HIGH-PROTEIN WHEATS IN POULTRY DIETS

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SUMMARY

Experiments on high-protein wheats in poultry diets have been carried out. Assays with broiler chicks indicated that lysine was the only limiting amino acid for growth on diets based on wheat containing crude protein (CP) greater than 16%. Threonine was found to be the second limiting amino acid for growth after lysine in diets based on wheat containing CP less than 16%. However, growth on the wheat-based diets did not equal that on the commercial, control diet.

Experiments designed to determine the interaction of dietary-protein level and lysine requirement of broiler chicks, using wheat-based diets, showed that lysine requirement of chicks for maximum growth increased linearly as the dietary CP level increased in the range 12 to 26%. The results also highlight the importance of amino acid balance (relative to lysine) in broiler diets.

In a layer experiment, lysine and/or methionine supplementation to the basal diets based on 13.7, 16.2 and 16.5%-CP wheats (as fed) containing lysine and methionine at 90% of the layer requirement did not generally elicit significant responses either on hen-day (HD) egg production (%), egg weight (g) or egg mass (g/b/d). Intakes of 396 and 825 mg/b/d of methionine and lysine respectively, were sufficient to maintain maximum laying performance. Layer diets, based on high-protein wheats with very little contribution of other protein sources, yield egg productions as efficient as on commercial layer crumbles.

INTRODUCTION

The use of high-protein wheat in poultry diets has been studied widely by many workers. Simmond (1962) reported that as the protein level of cereals increases, the lysine content (%) of this extra protein decreases, resulting in a greater possibility of a lysine deficiency when high-protein wheats predominate in practical poultry diets. Biely (1969), Turner (1970), Turner and Payne (1971) and Gardiner and Dubetz (1977) found that lysine was the first limiting amino acid in wheat protein for poultry and threonine was second limiting (Toepfer et al. 1972). In contrast, Gardiner and Dubetz (1977) found that methionine in wheat protein was the second limiting amino acid for poultry. In studies with rats, Ivan and Farrell (1975) found that lysine was the only limiting amino acid for rats in

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diets based on wheat -containing 17% CP.

Experimenting with laying hens, Turner (1970) concluded that high-protein wheat could be the sole protein.. source in laying diets when supplemented with lysine. The work of Turner and Payne (1971) confirmed that diets containing high-protein wheat (17.5% CP) supported egg-product ion equal to that on diets containing 10.7% CP. It was reported by Gardiner and Dubetz (1974) that diets containing a 19.7% CP wheat supplemented with lysine supported growth of broiler chicks as well as did traditional diets. Gardiner and Dubetz (1977) were in agreement with Turner (1970) in that high-protein wheats could be used as the sole protein source in laying diets when supplemented with lysine.

Studies on the amino acid requirements of chicks have been made by many workers (Almquist 1947 ; Grau 1948 , Almquist 1952 ; Nelson et al. 1960 ; Klain et al. 1960 ; Dobson et al. 1964 ; Dean and Scott 1965 ; Gous and Morris 1985). Grau (1948) and Almquist (1952) found that as the protein level of the diet increases, the lysine requirement for maximum growth at a particular protein level also increases when expressed as a percentage of the diet. Recent experiments conducted by Morris et al. (1987) concluded that the requirement of lysine by the chick is a simple linear function of the dietary protein content.

The objectives of these current experiments were (i) to determine the sequence of amino acids limiting broiler growth, (ii) to study the influence of protein levels on lysine requirement of the chicks using wheat-based diets, and (iii) to examine the use of high-protein wheats in laying diets.

MATERIALS AND METHODS

Experiment 1: broiler growth on different wheat-based diet

One hundred and twenty eight male, one-day-old broilers of a commercial strain were used in each of these experiments. The chicks were segregated on the basis of live weight into groups of eight chicks, and given one of four experimental diets, in four replicates. They were grown to 15 d in Experiments 1.1 and 1.2, and to 12 d in Experiments 1.3 and 1.4. The chicks were housed in electrically heated four-deck battery brooders with wire-mesh floors, and illumination was cont inous. Feed and water were supplied ad libitum. The chicks and uneaten feed were weighed at the end of the experiment.

Four basal diets, formulated to be deficient in lysine, methionine and threonine, contained mainly four different wheats. All diets were of equal energy and CP and were fed in mash form. Composition of the basal diets and calculated amino acid contents are presented in Tables 1 and 2 respectively. Synthetic L-lysine (L) alone or plus DL-methionine (M) or plus DL-methionine and L-threonine (T) were added to the basal diets to satisfy the chick's requirement (SCA 1987). Commercial broiler-starter crumbles obtained from Fielders Agricultural Products, Tamworth, were used as the control diet.It should be noted that NaCl was added to diets 1.3 & 1.4 but not to diets 1.1 & 1.2

Table 1, Composition (g/kg) of basal diets for Experiments 1.1 to 1.4.

	Experiments			
	1.1	1.2	1.3	1.4
Wheat (15.4% CP)	870.0	-	-	-
Wheat (17.3% CP)	-	900.0	=	=
Wheat (16.2% CP)	-	-	787.0	-
Wheat (16.5% CP)	-	-	-	787.0
Meat and bone meal	100.0	100.0	100.0	100.0
Soybean meal	30.0	-	100.0	100.0
Sunflower oil	-	-	10.0	10.0
Sodium chloride	-	-	3.0	3.0
Vitamins & minerals mix.	2.5	2.5	2.5	2.5
Determined nutrient content (on air-dry basis):				
Dry matter (%)	87.1	88.6	87.5	89.3
Crude protein (%)	20.0	20.6	21.0	22.0
ME (MJ/kg)	12.7	12.8	12.8	12.8

Table 2. Amino acids contents (% , on air-dry basis based on determined values for individual dietary ingredients) of basal diets for Experiments 1.1 to 1.4 and amino acid requirement of chicks 0-4 weeks (SCA 1987).

	Experiments				Requirement (SCA 1987)
	1.1	1.2	1.3	1.4	
Arginine	1.08	1.06	1.20	1.26	1.02
Glycine	1.35	1.32	1.38	1.46	-
Serine	0.96	0.98	0.93	0.99	-
Histidine	0.40	0.38	0.45	0.45	0.39
Isoleucine	0.62	0.63	0.74	0.78	0.67
Leucine	1.28	1.34	1.41	1.49	1.46
Lysine	0.77	0.71	0.87	0.92	1.13
Methionine	0.32	0.33	0.33	0.34	0.45
Cystine	0.34	0.35	0.34	0.38	0.75
Met + cystine	0.66	0.68	0.67	0.72	1.20
Phenylalanine	0.89	0.85	0.93	0.98	0.79
Tyrosine	0.58	0.54	0.59	0.62	0.56
Phe + tyrosine	1.47	1.39	1.52	1.60	1.35
Threonine	0.57	0.57	0.59	0.59	0.68
Tryptophan	0.19	0.19	0.22	0.23	0.21
Valine	0.80	0.81	0.84	0.94	0.90

The data obtained were subjected to analysis of variance using the NEVA program (Burr 1980) and Duncan's multiple-range test (Steel and Torrie 1960) was used to determine differences between means.

Experiment 2 : effect of altering lysine and protein contents of broiler diets

Experiments 2.1 and 2.2 were designed to measure chick growth rate and feed-conversion ratio on 20 diets containing 5 dietary lysine concentrations (g/kg CP) at each of 4 dietary-protein levels, using wheat-based diets.

Six hundred and forty male, one-day-old broilers of a commercial strain were used in each of the two experiments. The chicks were segregated on the basis of live weight into groups of 8 chicks, and were fed *ad libitum* on dry-mash experimental diets with water continously available, in four replicates. Diets were introduced at one day of age and fed to 21 d. Chicks and uneaten feed were weighed at days 7 , 14 and 21. Data obtained at 21 d were subjected to analysis of variance using the NEVA program (Burr 1980) and Duncan's multiple-range test (Steel and Torrie 1960) was used to determine differences between means,

In Experiment 2.1, diets varying in CP contents were obtained by formulating a summit diet (260 g CP/kg) and a basal diet (140 g CP/kg). The range of protein levels tested was from 260 g CP/kg down to 140 g CP/kg, in increments of 40 g CP/kg. The summit diet was formulated by fixing the lysine content at 11.2 g/kg diet (43 g lysine/kg CP) and all other essential amino acids at not less than 1.4 times the chick's requirement (SCA 1987). The range of lysine contents was from 43 g/kg CP to 63 g/kg CP in increments of 5 g/kg CP.

In Experiment 2.2, the summit diet was formulated to be 240 g CP/kg and the basal diet was 120 g CP/kg, to give a range of protein levels from 240 g CP/kg down to 120 g CP/kg with increments of 40 g CP/kg. The summit diet was formulated by fixing the lysine content at 11.3 g/kg diet (47 g lysine/kg CP) and all other essential amino acids at as close as possible to those of the chick's requirement (SCA 1987). The range of lysine contents was from 47 g/kg CP to 63 g/kg CP in increments of 4 g/kg CP. Glycine was incorporated in the summit diet to achieve N content equal to 240 g CP/kg but all other essential amino acids remain as close as possible to those of the chick's requirement (SCA 1987).

In both experiments, diets with intermediate protein levels were formulated by blending together the summit and basal diets in appropriate portions. All diets in both experiments were formulated to contain 13.0 MJ ME/kg. Composition of the summit and basal diets of both experiments and calculated amino acid contents are presented in Table 3.

Table 3, Composition (g/kg) of summit and basal diets and amino acids contents (% , on air-dry basis based on determined values for individual dietary ingredients) for Experiments 2.1 and 2.2.

	Experiment 2.1		Experiment 2.2	
	Summit	Basal	Summit	Basal
Blood meal	30.0	10.0	30.0	1.0
Field peas	60.0	30.0	40.0	1.0
Sweet lupins	30.0	30.0	40.0	1.0
Meat and bone meal	80.0	30.0	100.0	1.0
Wheat gluten	130.0	50.0	30.0	1.0
Corn starch	157.2	217.5	-	76.7
Wheat (17.3% CP)	502.5	-	688.0	520.0
Wheat (10.4% CP)	-	604.5	-	-
Sorghum	-	-	62.8	356.0
Sunflower oil	3.5	8.0	2.0	9.0
Dicalcium phosphate	-	-	-	12.0
Calcium carbonate	-	14.5	-	15.0
Sodium chloride	3.0	3.0	1.0	3.0
Vitamin & mineral premix.	5.0	5.0	5.0	5.0
L-lysine	1.5	1.1	2.5	3.0
DL-methionine	1.1	0.7	0.6	0.3
L-threonine	1.2	0.7		-
Glycine	-	-	3.1	-
Determined nutrient content (on air-dry basis):				
Dry matter (%)	91.5	90.7	94.4	94.2
Crude protein (%)	25.8	14.1	24.2	12.4
ME (MJ/kg)	12.6	12.8	13.0	12.9
Calculated amino acids contents (% , on air-dry basis):				
Arginine	1.42	0.78	1.29	0.50
Glycine	1.07	0.56	1.36	0.45
Serine	0.64	0.35	0.66	0.38
Histidine	0.70	0.34	0.53	0.24
Isoleucine	0.87	0.49	0.69	0.41
Leucine	1.89	0.98	1.67	0.95
Lysine	1.12	0.60	1.14	0.55
Methionine	0.71	0.36	0.35	0.20
Cystine	0.46	0.27	0.33	0.20
Met + cystine	1.17	0.63	0.68	0.40
Phenylalanine	1.43	0.68	1.08	0.53
Tyrosine	0.83	0.40	0.62	0.38
Phe + tyrosine	2.26	1.08	1.70	0.91
Threonine	0.94	0.50	0.70	0.33
Tryptophan	0.29	0.15	0.24	0.12
Valine	1.16	0.63	0.99	0.49

Experiment 3 : egg production

Two hundred and forty one-day-old single comb White Leghorn x New Hampshire (SCWL x NH) and two hundred and forty Black

Australorp (SIRO-CB) brown-egg layers, of the same age, were reared in floor pens with electrically heated brooders. Commercial starter crumbles obtained from Fielders Agricultural Products, Tamworth, were offered *ad libitum* in galvanized-iron suspended feeders to six weeks of age. Grower crumbles, from the same feedmill, were then provided *ad libitum* to eight weeks of age, and then in restricted amounts to the onset of lay (18 weeks of age). Water was continously available. The chicks were vaccinated against Marek's disease and were beak-trimmed at the hatchery.

At 18 weeks of age, the pullets were housed in single-bird cages in a naturally-ventilated, enclosed shed and had access to experimental diets in a feed trough common to five cages. Water was provided at all times and illumination was 16 h a day.

Three basal diets, based on three different wheats (WL, 13.7% CP; WH 16.2% CP and WT, 16.5% CP on air-dry basis) were formulated to be 13.0 MJ ME/kg and 16.5% CP by fixing the lysine and methionine contents at 90% of the recomended requirement for layers (SCA 1987). Composition of the basal diets and its calculated nutrient content are presented in Table 4. Shown in Table 5 are the amino acids contents based on determined values for individual dietary ingredients.

Table 4. Composition (g/kg) of the basal diets for Experiment 3.

	Basal 1	Basal 2	Basal 3
Wheat WL (13.7% CP)	788.2	-	-
Wheat WH (16.2% CP)	-	838.9	-
Wheat WT (16.5% CP)	-	-	838.9
Protein concentrate*	150.0	77.0	77.0
Sunflower oil	15.0	20.0	20.0
Sodium chloride	3.0	3.0	3.0
Calcium carbonate	40.0	44.0	44.0
Dicalcium phosphate	-	12.5	12.5
L-lysine	1.5	2.3	2.3
DL-methionine	1.1	1.1	1.1
Vitamin & mineral mix.	2.0	2.0	2.0
Determined nutrient content (on air-dry basis):			
Dry matter (%)	92.2	93.2	91.0
Crude protein (%)	16.5	16.3	16.5
Fat (%)	4.3	4.1	4.0
ME (MJ/kg)	12.4	12.2	12.0

* Comprised of 50% meat & bone meal, 20% sweet lupins and 30% field peas.

Table 5. Amino acid contents (%, on air-dry basis based on determined values for individual dietary ingredients) of basal diets for Experiment 3.

	Basal diets		
	1	2	3
Arginine	0.89	0.82	0.87
Glycine	1.01	0.81	0.89
Serine	0.27	0.29	0.21
Histidine	0.29	0.28	0.28
Isoleucine	0.50	0.49	0.54
Leucine	1.03	1.02	1.09
Lysine	0.68	0.69	0.69
Methionine	0.33	0.33	0.35
Cystine	0.27	0.27	0.31
Met + cystine	0.60	0.60	0.66
Phenylalanine	0.58	0.60	0.60
Tyrosine	0.38	0.38	0.38
Phe + tyrosine	0.96	0.98	0.98
Threonine	0.45	0.44	0.46
Tryptophan	0.16	0.16	0.17
Valine	0.57	0.58	0.68

Each of the basal diets was then divided into four fractions into which synthetic L-lysine or DL-methionine or a combination of both were added to cover 110% of requirement for both amino acids, to give a 2 x 3 x 2 x 2 factorial design (2 strains, 3 different wheats, 2 levels; of lysine and 2 levels of methionine). Commercial layer crumbles were used as the control diet. Details of the test diets are given in Table 6.

Table 6, Details of the treatment diets for Experiment 3.

Diet:	Treatment:
1	Basal diet 1
2	Diet 1 + L-lysine
3	Diet 1 + DL-methionine
4	Diet 1 + L-lysine + DL-methionine
5	Basal diet 2
6	Diet 5 + L-lysine
7	Diet 5 + DL-methionine
8	Diet 5 + L-lysine + DL-methionine
9	Basal diet 3
10	Diet 9 + L-lysine
11	Diet 9 + DL-methionine
12	Diet 9 + L-lysine + DL-methionine
13	Commercial layer crumbles (control)

Measurements commenced at 20 weeks and finished at 60 weeks of age. Feed consumption (g/d), lysine and methionine intakes (mg/d) were calculated every four weeks. Hen-day egg production (%) was recorded for each one-week period. Egg mass (g/b/d) was measured weekly from a one-day collection. Egg specific gravity was determined by flotation in saline solutions ascending from 1.060 to 1.090 specific gravity in increments of 0.005 (Voisey and Hamilton 1977) and was observed every four weeks from a three-day egg collection. The birds were weighed every eight weeks and mortality was recorded daily.

The data obtained were subjected to analysis of variance using the NEVA program (Burr 1980) and Duncan's multiple-range test (Steel and Torrie 1960) was used to determine differences between means.

RESULTS AND DISCUSSION

Experiment 1 : broiler growth on different wheat-based diets

Body weight gain (BWG,g/d) and feed-conversion ratio (FCR, feed/gain) of Experiments 1.1 to 1.4 are presented in Table 7.

Table 7. Mean ± SD of weight gain (BWG , g/d) and FCR (feed/gain) of broilers grown from 1 to 15 d in Experiments 1.1 and 1.2 , and from 1 to 12 d in Experiments 1.3 and 1.4 fed basal diet supplemented with L-lysine (L) , DL-methionine (M) , and L-threonine (T) .

Treatment	BWG	FCR
Wheat 15.4% CP (Experiment 1.1)		
Basal	5.9 ± 0.26[a*]	2.3 ± 0.16[a]
Basal + L	11.7 ± 0.38[b]	1.6 ± 0.03[b]
Basal + L + M	11.4 ± 0.42[b]	1.6 ± 0.01[b]
Basal + L + M + T	12.6 ± 0.67[c]	1.6 ± 0.04[b]
Control	21.2 ± 0.54[d]	1.2 ± 0.02[c]
Wheat 17.3% CP (Experiment 1.2)		
Basal	4.7 ± 0.72[a]	2.4 ± 0.18[a]
Basal + L	10.5 ± 1.00[b]	1.7 ± 0.06[b]
Basal + L + M	11.3 ± 1.20[b]	1.6 ± 0.20[b]
Basal + L + M + T	11.2 ± 0.75[b]	1.7 ± 0.09[b]
Control	21.2 ± 0.54[c]	1.2 ± 0.02[c]
Wheat 16.2% CP (Experiment 1.3)		
Basal	9.2 ± 0.27[a]	1.9 ± 0.08[a]
Basal + L	15.8 ± 1.01[b]	1.5 ± 0.06[b]
Basal + L + M	15.7 ± 1.24[b]	1.5 ± 0.02[b]
Basal + L + M + T	16.6 ± 0.93[b]	1.4 ± 0.18[c]
Control	18.0 ± 0.11[c]	1.4 ± 0.02[c]
Wheat 16.5% CP (Experiment 1.4)		
Basal	9.3 ± 0.42[a]	2.0 ± 0.26[a]
Basal + L	15.1 ± 1.57[b]	1.5 ± 0.10[b]
Basal + L + M	15.1 ± 0.32[b]	1.5 ± 0.02[b]
Basal + L + M + T	15.7 ± 0.76[b]	1.5 ± 0.10[b]
Control	18.0 ± 0.11[c]	1.4 ± 0.02[c]

* Values within a column with different superscripts (a-d) differ significantly (P<0.05).

There were significant differences (P<0.01) in both BWG and FCR in all experiments. Only in Experiment 1.1 was there a response to an amino acid other than to lysine. In all cases supplementation did not increase growth or improve FCR to that on the commercial diets.

In all experiments, lysine supplementation increased BWG significantly (P<0.01). This indicates that lysine was the first limiting amino acid in the basal and is in agreement with data of Biely (1969), Turner and Payne (1971) and Gardiner and Dubetz (1977) for poultry, and Ivan and Farrell (1975) for rats.

Methionine supplementation tc the basal diet, together with lysine, did not produce any significant difference either in BWG or FCR in all experiments, Threonine addition to the basal diet, together with lysine and methionine in Experiment 1.1, increased BWG significantly (P<0.01), but did not improve FCR. In Experiments 1.2, 1.3 and 1.4 neither methionine supplementation nor threonine addition to the basal diet together with lysine improved BWG and FCR. It can be concluded from these experiments that methionine was not the second limiting amino acid for growth after lysine in the test diets. Threonine may be the. second limiting amino acid after lysine in diets based on wheats containing less than 16% CP. Neither methionine nor threonine was the second limiting amino acid for growth in diets base6 on wheats containing CP greater than 16%. Ivan and Farrell (1975) reported that lysine was the only limiting amino acid in wheats containing CP greater than 17%, for rats. In all of these experiments, the highest BWG and the best FCR were achieved on the commercial control diet. This was partly due to its form; intake of crumbles is usually higher than that of mash.

There is also reason to believe that diets 1.1 & 1.2 were suboptimal in NaCl. In Experiments 1.3 & 1.4 with added NaCl a small growth response on the basal diets (Table 7) was obtained. In these latter experiments differences in growth rate and FCR between the control and supplemented groups were small although still significant (P<0.05). It appears that there is not only a single amino acid or a combination of essential amino acids in wheat protein limiting broiler growth, but other factors which these experiments failed to identify.

Experiment 2 : effect of altering lysine and protein contents of broiler diets

Mean ± SD of BWG (g/d) and FCR (feed/gain) of broilers in Experiments 2.1 and 2.2 are presented in Tables 8 and 9 respectively.

In both experiments BWG increased and FCR improved significantly (P<0.01) as protein levels increased. In Experiment 2.1, irrespective of protein level, lysine supplementation generally increased BWG and improved FCR significantly (P<0.01). In Experiment 2.2, however, the pattern of response to dietary lysine on each dietary-protein level both in BWG and FCR was not consistent. On diets containing 12% CP, lysine supplementation did not increase BWG , but improved FCR significantly ($P<0.01$). On diets containing 16 , 20 and 24% CP , lysine supplementation generally did not consistently increase BWG nor improve FCR significantly ($P>0.05$). Lysine supplementation of the diet to give lysine concentration above 58 g/kg CP in Experiment 2.1 tended to depress BWG , and above 51 g/kg CP in Experiment 2.2 generally did not produce significant differences in either BWG or FCR.

Table **8.** Mean + SD of BWG (g/d) and FCR (feed/gain) of broilers in Experiment 2.1 (0 - 21 d).

Lysine (g/kg CP)	CP level (%) of diets. 14	18	22	26
		BWG		
43	6.9±0.64^{aA*}	9.7±0.45^{aB}	13.4±1.44^{aC}	17.6±0.51^{aD}
48	8.6±0.25^{bA}	13.2±1.05^{bB}	14.9±1.56^{abB}	20.5±2.47^{bC}
53	9.2±1.01^{bcA}	13.8±1.45^{bB}	19.3±1.80^{bC}	20.1±0.99^{bC}
58	9.8±0.87^{bcA}	15.9±0.77^{cB}	19.7±1.18^{bC}	21.6±2.02^{bC}
63	10.4±0.55^{cA}	15.9±0.95^{cB}	17.6±1.07^{bBC}	20.1±1.34^{bC}
		FCR		
43	4.1±0.35^{aA}	3.0±0.17^{aB}	2.4±0.26^{aC}	2.0±0.11^{aC}
48	3.3±0.45^{bA}	2.4±0.19^{bB}	2.2±0.28^{aB}	1.7±0.20^{abB}
53	3.2±0.19^{bA}	2.4±0.12^{bB}	1.7±0.17^{bC}	1.6±0.15^{bC}
58	2.7±0.25^{cA}	2.0±0.08^{cB}	1.7±0.08^{bBC}	1.6±0.14^{bC}
63	2.8±0.29^{bcA}	2.0±0.05^{cB}	1.8±0.08^{bB}	1.7±0.17^{abB}

* Values within a row (A-D) or within a column (a-c) with different superscripts differ significantly ($P<0.05$).

Table **9.** Mean ± SD of BWG (g/d) and FCR (feed/gain) of broilers in Experiment 2.2 (0 - 21 d).

Lysine (g/kg CP)	CP level (%) of diets. 12	16	20	24
		BWG		
47	7.1±0.69^{aA*}	12.2±0.64^{aB}	15.6±1.44^{aC}	19.3±1.08^{aD}
51	7.6±0.57^{abA}	14.0±1.55^{abB}	17.3±1.58^{abC}	20.0±1.77^{abC}
55	8.7±1.31^{bA}	14.8±1.31^{bB}	19.7±0.20^{bC}	21.6±0.72^{bD}
59	8.4±0.42^{abA}	15.0±1.24^{bB}	19.4±0.66^{bC}	22.6±1.29^{bD}
63	8.2±1.22^{abA}	13.6±1.58^{abB}	18.9±1.32^{bC}	19.7±0.63^{abC}
		FCR		
47	3.8±0.26^{aA}	2.2±0.13^{aB}	1.9±0.18^{aB}	1.7±0.20^{aC}
51	3.3±0.15^{bA}	2.0±0.08^{bB}	1.7±0.09^{aBC}	1.6±0.15^{aC}
55	2.8±0.38^{cA}	2.0±0.14^{bB}	1.7±0.06^{aB}	1.6±0.12^{aB}
59	2.7±0.07^{cA}	2.0±0.14^{bB}	1.7±0.12^{aC}	1.5±0.09^{bC}
63	3.4±0.41^{abA}	2.2±0.15^{aB}	1.7±0.14^{aC}	1.7±0.06^{aC}

* Values within a row (A-D) or within a column (a-c) with different superscripts differ significantly ($P<0.05$).

In both experiments, at each dietary protein level, growth reached a plateau at a lysine level where all other essential amino acids were balanced relative to lysine, and this indicates the importance of amino acid balance in diets. In Experiment 2.1, as lysine concentration increased from 43 to 58 g/kg CP , the amino acids relative to lysine came into balance. In Experiment 2.2, however, because all other amino acids in both the summit and basal diets were fixed at as close as possible to the amino acid balance required by the chicks, the amino acids relative to lysine tended to be increasingly out of balance as the lysine concentration in the diets increased from 51 to 63 g/kg CP. In Experiment 2.1 growth rates obviously reflected intake of lysine, and this finding is in agreement with that reported by Gous and Morris (1985).

Our datain Experiment 2.2 suggest that amino acid imbalance is the major cause of the increased lysine requirement with increasing dietary protein content. It is almost impossible to formulate all amino acid requirements to be in 'ideal' balance. It was for this reason that the maximum dietary crude protein was 24%.Even then it likely not all of the amino acids were in complete balance.

In order to estimate the lysine dose-response giving maximum BWG or maximum efficiency of feed utilization, quadratic curves of BWG and FCR on lysine level (g/kg diet) of each dietary protein level (%) were fitted (Fig. l-4).

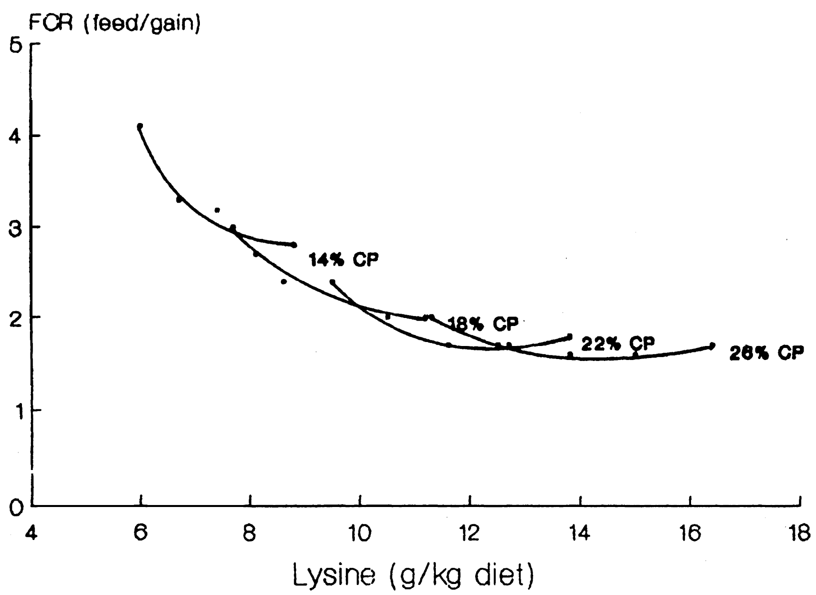

Figure 1. Response of FCR to dietary-lysine concentration (g/kg diet) in Experiment 2.1.

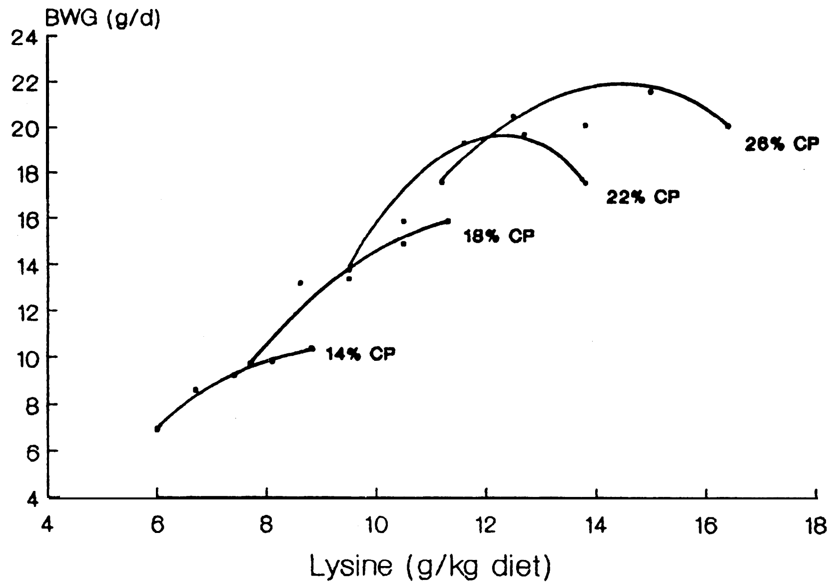

Figure 2. Response of BWG to dietary-lysine concentration (g/kg diet) in Experiment 2.1

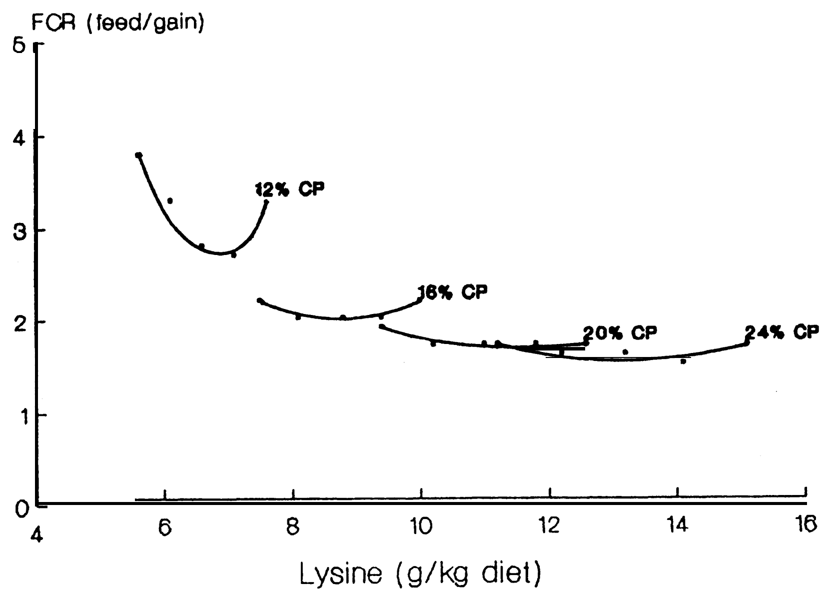

Figure 3. Response of FCR to dietary-lysine concentration (g/kg diet) in Experiment 2.2.

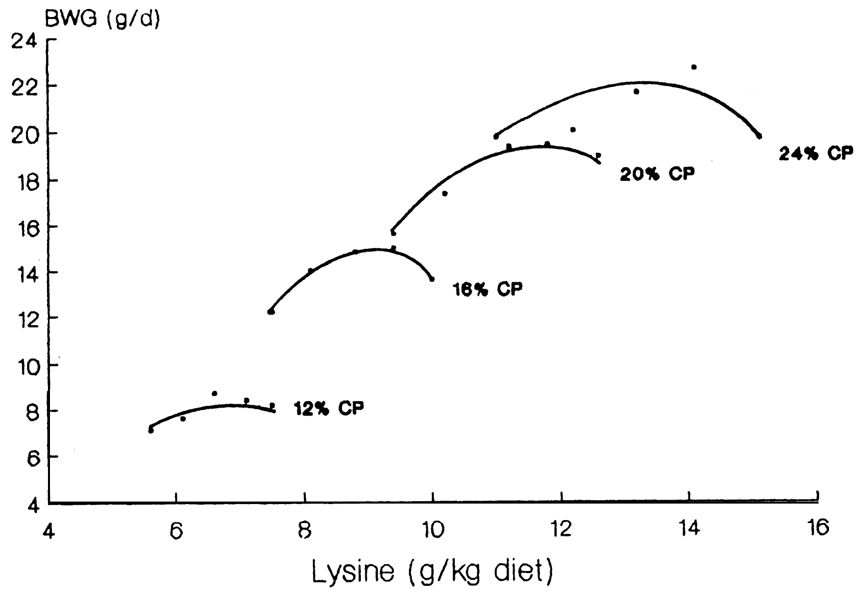

Figure 4. Response of BWG to dietary-lysine concentration (g/kg diet) in Experiment 2.2.

In Experiment 2.1 there were significant quadratic responses in both BWG and FCR to increasing dietary lysine concentration at each dietary protein level with the exception of BWG at 26% CP. In Experiment 2.2, however, the pattern of response to dietary lysine concentrations, as already mentioned, was not consistent. When lysine requirement (Y , g/kg diet) was regressed against protein levels (X , %), the lysine required (g/kg diet) to maximize both BWG and FCR was linear to protein level of the diets (Fig. 5-6). The linear regression equations were :

For maximum BWG :

Experiment 2.1 , $Y = 1.275 + 0.522\ X$ (1)
SD = 0.621 0.030
$R^2 = 0.99^{**}$

Experiment 2.2 , $Y = -0.640 + 0.605\ X$ (2)
SD = 0.839 0.045
$R^2 = 0.98^{**}$

For maximum FCR :

Experiment 2.1 , $Y = 0.075 + 0.572\ X$ (3)
SD = 0.135 0.006
$R^2 = 1.00^{**}$

Experiment 2.2 , $Y = -0.04 + 0.567\ X$ (4)
SD = 1.958 0.105
$R^2 = 0.93^{*}$

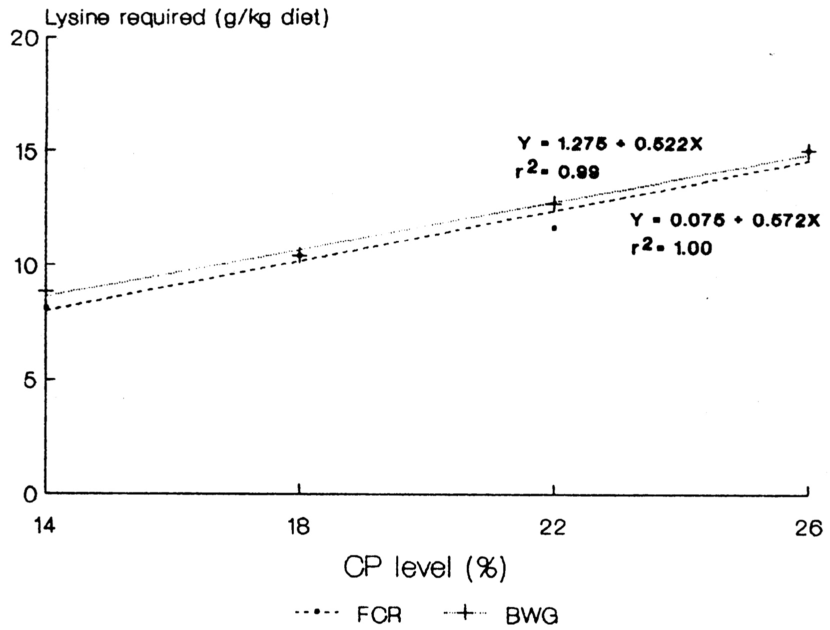

Figure 5. The regression of lysine required (Y) for maximum FCR (.) and BWG (+) on CP level (X) of the diet in Experiment 2.1

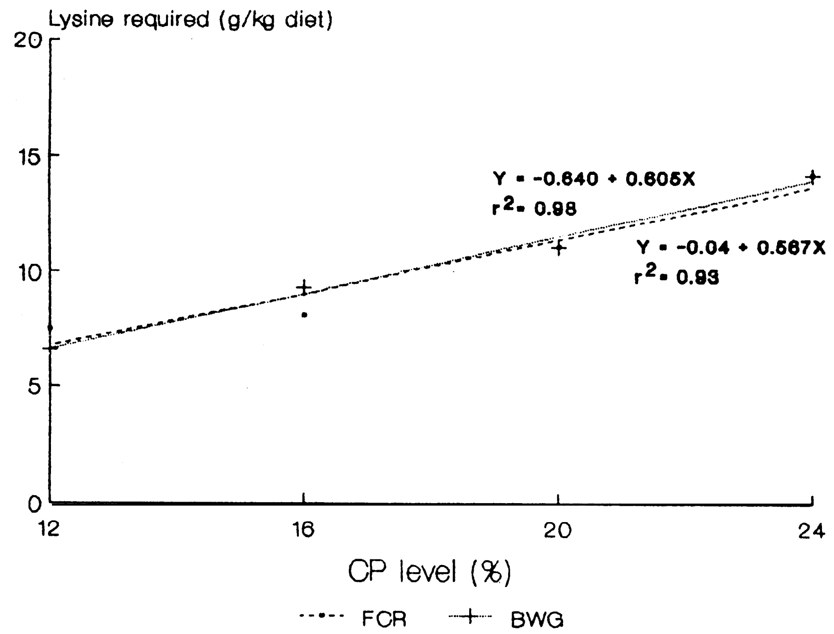

Figure 6, The regression of lysine required (Y) for maximum FCR (.) and BWG (+) on CP level (X) of the diet in Experiment 2.2

The slopes of the lines in Experiment 2.1 (Fig.5) are 53.4 and 57.2 g lysine/kg CP for BWG and FCR respectively. Since the intercepts were not significantly different (P>0.01) from zero, forcing the lines through the origin gives a slope of 57.5 and 57.6 g lysine/kg CP respectively for BWG and FCR. In Experiment 2.2 (Fig.6) the slope of the lines are 60.0 and 56.7 g lysine/kg CP for BWG and FCR respectively. The intercepts were also not significantly different (P>0.01) from zero, forcing the lines through the origin gives a slope of 57.8 g lysine/kg CP for BWG and 56.6 g lysine/kg CP for FCR. It can be concluded from this study that the lysine required for maximum BWG and the best FCR is 57.5 g lysine/kg CP. This finding is in agreement with that reported by Bdomgaardt and Baker (1973) and Morris (1989), but higher than that reported bv Morris *et al.* (1987) these were 57, 56 and 53 g lysine/kg CP respectively. This discrepancy may be due to difference in actual protein quality of the diets and possible to the strain of broiler used.

Morris (1989) has examined the interaction of lysine and arginine on the linear relationship between lysine requirement and dietary protein content. There was no effect on high or low dietary arginine levels on the lysine/protein relationship. Morris (1989) showed also for methionine and tryptophan linear relationship similar to that found previously between dietary lysine and crude protein.

In practical formulations, lysine requirement for chicks should be specified as a proportion of crude protein content rather than as a proportion of the diet *per-se*. From these studies lysine appears to be not more than 1.21% for each 20% of dietary crude protein at an ME of about 12.8 MJ/kg diet.

Experiment 3: egg production

Main effects of wheats, strains, lysine and methionine levels on intakes of layers and production performance are presented in Tables 10 and 11 respectively.

In general the HD egg-production (%) on all diets was acceptably high throughout the experimental period, with the exception that there was a slight drop in egg production at 40 to 44 weeks of age (late Dec.-late Jan.), Feed intake was gradually increased from 20 to 32 weeks of age, and was relatively stable from 32 weeks of age to the end of the experiment, with a slight reduction at 40 to 44 weeks of age. These results may be due to the higher environmental temperature during that period which were 29.2o-30.3oC for the maximum and 14.3o-15.0oC for the minimum. Three birds died during the experiment.

Birds on the 13.7% CP-wheat diets consumed significantly (P<0.05) less feed than those on the other diets. The likely explanation for this finding is the higher (12.4 MJ ME/kg) determined ME content of diets based on 13.7% CP-wheat. As a result of differences in energy content of the diets and daily feed intake, all birds on all wheats-based diets had consumed an equal amount of energy, which is 1.46 MJ ME/b/d. Because all wheats-based diets, by calculation, had equal content of lysine and methionine, consequently birds on the 13.7% CP-wheat diets also consumed significantly ($P<0.05$) less lysine and methionine than those on the other diets.

Table 10. Main effects of wheats , strains , lysine and methionine levels on intakes of layers from 20 to 60 weeks of age in Experiment 3.

Treatment	Feed intake g/b/d	ME intake MJ/b/d	Lysine intake mg/b/d	Methionine intake mg/b/d
WL	119*	1.45	912*	445*
WH	122	1.48	936	457
WT	122	1.45	937	457
LSD 5%	2.5	0.03	19.6	9.6
SIRO-CB	124**	1.50**	953**	465**
SCWL x NH	117	1.42	904	440
LSD 5%	2.1	0.02	16.1	7.8
L 90%	121	1.47	825**	455
L 110%	120	1.45	1032	450
LSD 5%	2.1	0.02	16.1	7.8
M 90%	120	1.45	924	396**
M 110%	121	1.47	932	509
LSD 5%	2.1	0.02	16.1	7.8

* Significant at $P<0.05$ ** Significant at $P<0.01$

Differences in these amino acids intakes did not elicit any significant differences in either HD-egg production (%), egg weight (g) or egg mass (g/b/d). This finding is probably due to the higher minimum lysine and methionine intakes (on the 13.7% CP-wheat diets) which were 912 and 445 mg/b/d respectively than the recomended levels (SCA 1987). Body weight gain was affected by wheats ; it decreased significantly ($P<0.01$) as wheat protein increased. The reason for this finding is unknown.

Lysine or methionine alone or in combination generally did not yield significant differences in hen performance. Two possible explanations for this are, firstly, the average lysine and methionine intakes were 825 and 396 mg/b/d in diets containing both amino acids at 90% of the laying's requirement (SCA 1987), are sufficient to maintain maximum egg production. Turner (1970) found that lysine supplementation to the basal diet comprised mainly of wheats as the sole protein source, increased HD-egg production to a level similar to those on the control diets, which was 67.5%. Since their experiment was run over 12 weeks and the birds were 24 weeks cf age when the experiment commenced, the HD-egg production of 80% should be expected. It was reported further that egg weight increased significantly by lysine supplementation. Unfortunately, Turner (1970) did not calculate intake of lysine, but since the lysine content of the basal diets was 80% of the laying requirement, this level was probably low enough to obtain responses to lysine Supplementation. Secondly, these results indicate that high-protein wheats (16.2 and 16.5% CP) have similar protein quality to normal wheats (13.7%). Karunaajeewa (1985) found that sprouted wheats also had a similar protein quality to normal wheats.

Table 11. Main effects of wheats, strains, lysine (L) and methionine (M) levels on production performance from 20 to 60 weeks of age in Experiment 3.

Treatment	HD-egg production (%)	Egg weight (g)	Egg mass (g/b/d)	Body weight gain (g/d)
WL	78.8	54.4	42.9	2.00*
WH	78.1	54.5	42.6	1.92
WT	78.8	54.4	42.8	1.91
LSD 5%	1.71	0.66	1.15	0.032
SIRO-CB	78.2	53.0*	41.4*	2.25*
SCWL x NH	78.9	55.9	44.1	1.63
LSD 5%	1.39	0.54	0.94	0.026
L 90%	78.4	54.5	42.7	1.77*
L 110%	78.7	54.4	42.8	2.11
LSD 5%	1.39	0.54	0.94	0.026
M 90%	78.4	54.3	42.5	1.98*
M 110%	78.7	54.6	43.0	1.90
LSD 5%	1.39	0.54	0.94	0.026
Control	77.6	55.3	42.9	2.40

* Significant at $P<0.01$

There was no significant difference in HD egg production (%) between strains. However, SIRO-CB birds laid significantly ($P<0.01$) smaller eggs than SCWL x NH. As a result, SIRO-CB birds also produced a significantly ($P<0.01$) lower egg mass. SIRO-CB birds consumed significantly ($P<0.01$) more feed and gained significantly ($P<0.01$) greater body weight than SCWL x NH. These findings are not surprising and are due to known strain differences in performance.

Egg specific gravity (not presented in a tabular form) on all diets declined from 1.0886 to 1.0755 as the birds aged but was not affected by supplementation of lysine or methionine. This finding is in agreement with that reported by Gardiner and Dubetz (1977).

There was also a significant interaction between strain x lysine on HD egg production and between strain x methionine on egg weight (Table 12). Lysine supplementation to the basal diets did not produce significant difference in HD egg production of

SIRO-CB birds; In SCWL x NH birds, however HD egg production was increased significantly ($P<0.05$) by lysine supplementation.A lysine requirement of more than 805 mg/d is needed. This is in agreement with a suggested intake of 833 mg/d for a 50-g egg mass/day. A similar response was observed in egg weight by methionine supplementation. The SCA (1987) recomendation for methionine-of 389 mg/d is in adequate for the SCWL x NH strain to maintain maximum egg weight over 40 weeks of lay.

Uzu and Larbier (1985) found that crossbred (ISA brown) semi-heavy laying hens fed diets based on maize and soybean oilmeal yielded optimum laying rate and egg weight when daily lysine intake was 790 mg/b/d. Higher lysine intake had no additional effects.

Table 12. Effect of interaction between strain x lysine (L) on HD egg production (%) and between strain x methionine (M) on egg weight (g) and intake of lysine , methionine (mg/b/d) and ME (MJ/b/d).

	HD egg production	Egg weight	Lysine intake	Methionine intake	ME intake
SIRO-CB					
L 90%	79.2[a*]	-	844	-	1.51
L 110%	77.3[a]	-	1061	-	1.49
M 90%	-	53.2[a]	-	407	1.49
M 110%	-	52.9[a]	-	524	1.51
SCWL x NH					
L 90%	77.7[a]	-	805	-	1.43
L 110%	80.1[b]	-	1003	-	1.41
M 90%	-	55.5[b]	-	386	1.42
M 110%	-	56.3[c]	-	495	1.43
LSD 5%	1.97	1.97	22.72	11.10	0.03

*Values within a column with different superscript (a-c) differ significantly ($P<0.05$)

It was assumed that birds would consume on average 110 g/b/d. This was an underestimate, therefore fixing lysine and methionine contents of the basal diets at 90% of requirement (SCA 1987) was probably too generous to get production responses to those amino acid supplementations. As already mentioned, the lowest intake of lysine and methionine on all diets containing those amino acids at 90% of estimated requirement was in reasonably close to the bird's requirement (SCA 1987).

It can be concluded from this experiment that a diet based on high-protein wheats with a small contribution from other protein sources produced hen production performance as efficient as that produced on a commercial layer diet.

ACKNOWLEDGEMENTS

We thank the Poultry Research Council for some financial support for this project and Degussa Corporation for amino acid analysis.

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