.89	2.84	3.23	4.18	3.23
12	5.27	3.14	2.83	3.72	1.98	6.36

Summary of Average Feed/Gain Ratio

Period	Diets						SE Means
	1	2	3	4	5	6	
0 – 5 weeks	3.25a	3.13a	2.48b	2.2ab	2.16b	1.95b	0.207**
7 – 12 "	3.16b	2.82b	2.72b	2.62b	2.82ab	3.02ab	0.069*
0 – 12 "	3.25a	2.89b	2.67b	2.66b	2.72b	2.90a	0.055**

* — Signifies at treatment differences among the means ($P < 0.05$)
** — Highly significant differences among treatments ($P < 0.01$)
a,b,c,d Treatment means not followed by the same superscripts are significantly different

In experiment 2, there were no significant differences in the average amounts of feed consumed/day among the different treatments (table 9) in any of the periods considered. Although the best consumed diet was diet 4 (26% protein) in the first period (1-6 weeks), diet 1 (20% protein) was best consumed in the periods 7 to 12 weeks and 0 to 12 weeks.

In the broiler finisher experiment (trial 3), the best consumed diet was the 20% protein diet (diet 4). The average daily feed consumption figures were close for all the treatments and the differences among them were not statistically significant as shown in table 10.

Average Weekly Feed/Gain Ratios

A summary of the weekly feed/gain ratios for all the treatments in experiment 1 appear in table 11. In the first period (0-6 weeks) the best utilized diet was diet 6 which had significantly better feed/gain ratio than those on diets 1 and 2. ($P<0.01$) but not diets 3,4 and 5. In the second period (7-12 weeks), birds on diet 3 (18% protein) had the lowest ratio which was significantly lower than that of the birds on diet 1 ($P<.05$) but not significantly lower than those on diets 2, 4, 5 and 6 ($P<0.05$). Considering the entire 0 to 12 weeks period, birds on the 18% protein diet also had the best ratio, which was also significantly better than the ratio for the birds on diet 1, ($P<0.01$) but not significantly better than the ratios for birds on diets 2, 4, 5 and 6 ($P<0.05$).

In experiment 2, although the best utilized diet was diet 4 with 26% protein, in the periods 0 to 6 and 0 to 12 weeks (table 12) all the feed/gain ratios were very close and were, therefore, not significantly different from one another.

The overall feed/gain ratios for birds on the finisher diets (experiment 3) appear at the bottom of table 10. The best utilized diet was the 18% protein diet, but the ratios were also very close and not significantly different from one another.

TABLE 12

Average Weekly Feed/Gain Ratios of Broiler Starter Chicks fed Diets containing Graded Levels of Protein: Expt. 2

	Diets			
Weeks	1	2	3	4
1	1.66	1.50	1.62	1.38
2	2.01	1.80	1.84	1.98
3	1.81	1.52	1.48	1.22
4	1.39	2.68	2.29	1.60
5	1.52	1.80	2.15	2.15
6	2.42	2.54	2.17	2.16
7	2.20	3.20	2.85	2.73
8	2.45	3.78	3.18	3.19
9	4.33	3.61	3.04	3.00
10	3.80	3.25	3.51	3.98
11	4.29	4.02	3.43	3.52
12	4.63	5.03	5.10	5.42

Summary of Feed/Gain Ratios

Periods	*Diets*				*SE Means*
	1	2	3	4	
0 - 6 weeks	2.05	2.03	1.97	1.86	0.098(NS)
7 - 12 weeks	3.87	3.49	3.34	3.40	0.238(NS)
0 - 12 weeks	3.19	2.96	2.84	2.79	0.173(NS)

NS = No significant differences among treatment means.

Mortality Rates

A summary of the mortality rates, expressed as percentages of the initial numbers of birds per treatment at the commencement of the experiment appear in table 13. This exercise was carried for experiment 1 only, but observations were made on subsequent trials. These figures showed that the mortality rates of birds on diets 1 and 2 were highest, being significantly higher than those on all other diets ($P<0.01$). The third highest mortality rate was obtained from birds on diet 2, and this was also significantly higher than the rates obtained for birdson diets 4, 5 and 6 ($P<0.01$). The lowest mortality percentage was obtained from birds on diet 6, closely followed by that for birds on diet 5, although the difference between these two was significant ($P<0.05$). In nearly all cases, most of the birds that died did so within the first 6 weeks, but post mortem examinations of the dead birds were not done because many of them died shortly after the attendants had gone home and had therefore, significantly deteriorated before the following day to render them useless for such meaningful examinations. The clear trend in the mortality rate was that of decreased mortality as the percentages of protein in the diets increased.

Average Nitrogen Retention

This was done also on the birds in experiment 1 and the closeness of the figures obtained (table 13) discouraged further investigations on subsequent trials. Nevertheless, the trend observed was that of slightly increasing percentages of nitrogen retained as the dietary protein levels increased up to 22% with the highest percentage nitrogen retained, followed by a decline at 24% crude protein level. The percentages were close and not significantly different from one another.

TABLE 13

Average Mortality and Apparent Nitrogen Retention Figures for Broiler Starter Chicks Fed Diets containing Levels of Protein: Experiment 1

Diets	*Mortality* 0-6 *Weeks*	7-12 *wks*	0-12 *wks*	*Apparent Nitrogen Retained (%)*
1	41.82c	44.44b	67.29d	40.98
2	42.02c	26.58b	63.85d	41.98
3	27.31b	10.45	34.80c	43.78
4	14.69a	6.84a	20.35b	47.35
5	13.64a	3.43a	16.67b	42.62
6	6.03a	0.00a	6.03a	45.03
S E Means	3.56**	4.47**	2.08**	2.15 (NS)

** Highly significant differences among treatment means ($P < 0.01$)
NS — No significant differences among treatment means ($P > 0.05$)
a,b,c,d. Treatment means not underscored by the same superscripts are significantly different from one another ($P < 0.05$ or $P < 0.01$)

DISCUSSION

The data and illustrations presented in these studies show the following (a) the broiler chicks used grew at a relatively poor rate within the first six weeks of life than the birds reared in the temperate environment even when the protein levels were good (b) during the period 7 to 12 weeks of life, the birds grew at rates comparable to those that have been obtained in the temperate countries when the dietary protein levels were adequate; (c) the broiler chicks used in these studies consumed less feed than their temperate counterparts during their first six weeks of life, but gradually increased their feed

consumption during the 7 to 12 weeks, periods of life, even though these figures were still relatively lower than expected, and lower than the recommended rates by the ARC (1963) and NRC (1971) (d) the feed/gain ratios were good and comparable to the values reported in the literatures on good diets, but were poor on inadequate protein diets, especially during the first six weeks of life, and (e) low protein diets encouraged high mortality rates especially in the first six weeks of life also.

Of particular interest in these studies were the comparative responses of the chicks between 0-6 weeks and 7 to 12 weeks. While differences were expected between them, they were not expected to be so large, and when the graphs of the cummulative weight gains and weekly gains are closely scrutinized, (figs 1 & 2) it becomes very clear that the period between 0 to 6 weeks is the one to pay very stringent attention to nutritionally if progress in broiler production is expected to be made. These studies revealed, among other things, that even the feeding of the usually recommended 20% protein diet (ARC, 1963; Bolton, 1967, NRC, 1971) or higher levels failed to produce gains comparable to those usually obtained in the temperate countries. The most satisfactory growth responses at this critical period were obtained at the 24% to 26% crude protein levels which are far in excess of the recommended levels.

Plausible explanations for this low growth rate may be found in the abnormally low daily feed intake of the birds when compared with the recommended daily nutrient requirements for broiler chicks at various ages (NRC, 1971), and probably also due to poorer quality protein and the lower metabolizable energy densities of the diets. In fact, even on the best consumed diet, the daily feed intakes per bird within the periods 0 to 6 weeks and 7 to 12 weeks were only about half the recommended daily allowances. Obviously with such low feed intakes, growth is expected to be small. What then comes to mind is why the intake should be so small. The balance of amino acids in the diet is a possible cause but in these studies, attempt was made to have equal proportions of the amino acids as mentioned earlier on all the protein levels so as to remove the influence of this variable (see table 4). Once this was taken care of, then the absolute quantities of the essential amino acids particularly those of lysine, methionine and tryptophan, as well as the differences in protein levels are the other probable causes of the low intakes. As for the protein levels, the trend was clearly established that the higher the dietary protein level, the higher the amount of feed consumed. With respect to the absolute amounts of the essential amino acids, table 3 shows that all the high protein diets (diets 4, 5, 6 and 7 with 18, 20, 22, 24 and 26% protein respectively) contained enough of the essential amino acids at the recommended levels except methionine, and since it has been well documented that methionine is usually the most limiting amino acid in the diets of chicks and that its deficiency not only depresses feed intake but also growth rate (Carew and Hill, 1961; Klain, Scott and Johnson, 1960; Nelson Young, Bradfield, Anderson, Norris, Hill and Scott, 1960, and Bornstein and Lipstein, 1964, 1966) its deficiency in these studies reported here could be a major factor contributing to the low feed intake and poor growth rate. Further investigations are going on along these lines. And with respect to the metabolizable energy densities of the diets, this factor could also be very potent because although the caloric densities of the diets compared favourably well with those recommended levels, the actual amounts of the energy ingested daily fell below the recommended amounts primarily because the absolute amounts of daily feed intake were very low.

The feed/gain ratios progressively improved as the dietary protein levels increased as expected, and these absolute ratios on the high protein diets also compared favourably well with those reported by other workers and even showed some improvement (Payne and Lewis, 1963; Carew and Hill, 1961) primarily because of the very much reduced feed intake by the birds in these studies. In addition, the usual decline in feed conversion efficiencies as the birds mature was well demonstrated in these studies, the feed/gain ratios being higher for the 7 to 12 weeks period than

the 0 to 6 weeks period. The abnormally high percentage mortalities on the low protein diets also confirmed the widely accepted fact that good quality and quantity of protein are needed by the animal to keep it in a good disease — fighting state.

Finally, the broiler finisher stage presented fewer problems than those encountered the starter period. All the performances were reasonably good although still lower than the performances reported in the literatures mentioned earlier. It is believed that if the birds could be given much better start at the starter period, then the results obtained for the finisher period would be better still. If all those performance characteristics are considered together, it will be difficult to really select the minimum protein level since there were no significant treatment differences in them. All things considered, the feeding of an 18% crude protein diet world probably be the recommendation for the broiler finisher period, although it might still be fairly safe to go as low as 16%. But if the chicks were not well fed in their starter period, then the feeding of 18% to 20% crude protein diet would be recommended under the tropical environment.

By making the recommendation of a minimum of 24% crude protein for the broiler starter and 18% for the broiler finisher in the tropics, it is realised that such recommendations may change, depending on the protein qualities of the ingredients that make up the diets. If the ingredients are rich in methionine or methionine is added in the diet during mixing slightly lower levels of protein might be adequate.

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