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Choice Feeding as a Means of Identifying Nutritional Needs With Two Methods of Amino Acid Formulation[1]

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Abstract: Male broilers from 11 to 49 days of age were assigned to one of four feeding treatments: Single diets (control), a choice of starter and finisher diets, a choice of high energy and high protein diets in relation to amino acid: lysine ratio and a choice of high energy and high protein diets in relation to amino acid: protein ratio. Birds fed both energy-protein treatments had worse body weight, feed conversion and carcass characteristics than did birds fed single diets or starter and finisher diets. The high energy-protein diets formulated in relation to lysine had the poorest carcass characteristics for all parameters except for wing and leg quarter yields. Birds given the choice feeding systems selected more high energy diet than high protein diet especially during the period of 11 to 22 days of age. Choice-fed broilers of both energy-protein treatments consumed less protein (total intake or percentage of consumed feed) for all periods, whereas these birds consumed similar energy intake at all age periods except for 42 to 49 days of age and higher energy density than did birds fed the other two feeding systems. As the choice-fed birds grew older, the selected energy content tended to wane while the selected protein contents tended to increase. These data indicate that the high protein diet formulated with amino acids in relation to lysine did not overcome the failure of choice feeding with high energy and high protein diets to sustain productivity since energy may be the driving force for feed selection.

Key words: Broilers, choice feeding, self-selection, energy needs

Introduction

The failure of choice-fed birds to select satisfactorily nutrients and not perform as well as birds fed conventional complete diets is mainly due to the type of formulation of self selection diets. One possible cause of this negative effect is the influence of amino acid profile of the choice-fed diets. The feed intake and feed selection can be influenced by the amino acid pattern of the diet. Chickens fed single diets have increased their feed intake due to marginal deficiency of sulfur amino acids (Cherry and Siegel, 1981) or marginal imbalance of a mixture lacking lysine (Boorman, 1979), however, birds fed a severe imbalance or deficiency of amino acids have reduced their feed intake (Lewis, 1965; Tobin *et al*., 1973; Wethli *et al*., 1975). In a choice feeding situation broilers have selected a balanced diet over diets deficient in lysine, tryptophan or/and methionine (Noble *et al*., 1993; Picard *et al*., 1993) or diets excess in some amino acids (Edmonds and Baker, 1987). Further, rats fed a choice of an imbalanced amino acid or protein-free diets have exclusively preferred the latter (Sanahuja and Harper, 1962; Leung *et al*., 1968).

It has been suggested that the piriform cortex of the chick brain may be involved in monitoring the amino acid balance in order to restore the feed intake (Firman and Kuenzei, 1988). Thus not only concentrations of amino acid in the blood and tissues but also neurotransmitters derived from amino acids may control the feed intake or selection. Tryptophan, a precursor of serotonin, competes for uptake into the brain with other neutral amino acids that are derived from the addition of dietary protein (Wurtman and Fernstrom, 1975).Thus in rats the plasma ratio of tryptophan to large neutral amino acids (Val, Ile, Leu, Tyr and Phe) (Trp:LNAA) and the selected protein have had an indirect relationship (Anderson, 1979). In chicks the relationship between the plasma or brain Trp:LNAA ratio and the protein intake has showed some inverse trends (Elkin *et al*., 1985). Moreover, Lacy *et al*. (1982) demonstrated that intubation of tryptophan decreased the feed intake in broilers.

Whereas it has been demonstrated in isoenergetic diets that severe derangements of protein quality (amino acid imbalance or deficiencies) causes a large decrease in feed intake of a single diet or rejection of that imbalanced diet in a choice situation, different balances of dietary amino acids have not been shown in a choice of high energy or high protein diets in broilers. Furthermore, since birds select their feed intake in order to supply firstly their energy requirement (Mastika and Cumming, 1981a, b; Mastika, 1983), the possible deficiency of protein or amino acids in choice-fed broilers may provoke a nutritional stress which can be associated with high plasma levels of corticosterone or an amino acid imbalance situation.

In a previous study from this laboratory (Cerrate *et al*., 2007) chicks failed to consume sufficient protein when given a choice between a high energy and a high protein diet when diets were formulated to provide essential amino acids as a minimum percentage of dietary crude protein content, resulting in possible excesses of certain amino acids in the high protein diet. The objectives of this study were to estimate nutritional needs for energy and protein and evaluate performance by choice feeding methods with two methods of amino acid formulation.

Materials and Methods

Cobb 500 male broilers grown on three different choice systems were compared to cohort birds fed a commercial feeding schedule based on recommendations given by the breeder[3]. For the choice systems, birds were allowed to choose between 1) a typical commercial starter diet and a finisher diet; 2) a diet high in energy and a diet high in protein, each containing sufficient amounts of vitamins and minerals and balanced in amino acids related to crude protein level (CP) or 3) a diet high in energy and a diet high in protein, each containing sufficient amounts of vitamins and minerals and balanced in amino acids related to lysine content with lysine at a minimum of 5.4% of CP. Six pens of 25 birds were grown on each treatment. A low bird density (2 ft^2 per bird) was chosen so that birds could move freely within the pen and not be impeded in their choice of feeder. Each pen contained two feeders, one containing each feed type and one automatic water font, located approximately midway between the two feeders.

Diet formulation: Composition of experimental diets is given in Table 1 with the calculated nutrient content given in Table 2. One series of diets (NORMAL) was formulated to provide diets that met nutrient standards for growing broilers suggested by the breeder using corn and soybean meal as intact sources of crude protein with commercially available supplemental amino acids (Diets 1, 2, 3 and 4, Table 1). Another diet (ENERGY 1) was formulated to provide normal amounts of vitamins, trace minerals, calcium and available phosphorus found in the normal diets with the bulk of the diet consisting of ground corn (Diet 5, Table 1). A level of 10% CP was specified with minimum amino acid:crude protein ratios as specified for broiler starter diets by NRC (1994) with an adjustment of lysine to 5.4% of CP, equivalent to 1.25% Lys in a diet with 23% CP. Another diet (PROTEIN 1) was formulated to provide normal amounts of vitamins, trace minerals, sodium, calcium and available phosphorus found in the normal diets with the bulk of the diet consisting of soybean meal (Diet 6, Table 1). The protein level of this diet was fixed at 40%, again with minimum amino acid:crude protein ratios as specified for broiler starter diets by NRC (1994) with an adjustment of lysine to 5.4% of CP. Another diet (ENERGY 2) was formulated to provide normal amounts of vitamins, trace minerals, calcium and available phosphorus found in the normal diets with the bulk of the diet consisting of ground corn (Diet 7, Table 1). A level of 10% CP was specified with minimum amino acid:lysine ratios with lysine specified as a minimum of 5.4% of CP. Another diet (PROTEIN 2) was formulated to provide normal amounts of vitamins, trace minerals, sodium, calcium and available phosphorus found in the normal diets with the bulk of the diet consisting of soybean meal (Diet 8, Table 1). The protein level of this diet was fixed at 40%, again with minimum amino acid:lysine ratios with lysine specified at a minimum of 5.4% of CP. Analysis of the mixed feeds indicates good agrement with calculated values for most nutrients (Table 2).

Table 1: Composition (g kg^{-1}) of test diets

	0-10 days	11-22 days	22-42 days	42-49 days	Hi NRG 1	Hi Pro 1	Hi NRG 2	Hi Pro 2
Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
Yellow corn	629.28	670.23	682.37	713.80	869.45	95.30	869.38	91.86
Soybean meal 47.5%	304.21	254.26	230.59	203.65	43.66	823.42	43.66	823.71
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Poultry oil	0.62	10.21	23.36	18.46	20.00	20.00	20.00	20.00
Ground limestone	10.37	10.00	9.29	9.39	12.79	10.92	12.75	9.54
Dicalcium phosphate	16.25	15.52	14.12	14.27	15.32	10.27	15.32	10.28
Sodium chloride	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Vitamin premix[2]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
MHA 84	1.81	1.81	2.00	1.81	0.00	2.84	0.11	7.17
L-Lysine HCl	0.21	0.72	1.02	1.25	1.53	0.00	1.53	0.00
L-Threonine	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.19
Mintrex P_Se mix[3]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Coban 60[4]	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
BMD 50[5]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1]: H.J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407, [2]Provides per kg of diet: vitamin A 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.15 mg, [3]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg; Novus International, St. Louis MO.
[4]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825, [5]Alpharma, Inc., Ft. Lee, NJ 07024.

Table 2: Calculated and analyzed (A) nutrient composition of experimental diets

	0-10 days	11-22 days	22-42 days	42-49 days	Hi NRG 1	Hi Pro 1	Hi NRG 2	Hi Pro 2
Nutrients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
ME kcal kg^{-1}	2986.42	3083.00	3176.00	3176.00	3324.25	2609.56	3324.02	2599.10
CP (%)	21.00	19.00	18.00	17.00	10.00	40.00	10.00	40.00
CP (%) (A)[1]	21.90	19.80	19.10	18.60	12.30	37.60	12.20	37.60
Ca (%)	1.00	0.96	0.90	0.90	1.00	1.00	1.00	1.00
Nonphytate P (%)	0.50	0.48	0.45	0.45	0.45	0.45	0.45	0.45
Met (%)	0.50	0.48	0.48	0.45	0.25	0.87	0.23	1.21
Met (%) (A)	0.49	0.45	0.48	0.43	0.23	0.89	0.21	1.25
Lys (%)	1.21	1.10	1.06	1.00	0.57	2.64	0.57	2.64
Lys (%) (A)	1.23	1.06	1.11	1.01	0.59	2.58	0.54	2.61
Trp (%)	0.25	0.23	0.21	0.20	0.10	0.56	0.10	0.56
Thr (%)	0.84	0.76	0.72	0.69	0.42	1.67	0.42	1.69
Arg (%)	1.43	1.26	1.18	1.10	0.57	3.10	0.57	3.10
Arg (%) (A)	1.46	1.21	1.26	1.13	0.59	3.15	0.57	3.14
Met+Cys (%)	0.90	0.84	0.83	0.79	0.49	1.56	0.47	1.90
Met+Cys (%) (A)	0.86	0.77	0.83	0.73	0.45	1.52	0.45	1.92
Dig Lys (%)	1.08	0.99	0.95	0.90	0.51	2.41	0.51	2.40
Dig Trp (%)	0.22	0.20	0.18	0.17	0.09	0.49	0.09	0.49
Dig Thr (%)	0.73	0.66	0.62	0.60	0.35	1.48	0.35	1.50
Dig Met+Cys (%)	0.80	0.75	0.74	0.70	0.42	1.40	0.53	1.73
Sodium (%)	0.24	0.23	0.23	0.24	0.23	0.25	0.40	0.25

[1]: Where: A = Analyzed

Dietary treatments: One group of birds was fed the Normal diets in chronological order (Diets 1 through 4). The second group of birds was fed the Normal starter diet for the first eleven days and then given a choice of diet 1 (starter) or diet 4 (finisher). The third group of birds was fed Normal starter for the first eleven days and then given a choice of diet 5 or diet 6. The fourth group of birds was fed the Normal starter diet for first eleven days and then given a choice of diet 7 or diet 8. Diets were fed as crumbles for the first eleven days and as 3/16" pellets for the remainder of the trial. Although no quantitative studies were done on pellet quality, visual examination of the pellets indicated that all diets pelleted well.

Measurements: For the first 11 days all birds were fed the starter diet (Diet 1) in supplemental feeder flats on the litter floor and in two tube-type feeders. At the end of 11 days, feed and birds were weighed and feed changed as noted above. For all the dietary treatments one feed was placed in a feeder appropriately marked and the other feed was placed in a second feeder, also appropriately marked. To avoid possible bias as to side of pen or feeder location, in three of the replicate pens the A feeder was on the side of the pen facing west and in the remaining three replicate pens the A feeder was on the side of the pen facing east. All birds were weighed at each feed change interval indicated for the NORMAL feeding diets (11, 22, 42 and 49 days) and also at 32 days of age. The feed consumption for that period was noted, including the pens with feed choice. In pens with choice or control feeds, consumption of the two different feeders was determined. At 49 d of age, five representative males from each pen were processed as described by Fritts and Waldroup (2006) to determine processing yield.

The intake of each diet in the choice feeding setting was measured by the consumption of each diet expressed as a percentage of total intakes. Energy and protein intakes were estimated by multiplying the amount of feed consumed by the respective protein and energy contents of each diet. The selected energy and protein content as a percentage of total intake were estimated by dividing the nutrient intake by the feed intake of each period.

The data were subjected to statistical analysis using the General Linear Models (GLM) procedure of SAS (SAS Institute, 1991) and the means were compared by repeated t-tests using the LSMEANS option of SAS. Mortality data were transformed to the square root of n +1 prior to analysis; data are presented as natural numbers.

Results

The effects of the different feeding systems on body weight of male broilers are shown in Table 3. Body weight gains at all intervals after eleven days of age were significantly influenced by the dietary treatment with the exception of the period between 42 to 49 days of age. At all other intervals birds fed both Energy-Protein treatments had significantly lower body weight than did birds fed the other dietary treatments.

The feed intake was not significantly affected by dietary treatments (Table 4) however, birds fed both Energy-Protein treatments had numerically lower feed intake especially between 42 and 49 d of age ($p = 0.068$) and for cumulative intake from 11 to 49 days of age ($p = 0.087$).

Feed conversion or feed efficiency was significantly affected by the feeding system used (Table 5 and 6). There were significant treatment differences between 11

Table 3: Effect of different feeding systems on body weight (kg $bird^{-1}$) of male broilers at different feeding intervals (means of six pens of 25 birds each)

	Feeding system						
Period (days)	Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	0.293	0.299	0.295	0.295	0.968	0.008	6.55
11-22	0.695[a]	0.674[a]	0.428[b]	0.376[b]	<0.001	0.023	10.36
22-32	0.967[a]	0.955[a]	0.615[b]	0.523[b]	<0.001	0.043	13.62
32-42	1.049[a]	1.066[a]	0.847[b]	0.757[b]	0.008	0.067	17.53
42-49	0.655	0.696	0.644	0.636	0.815	0.048	17.79
11-32	1.661[a]	1.629[a]	1.043[b]	0.898[b]	<0.001	0.056	10.51
11-42	2.710[a]	2.694[a]	1.890[b]	1.655[b]	<0.001	0.118	12.95
11-49	3.365[a]	3.391[a]	2.533[b]	2.291[b]	<0.001	0.158	13.34

[ab]: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 4: Effect of different feeding systems on feed intake (kg $bird^{-1}$) of male broilers at different feeding intervals (means of six pens of 25 birds each)

	Feeding system						
Period (days)	Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	0.340	0.346	0.347	0.338	0.607	0.006	3.990
11-22	1.114	1.090	1.035	1.100	0.528	0.043	8.860
22-32	1.657	1.652	1.522	1.590	0.169	0.051	7.080
32-42	2.002	1.993	1.838	1.882	0.129	0.060	6.970
42-49	1.553	1.533	1.431	1.315	0.068	0.066	11.010
11-32	2.769	2.737	2.554	2.690	0.168	0.076	6.311
11-42	4.765	4.720	4.393	4.573	0.111	0.122	5.890
11-49	6.283	6.223	5.824	5.986	0.087	0.146	5.360

[ab]: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 5: Effect of different feeding systems on feed conversion (feed:gain) of male broilers at different feeding intervals (means of six pens of 25 birds each)

	Feeding system						
Period (days)	Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	1.389	1.383	1.407	1.377	0.932	0.034	6.03
11-22	1.604[c]	1.618[c]	2.437[b]	2.896[a]	<0.001	0.077	8.23
22-32	1.717[b]	1.730[b]	2.550[a]	2.978[a]	<0.001	0.194	19.59
32-42	1.911	1.870	2.282	2.432	0.188	0.220	23.31
42-49	2.382	2.213	2.291	2.134	0.509	0.119	12.90
11-32	1.668[c]	1.680[c]	2.491[b]	2.920[a]	<0.001	0.137	14.17
11-42	1.760[b]	1.752[b]	2.390[a]	2.675[a]	<0.001	0.162	17.07
11-49	1.867[b]	1.835[b]	2.363[a]	2.478[a]	0.003	0.135	14.19

[ab]: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 6: Effect of different feeding systems on feed efficiency (gain:feed) of male broilers at different feeding intervals (means of six pens of 25 birds each)

	Feeding system						
Period (days)	Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	0.722	0.725	0.712	0.730	0.908	0.018	6.05
11-22	0.624[a]	0.618[a]	0.414[b]	0.348[c]	<0.001	0.012	5.47
22-32	0.584[a]	0.579[a]	0.405[b]	0.355[b]	<0.001	0.028	12.98
32-42	0.524	0.535	0.457	0.445	0.136	0.034	15.32
42-49	0.423	0.453	0.448	0.476	0.383	0.021	11.42
11-32	0.600[a]	0.596[a]	0.409[b]	0.351[c]	<0.001	0.020	9.06
11-42	0.569[a]	0.571[a]	0.429[b]	0.389[b]	<0.001	0.024	10.73
11-49	0.536[a]	0.545[a]	0.433[b]	0.414[b]	<0.001	0.021	9.67

[ab]: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

and 22 and 22 and 32 d of age and for cumulative values from 11 to 32 d, 11 to 42 d and 11 to 49 d of age. In these periods the feed conversion or feed efficiency by birds given the choice of both high energy and high protein feeds was significantly worse than those birds fed the other two feeding systems. The treatment of Energy-Protein diets in relation to amino acid: lysine ratio showed significantly the worst performance during the period of 11 to 22 d of age and for the 11 to 32 d of age and was numerically the worse from 11 to 42 and 11 to 49 d of age.

The relative intakes of diets in the different the feeding systems are shown in Table 7. The relative intake of control diets was not significantly influenced by the position of the feeders with the exception of the period between 11 to 22 d of age, favoring the A feeder over the B feeder only in this period. The relative intake of starter and finisher diets was significantly affected by the preference of the birds. It is interesting that during the experimental feeding period of 11 to 22 days, 22 to 32 days, 11 to 32 days, 11 to 42 days and 11 to 49 days, birds consumed a much higher percentage of the lower protein, higher energy finisher diet than those of the starter diet. As birds grew older this tendency is numerically decreased. In an almost similar way the relative intake of both Energy-Protein dietary treatments was affected by the preference of the birds. These choice-fed broilers at all age periods consumed a markedly greater percentage of the high energy diet; however, as birds grew older, this tendency is numerically decreased.

The effect of the different feeding systems on total protein consumption is shown in Table 8. Birds given choice of the energy and protein diets consumed much less protein than did birds fed the normal diets or the choice of starter and finisher diets. The average protein content of the consumed diets is shown in Table 9. The protein content of the consumed feed of the three choice feeding treatments tended to increase as the birds grew older, but was much lower for those birds given the choice of the energy-protein diets as compared to those fed the normal diets or choice of starter-finisher diets. Over the course of the study, the average protein content of the feed consumed by birds given a choice of starter and finisher diets was similar to that of birds fed the normal diets.

The effects of the different feeding systems on energy intake are shown in Table 10. Treatment differences on energy intake were noted only during the period of 42 to 49 d of age. During this period of time, birds fed Energy-Protein diets in relation to amino acid: lysine ratio (Energy-Protein, % of Lysine) had the lowest energy intake while birds fed Energy-Protein diets in relation to amino acid: protein ratio consumed similar energy intake as normal diets and started-finisher diets as well as Energy-Protein, % of Lysine diets. The selected energy contents diets expressed on the basis of

Table 7: Relative intake of different diets by male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Normal diets A	Normal diets B	Starter/ finisher Starter	Starter/ finisher Finisher	Energy-protein (% of CP) Energy	Energy-protein (% of CP) Protein	Energy-protein (% of Lys) Energy	Energy-protein (% of Lys) Protein	P diff	SEM	CV
11-22	54.18^{c}	45.82^{d}	17.76^{e}	82.24^{b}	90.96^{a}	9.04^{f}	94.87^{a}	5.13^{f}	<0.001	2.334	11.43
22-32	45.28^{cd}	54.72^{bc}	35.89^{d}	64.11^{b}	89.98^{a}	10.02^{e}	91.28^{a}	8.72^{e}	<0.001	6.308	30.90
32-42	42.05^{b}	57.95^{b}	41.65^{b}	58.35^{b}	84.35^{a}	15.65^{c}	84.43^{a}	15.57^{c}	<0.001	5.993	29.36
42-49	49.41^{b}	50.59^{b}	51.29^{b}	48.71^{b}	75.23^{a}	24.77^{c}	75.84^{a}	24.16^{c}	<0.001	4.163	20.39
11-32	49.07^{c}	50.93^{c}	28.32^{d}	71.68^{b}	90.35^{a}	9.65^{e}	92.78^{a}	7.22^{e}	<0.001	4.409	21.60
11-42	46.21^{cd}	53.79^{bc}	33.89^{c}	66.11^{b}	87.88^{a}	12.12^{e}	89.35^{a}	10.65^{e}	<0.001	4.621	22.64
11-49	46.72^{cd}	53.28^{bc}	37.77^{d}	62.23^{b}	84.83^{a}	15.17^{e}	86.21^{a}	13.79^{e}	<0.001	4.028	19.73

abcdef Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 8: Effect of different feeding systems on protein intake (g $bird^{-1}$) of male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Feeding system: Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	71	72	73	71	0.613	1.163	3.97
11-22	212^{a}	193^{a}	132^{b}	129^{b}	<0.001	9.267	12.33
22-32	298^{a}	305^{a}	198^{b}	208^{b}	<0.001	14.188	12.48
32-42	360^{a}	372^{a}	272^{b}	292^{b}	0.002	20.280	13.93
42-49	264	292	252	23^{4}	0.342	22.388	21.06
11-32	510^{a}	498^{a}	330^{b}	336^{b}	<0.001	19.041	10.08
11-42	870^{a}	870^{a}	602^{b}	629^{b}	<0.001	36.143	10.81
11-49	1134^{a}	1162^{a}	854^{b}	892^{b}	<0.001	53.197	11.71

ab: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 9: Effect of different feeding systems on protein content (% of consumed feed) of male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Feeding system: Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)
0-11	20.88	20.81	21.04	21.01
11-22	19.03	17.71	12.75	11.73
22-32	17.98	18.46	13.01	13.08
32-42	17.98	18.67	14.80	15.52
42-49	17.00	19.05	17.61	17.79
11-32	18.42	18.20	12.92	12.49
11-42	18.26	18.43	13.70	13.75
11-49	18.05	18.67	14.66	14.90

consumed feeds is shown in Table 11. The actual energy content of the diets consumed by both energy-protein dietary treatments was higher than consumed by those fed the choice of starter and finisher diets at all age periods. It is interesting to note that the energy contents of Starter-Finisher diets and Energy-Protein diets tended to lessen as the birds grew older.

The effects of the different feeding systems on mortality are shown in Table 12. There was no significant treatment differences at all age periods. The effects of different feeding systems on various processing parameters are shown in Table 13. Carcass characteristics were significantly influenced by the dietary treatment. There were no differences between

Table 10: Effect of different feeding systems on energy intake (ME Kcal $bird^{-1}$) of male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Feeding system: Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	1015	1033	1037	1010	0.593	16.691	3.99
11-22	3435	3423	3372	3612	0.592	133.528	8.64
22-32	5263	5135	4949	5165	0.515	161.618	7.05
32-42	6358	6170	5901	6005	0.297	188.993	6.91
42-49	4932^{a}	4718^{a}	4499^{ab}	4124^{b}	0.042	190.514	10.22
11-32	8697	8558	8321	8778	0.515	240.204	6.26
11-42	15056	14728	14222	14783	0.417	381.292	5.80
11-49	19987	19446	18721	19180	0.230	461.383	5.33

^{ab}: Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

Table 11: Effect of different feeding systems on energy level (ME Kcal kg^{-1} of the consumed feed) of male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Feeding system: Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)
0-11	2985	2986	2988	2988
11-22	3083	3140	3258	3284
22-32	3176	3108	3252	3248
32-42	3176	3096	3211	3191
42-49	3176	3078	3144	3136
11-32	3141	3127	3258	3263
11-42	3160	3120	3237	3233
11-49	3181	3125	3214	3204

Table 12: Effect of different feeding systems on mortality (%) of male broilers at different feeding intervals (means of six pens of 25 birds each)

Period (days)	Feeding system: Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
0-11	0.667	1.333	1.333	0.000	0.472	0.683	200.80
11-22	0.667	1.333	0.667	0.667	0.883	0.715	210.14
22-32	0.000	1.333	0.667	2.000	0.241	0.699	171.27
32-42	4.000	6.667	2.000	0.667	0.195	1.989	146.15
42-49	4.667	4.000	2.000	0.667	0.337	1.680	145.24
11-32	0.667	2.667	1.333	2.667	0.483	1.085	145.00
11-42	4.667	9.333	3.333	3.333	0.276	2.418	114.62
11-49	9.333	13.333	5.333	4.000	0.283	3.615	110.68

Table 13: Effect of different choice feeding systems compared to Normal feeding on processing parameters of male broilers (means of six pens with five birds per pen each)

	Feeding system						
Measurements	Normal diets	Starter/ finisher	Energy-protein (% of CP)	Energy-protein (% of Lys)	P diff	SEM	CV
Body weight (kg)	3.731[a]	3.693[a]	3.056[b]	2.735[c]	<0.001	0.098	16.02
Carcass weight (kg)	2.754[a]	2.722[a]	2.169[b]	1.917[c]	<0.001	0.078	17.56
Dressing percentage	73.82[a]	73.67[a]	70.51[b]	69.40[b]	<0.001	0.466	3.50
Breast weight (kg)	0.867[a]	0.852[a]	0.571[b]	0.455[c]	<0.001	0.031	24.15
Wing weight (kg)	0.284[a]	0.282[a]	0.239[b]	0.217[c]	<0.001	0.008	16.20
Leg quarter weight (kg)	0.856[a]	0.835[a]	0.713[b]	0.642[c]	<0.001	0.024	16.91
Breast % of carcass	31.44[a]	31.29[a]	25.21[b]	22.73[c]	<0.001	0.691	13.46
Wings % of carcass	10.33[b]	10.38[b]	11.11[a]	11.50[a]	<0.001	0.153	7.62
Leg quarter % of carcass	31.13[b]	30.74[b]	33.21[a]	33.77[a]	<0.001	0.386	6.45

[abc]:Means within a row with common letter(s) do not differ significantly ($p \leq 0.05$)

the carcass characteristics of birds fed the normal diets and those given a choice between starter and finisher diets for any parameter. Birds fed both Energy-Protein dietary treatments had lower performance than the other two feeding systems; moreover, birds fed the Energy-Protein, % of Lysine diets had the lowest performance at all parameters except for wing and leg quarter yields.

Discussion

The fact that birds given the high energy-protein diets in relation to amino acid: lysine ratio had lower body weight, feed conversion, or carcass characteristics than did birds fed the normal diets or the choice of starter and finisher diets shows that the formulation system adjusting amino acids to lysine had no effect on correcting a possible amino acid imbalance as compared to formulating with amino acids as a percentage of crude protein. The greater quantity of free amino acids added to these free-choice diets may have exacerbated the reluctance of chicks to consume this high protein diet because these choice-fed broilers selected a lower percentage of the high protein diet than did birds fed Energy-Protein diets with amino acids adjusted to protein; although this difference was not significant this lower preference was consistently observed for all age periods.

It is interesting to note that the feed intake of the four feeding systems was statistically similar, even though the birds given both high energy-protein treatments had lower body weight than those birds fed the other feeding systems. Probably these choice-fed broilers ate more feed per unit of body gain in order to meet their energy needs since the birds fed all the feeding systems had almost similar energy intake at all age periods except for 42 to 49 days of age.

The position of the feeder had no effect on the preference of the bird, thus in the control group birds ate an almost similar quantity of feed for each feeder placed on opposite sides of the pen. Forbes and Shariatmadari (1996) have also shown that the feeder position does not influence the self-selection. The preference for high energy diets especially during the early period (11 to 22 days) by birds fed the free choice diets shows that in this period the energy requirement was higher or equal than 3.140 Mcal kg^{-1}. These preferences and selected energy contents are in agreement with results obtained by Cerrate *et al.* (2007). Otherwise, these high selected energy levels may be a consequence of a previous energy density deficiency (2.986 Mcal kg^{-1}) which was supplied during the first eleven days for the choice feeding treatments. Hence, a probable nutrient deficiency in the previous phase may increase the selected nutrient content in the consecutive period as shown for methionine (Kirchgessner and Paulicks, 1994) and protein (Forbes and Shariatmadari, 1996). Furthermore, during a continuous choice feeding from 0 to 14 days of age the selected energy densities were lower than 3.140 but higher than 3.000 Mcal kg^{-1} (Sinurat and Balnave, 1986; Benson *et al.*, 1993). As the choice-fed broilers grew older a greater percentage of the high protein diets was preferred likely because the selected energy density decreased as the birds aged, allowing the birds to select more of the high protein diets.

It appears that the energy intake was the driving force to regulate feed selection since the energy intake at all age periods except for 42 to 49 days of age was similar for all the treatments. Many choice feeding studies have indicated that the feed selection is regulated to satisfy firstly the energy requirement (Mastika and Cumming, 1981a, b; Mastika, 1983). Although the birds can select a balanced amount of amino acids avoiding amino acid deficiency or amino acid excess diets (Noble *et al.*, 1993; Picard *et al.*, 1993; Edmonds and Baker, 1987), they may fail to balance their amino acids or proteins when the energy is the limiting factor.

The lower selected protein intakes in both choice Energy-Protein treatments compared to the other two feeding systems may have caused a dietary protein stress in which the plasma levels of corticosterone increased (Weber *et al.*, 1990) and consequently the preference for high energy diets or high carbohydrate diets (Cosava and Forbes, 1995). Therefore in these choice-fed broilers the energy contents were higher than those of birds fed the normal diets or Starter-Finisher diets. Otherwise, in this protein deficiency situation the plasma of amino acid pattern may exacerbate an imbalance of amino acids which reinforces the reluctance of high protein diets as shown in rats by Sanahuja and Harper (1962) and Leung *et al.* (1968). Thus the high protein diet formulated with amino acids in relation to lysine was probably not successful in increasing the protein intake because the birds supplied first their energy requirements and in turn probably originated a severe physiological amino acid imbalance. Another possibility is that elevated dietary Trp:LNAA ratio in the high protein diets may increase the reluctance by birds to consume feed since an inverse relationship has been shown to exist between plasma Trp:LNAA ratio and protein intake in animals (Anderson, 1979).

The decreased energy content and increased protein content of selected diets as the birds aged represent a unique characteristic which may be affected by a previous energetic deficiency in the early period (0 to 11 days). Otherwise it can represent the actual nutrient requirements of the birds, a greater need for energy during the early growth period and a greater need for protein during the later periods where breast meat is being formed. This can be an economic advantage because the energy contents of Starter-Finisher diets were lower than those of Normal diets at all age periods, whereas the performance of both dietary treatments were similar.

The variability found in feed selection and performance may reflect the individual variation in nutrient requirement, variation in the actual composition of the feeds or variation of the physical forms of the feed. Though visual examination of the pellets indicated that all diets pelleted well, some samples of feed had a poor quality pellet. Some studies have showed that the physical forms affect the feed selection (Rose *et al.*, 1986; Yo *et al.*, 1997).

The results of this study showed that high protein diets formulated with amino acids in relation to lysine did not overcome the failure of choice feeding diets with high protein and high energy since the energy is main regulator for feed selection. Further studies are suggested in which energy content of choice diets is maintained isocaloric while varying in protein content.

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