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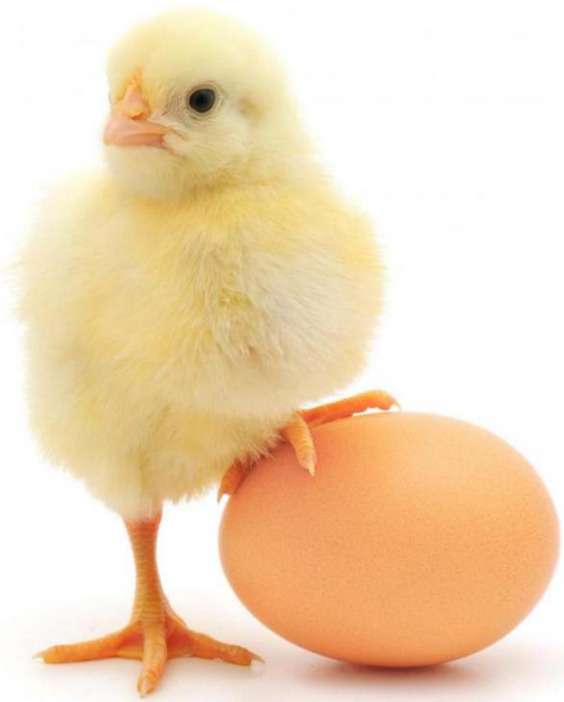

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Choice Feeding as a Means of Identifying Differences in Nutritional Needs of Broiler Strains Differing in Performance Characteristics[1]

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Abstract: Chickens from two broiler strains known to differ in growth rate and feed conversion (GROWTH) and in high breast meat yield (YIELD) were grown to 10 days of age on a common starter diet and from 11 to 49 days were provided single diets (control), a choice between high energy and high protein diets, or a choice between starter and finisher diets. Overall the YIELD strain had greater body weight, feed intake and breast yield than did GROWTH strain. However, the YIELD strain had better feed conversion only when offered a choice of starter and finisher diets. Birds fed single diets and Starter-Finisher diets had better body weight, feed intake, feed conversion and breast yield than those birds fed Energy-Protein diets. Birds fed both choice feeding systems selected more high energy diets than high protein diets especially during the period of 11 to 22 d of age. The YIELD strain had a preference for the high protein diet and consequently had greater protein intake and average dietary protein content than did the GROWTH strain, while the former ate more energy intake but less energy content than did the latter. Birds given choice of the energy and protein diets had less protein intake and content for all periods, whereas these birds chose less energy intake for the period of 22 to 42 d of age and a higher energy level than did birds fed the other two feeding systems. These data indicate that choice feeding systems can identify differences in performance according to the selected nutritional needs for new strains of broilers.

Key words: Broilers, strain differences, choice feeding, diet self-selection

Introduction

As new strains of broilers are developed, the question frequently arises as to whether they will have differing nutrient requirements from that of previous strains, due to differences in growth rate, ability to convert feed to gain, increased feathering, greater breast meat yield, or other characteristics. Several researchers have pointed out that dietary self-selection methods can estimate tailored nutrient requirements in an easy way when the choice feeding method gives the opportunity to do so (Hughes, 1984; Mastika and Cumming, 1987; Rose and Kyriazakis, 1991). The choice feeding method may also be of value in identifying differences in nutritional needs of broiler strains. Thus heavy strains have selected more protein and less energy than did light strains (Huey *et al*., 1982; Brody *et al*., 1984). Further the selected protein level was greater by lean strains compared to fat strains (Mastika and Cumming, 1981; Leclercq and Guy, 1991). The nutrient requirements of broilers are basically determined as a function of the best performance such as body weight or feed conversion. Choice feeding studies have shown positive or negative performance compared to standard systems. The conflicting situation is probably because of differences in protein and energy levels of self selection or control diets. The successful choice-fed broilers were able to select similar energy and protein levels as those fed the control diets probably due to three reasons: 1) the metabolizable energy level (ME) of control diets was equal or lower than 3.0 Mcal/kg and thus the energy content was easy to reach by choice feeding diets (Cowan and Michie, 1978; Yokota and Segawa, 1979; Mastika and Cumming, 1981, 1985, 1987; Munt *et al*., 1995); 2) the choice feeding system had a diet high in ME (3.176 to 3.602 Mcal/kg) and a diet high in protein level (41.5 to 44%), allowing the selection of adequate amounts of energy and protein (Sinurat and Balnave, 1986; Yo *et al*., 1998; Olver and Jonker, 1997); and 3) the choice feeding and control diets had the same ME and the choice feeding diets had variations of protein level (Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993). On the other hand, failing choice-fed broilers have chosen similar energy levels but different protein levels compared to those birds fed control diets (Cowan and Michie, 1977, 1978; Yokota and Segawa, 1979; Sinurat and Balnave, 1986; Yo *et al*., 1998; Zulkifli *et al*., 2001; Munt *et al*., 1995). It appears that birds select their feed intake to first meet their energy requirement and then their protein requirement. Thus the ability of a choice feeding system to get a good performance will depend on the nutrient requirements of broiler strains and a well-designed choice feeding system. Moreover, birds have the ability to regulate their nutrients according to fluctuating ambient temperature, the "natural" situation (Mastika and Cumming, 1985). The objective of the present study was to attempt to identify differences in nutritional needs for energy and protein of two broiler strains by choice feeding method.

Table 1: Composition (g/kg) and calculated nutrient analysis of test diets

Ingredients	Normal diets 0-10 d Diet 1	11-22 d Diet 2	22-42 d Diet 3	42-49 d Diet 4	High Energy Diet 5	High Protein Diet 6
Yellow corn	629.28	670.23	682.37	713.80	835.19	180.23
Soybean meal 47.5%	304.21	254.26	230.59	203.65	78.25	737.49
Pro-Pak[1]	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
Ground limestone	10.37	10.00	9.29	9.39	12.66	10.87
Dicalcium phosphate	16.25	15.52	14.12	14.27	15.10	10.83
Sodium chloride	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
MHA 84	1.81	1.81	2.00	1.81	0.27	3.33
L-Lysine HCl	0.21	0.72	1.02	1.25	1.28	0.00
L-Threonine	0.00	0.00	0.00	0.12	0.00	0.00
Trace mineral mix[3]	1.00	1.00	1.00	1.00	1.00	1.00
Coban 60[4]	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
TOTAL	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/lb	1355.00	1398.82	1441.00	1441.00	1494.00	1219.15
ME kcal/kg	2986.42	3083.00	3176.00	3176.00	3293.00	2687.00
CP %	21.00	19.00	18.00	17.00	12.00	38.00
Ca %	1.00	0.96	0.90	0.90	1.00	1.00
Nonphytate P %	0.50	0.48	0.45	0.45	0.45	0.45
Met %	0.50	0.48	0.48	0.45	0.26	0.84
Lys %	1.21	1.10	1.06	1.00	0.65	2.40
Trp %	0.25	0.23	0.21	0.20	0.12	0.50
Thr %	0.84	0.76	0.72	0.69	0.48	1.53
Arg %	1.43	1.26	1.18	1.10	0.69	2.83
Met+Cys%	0.90	0.84	0.83	0.79	0.52	1.49
Dig Met %	0.47	0.45	0.45	0.42	0.24	0.80
Dig Lys %	1.08	0.99	0.95	0.90	0.58	2.17
Dig Trp %	0.22	0.20	0.18	0.17	0.11	0.44
Dig Thr %	0.73	0.66	0.62	0.60	0.40	1.35
Dig Met+Cys %	0.80	0.75	0.74	0.70	0.45	1.33
Sodium %	0.24	0.23	0.23	0.24	0.23	0.24

[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 (from $MnSO_4{\bullet}H_20$) 100 mg; Zn (from $ZnSO_4{\bullet}7H_2O$) 100 mg; Fe (from $FeSO_4{\bullet}7H_2O$) 50 mg; Cu (from $CuSO_4{\bullet}5H_20$) 10 mg; I from $Ca(IO_3)_2{\bullet}H_2O$), 1 mg; [4]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825; [5]Alpharma, Inc., Ft. Lee, NJ 07024

Materials and Methods

An experimental strain of birds generally selected for growth rate and feed conversion (GROWTH) and an experimental strain of birds generally selected for high breast meat yield (YIELD) were used in these studies. Birds grown on two different choice systems were compared to birds fed a commercial feeding schedule. Birds of each strain were allowed to choose between 1) 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; or 2) a typical commercial starter diet and a finisher diet. A standard feeding program similar to that used in the commercial broiler industry was used as the positive control. The treatments were as follows: GROWTH, normal feeding program; YIELD, normal feeding program; GROWTH, high energy vs. high protein; YIELD, high energy vs. high protein; GROWTH, starter diet vs. finisher diet and YIELD, starter diet vs. finisher diet. Each of the six experimental treatments was assigned to eight replicate pens of 25 birds each. 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 tube feeders, one containing each feed type and one automatic water font, located approximately midway between the two feeders.

One group of birds (NORMAL) was fed the Normal diets in chronological order as shown in Table 1. The second group of birds (ENERGY/PROTEIN) was fed the Normal starter diet for the first ten days and then given a choice of diet 5 (High Energy) or diet 6 (High Protein). The third group of birds (STARTER/FINISHER) was fed the Normal starter diet for the first ten days and then given a choice of diet 1 (Starter) or diet 4 (Finisher). Diets were fed as crumbles for the first ten days and as 3/16"

Table 2: Amino acid specifications as percentage of crude protein and calculated content for high energy and high protein diets

	--- Specified ---	----- As formulated -----	
Amino acid	Amino acid % of CP	High Energy	High Protein
Met	2.17	2.17	2.22
Lys	5.43	5.43	6.30
Trp	0.87	1.00	1.35
Thr	3.48	3.95	4.05
Ile	3.48	3.83	4.48
His	1.52	2.91	2.70
Val	3.91	5.04	4.83
Leu	5.21	10.70	8.17
Arg	5.43	5.74	7.43
TSAA	3.91	4.34	3.91
Gly+Ser	5.43	9.00	9.48
Phe+Tyr	5.82	8.22	9.00
Trp/LNNA		0.036	0.051

Where: LNNA: Val + Ile + Leu + Tyr +Phe

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.

Diet formulation: 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 supplemental amino acids (Diets 1, 2, 3 and 4, Table 1). Another diet (ENERGY) was formulated to provide similar amounts of vitamins, trace minerals, sodium, 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 12% Crude Protein (CP) was specified with minimum amino acid: crude protein ratios as specified for broiler normal diets by NRC (1994) with an adjustment of lysine to 1.25% per 23% CP. A final diet (PROTEIN) was formulated to provide similar 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 38%, again with minimum amino acid: crude protein ratios as specified for broiler normal diets by NRC (1994) with an adjustment of lysine to 1.25% per 23% CP. There were no attempts to maintain any ratio among or between any of the amino acids during formulation.

As seen in Table 2, all of the diets met or exceeded the minimum specifications for amino acids as percent of crude protein. As would be expected, the high energy diet based largely on corn protein was considerably higher in leucine and valine than the minimum specifications while the high protein diet based largely on soybean meal was considerably higher in lysine and arginine than the minimum specifications. Both choice feeding diets were higher in glycine+serine and phenylalanine+tyrosine than the minimum specifications.

Measurements: For the first 10 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 10 d, feed and birds were weighed and feed changed as noted above. Where a choice of feeds was offered, 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 four of the replicate pens the "A" feeder was on the side of the pen facing west and in four of the 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 (10, 22, 42 and 49 d) and the feed consumption for that period measured, including the pens with feed choice. An additional weight was taken at 32 d of age. In pens with choice of feeds, consumption of the two different feed choices was determined. At 49 d of age, five representative males from each pen were processed 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 level expressed as a percent of the diet was estimated by dividing the energy and protein intakes by the total amount of feed consumed.

The data were analyzed 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 two strains of male broilers are shown in Table 3. Strains differed significantly in body weight at ten days of age and at all intervals throughout the study. Body weight gains at all intervals after ten days of age were significantly influenced by the dietary treatment; with the exception of the period between 42 and 49 d of age, birds fed the Energy-Protein diets had lower body weight than did birds fed the other dietary treatments. Significant treatment by strain interactions for body weight gain were noted for gains between 22 and 32 d and 32 and 42 d of age and for cumulative gains from 10 t o 32 d, 10 to 42 d and 10 to 49 d of age; this was largely due to much lower body gain of the Energy-Protein diets by the GROWTH strain compared

Table 3: Effect of different feeding systems on body weight of two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Parameter	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
0-10 d BW (kg)	0.220	0.241	0.262	0.222	0.240	0.258	0.218	0.242	0.267	5.51
Wt. gain 10-22 d (kg)	0.633	0.661^{b}	0.689	0.398	0.455^{a}	0.512	0.596	0.641^{b}	0.686	8.16
Wt. gain 22-32 d (kg)	0.868^{c}	0.879^{b}	0.890^{c}	0.533^{a}	0.614^{a}	0.696^{b}	0.873^{c}	0.889^{b}	0.906^{c}	6.60
Wt. gain 32-42 d (kg)	0.949^{b}	0.982^{b}	1.016^{c}	0.679^{a}	0.802^{a}	0.924^{b}	0.937^{b}	0.957^{b}	0.977^{bc}	6.90
Wt. gain 42-49 d (kg)	0.564	0.574	0.585	0.522	0.564	0.605	0.585	0.596	0.608	11.35
Wt. gain 10-32 d (kg)	1.501^{cd}	1.540^{b}	1.579^{d}	0.932^{a}	1.070^{a}	1.207^{b}	1.468^{c}	1.530^{b}	1.593^{d}	6.66
Wt. gain 10-42 d (kg)	2.450^{cd}	2.523^{b}	2.595^{e}	1.611^{a}	1.871^{a}	2.132^{b}	2.405^{c}	2.487^{b}	2.569^{de}	5.98
Wt. gain 10-49 d (kg)	3.014^{cd}	3.097^{b}	3.179^{d}	2.133^{a}	2.435^{a}	2.737^{b}	2.990^{c}	3.083^{b}	3.176^{d}	6.13

Parameter	Treatment	Strain	Treat×Strain
0-10 d BW	0.83	<0.001	0.35
10-22 gain	<0.001	<0.001	0.24
22-32 gain	<0.001	<0.001	<0.001
32-42 gain	<0.001	<0.001	<0.001
42-49 gain	0.36	0.03	0.32
10-32 gain	<0.001	<0.001	0.01
10-42 gain	<0.001	<0.001	<0.001
10-49 gain	<0.001	<0.001	<0.001

[abcde]Means within a row with common letters do not differ significantly ($p \leq 0.05$)

to the YIELD strain. The YIELD strain tended to do much better on either of the choice feeding systems (Energy-Protein or Starter-Finisher) than did the GROWTH strain. Similar effects were observed on feed intake (Table 4). There were significant treatment differences at all age periods except for 0-10 d and 42-49 d of age while strain differences were observed at every age period; birds fed the Energy-Protein diets had lower feed intake than did birds fed the other dietary treatments. Treatment by strain interactions were observed during the period of 22-32 d of age and for cumulative feed intakes from 10 to 32 d and 10 to 49 d of age; this was largely due to much greater feed intake of the Energy-Protein diets by the YIELD strain compared to the GROWTH strain.

Feed conversion was significantly affected by the feeding system used (Table 5). Feed conversion within any feeding period or overall except for 42-49 d of age was similar for birds fed either the Normal feed or given a choice between starter and finisher diets. The feed conversion by birds given the choice of high energy or high protein feeds was significantly worse than that of birds fed the other two systems. There generally were few strain differences (significant only for the 10 to 42 d period) but there were several periods when there were significant strain by treatment interactions. Both strains appeared to have similar feed conversion when fed the Normal feed or given choice between starter and finisher feed; however, the YIELD strain had significantly better feed conversion than did the GROWTH strain when offered a choice between the high energy and high protein feed.

One of the most striking differences between the two strains in their response to the different choice diets can be seen in Table 6, which shows the relative intake of high energy or high protein diets by the two strains. The YIELD strain consistently consumed a greater percentage of the high protein diet and a lower percentage of the high energy diet than did the GROWTH strain. Also, the YIELD strain consumed an increasingly higher percentage of the high protein diet as the birds aged, in contrast to the GROWTH strain which consumed about the same relative percentage of the high protein diet throughout the study.

Relative intake of starter and finisher diets is shown in Table 7. It is interesting that during the first feeding period of 10-22 d, birds of both strains consumed a much higher percentage of the lower protein, higher energy finisher diet than of the starter diet. As the birds grew older, they tended to consume a greater percentage of the higher protein, lower energy starter diet. Perhaps this was in response to a greater need for

Table 4: Effect of different feeding systems on feed intake (kg/bird) by two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Parameter	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
FI 0-10	0.246		0.281	0.247		0.277	0.243		0.286	4.85
		0.263			0.262			0.264		
FI 10-22	0.980		1.080	0.912		1.059	0.966		1.111	5.60
		1.030^{b}			0.986^{a}			1.038^{b}		
FI 22-32	1.468^{bcd}		1.538^{d}	1.179^{a}		1.440^{bc}	1.428^{b}		1.521^{cd}	5.98
		1.503^{b}			1.309^{a}			1.475^{b}		
FI 32-42	1.841		1.921	1.515		1.800	1.785		2.033	8.83
		1.881^{b}			1.658^{a}			1.909^{b}		
FI 42-49	1.373		1.460	1.299		1.433	1.355		1.497	9.24
		1.417			1.366			1.426		
FI 10-32	2.447^{b}		2.617^{cd}	2.083^{a}		2.500^{bc}	2.393^{b}		2.642^{d}	4.74
		2.532^{b}			2.292^{a}			2.518^{b}		
FI 10-42	4.270^{b}		4.535^{c}	3.614^{a}		4.301^{b}	4.173^{b}		4.580^{c}	4.95
		4.402^{b}			3.958^{a}			4.376^{b}		
FI 10-49	5.601		5.981	4.898		5.730	5.564		6.252	5.55
		5.791^{b}			5.314^{a}			5.908^{b}		

Parameter	Treatment	Strain	Treat×strain
0-10	0.86	<0.001	0.36
10-22	0.03	<0.001	0.41
22-32	<0.001	<0.001	0.005
32-42	<0.001	<0.001	0.17
42-49	0.38	0.002	0.81
10-32	<0.001	<0.001	0.01
10-42	<0.001	<0.001	0.02
10-49	<0.001	<0.001	0.13

[abcd]Means within a row with common letters do not differ significantly ($p \leq 0.05$)

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

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
0-10	1.347		1.291	1.334		1.274	1.340		1.281	5.93
		1.319			1.304			1.311		
10-22	1.550^{a}		1.567^{a}	2.303^{c}		2.105^{b}	1.623^{a}		1.614^{a}	7.31
		1.559^{a}			2.204^{b}			1.618^{a}		
22-32	1.692		1.729	2.206		2.100	1.637		1.680	6.99
		1.711^{a}			2.153^{b}			1.658^{a}		
32-42	1.943^{ab}		1.893^{a}	2.241^{c}		1.949^{ab}	1.907^{a}		2.086^{bc}	8.35
		1.918^{a}			2.095^{b}			1.996^{ab}		
42-49	2.467		2.515	2.489		2.381	2.327		2.474	9.14
		2.491			2.435			2.400		
10-32	1.631^{a}		1.657^{a}	2.242^{c}		2.100^{b}	1.631^{a}		1.659^{a}	6.05
		1.644^{a}			2.171^{b}			1.645^{a}		
10-42	1.744^{a}		1.748^{a}	2.247^{c}		2.030^{b}	1.735^{a}		1.778^{a}	3.87
		1.746^{a}			2.138^{b}			1.757^{a}		
10-49	1.860^{a}		1.882^{ab}	2.298^{d}		2.105^{c}	1.850^{a}		1.969^{b}	4.52
		1.871^{a}			2.202^{b}			1.910^{a}		

Parameter	Treatment	Strain	Treat×strain
0-10	0.86	0.14	0.99
10-22	<0.001	0.10	0.05
22-32	<0.001	0.81	0.19
32-42	0.017	0.26	0.001
42-49	0.51	0.65	0.27
10-32	<0.001	0.36	0.05
10-42	<0.001	0.012	0.001
10-49	<0.001	0.51	0.001

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

Table 6: Relative intake of high energy or high protein diets by two different strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

Period (d)	Choice feed	Strain GROWTH	YIELD	P diff	SEM	CV
10-22 d	Energy	96.407[b]	89.405[a]	0.014	1.753	5.337
	Protein	3.593[a]	10.595[b]	0.014	1.753	69.891
22-32 d	Energy	98.428[b]	90.358[a]	0.001	1.389	4.162
	Protein	1.572[a]	9.642[b]	0.001	1.389	70.061
32-42 d	Energy	97.754[b]	77.971[a]	<0.0001	2.416	7.777
	Protein	2.246[a]	22.029[b]	<0.0001	2.416	56.295
42-49 d	Energy	92.504[b]	78.665[a]	0.007	3.123	10.323
	Protein	7.496[a]	21.335[b]	0.007	3.123	61.284
10-32 d	Energy	97.539[b]	90.030[a]	0.001	1.334	4.023
	Protein	2.461[a]	9.970[b]	0.001	1.334	60.702
10-42 d	Energy	97.629[b]	85.028[a]	<0.0001	1.632	5.053
	Protein	2.371[a]	14.972[b]	<0.0001	1.632	53.216
10-49 d	Energy	96.421[b]	83.555[a]	<0.0001	1.514	4.758
	Protein	3.579[a]	16.445[b]	<0.0001	1.514	42.764

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

Table 7: Relative intake of starter and finisher diets by two different strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

Period (d)	Choice feed	Strain GROWTH	YIELD	P diff	SEM	CV
10-22 d	Starter	7.529[a]	17.176[b]	0.008	2.222	50.871
	Finisher	92.471[b]	82.824[a]	0.008	2.222	7.170
22-32 d	Starter	37.298	37.899	0.940	5.256	41.568
	Finisher	62.702	62.101	0.940	5.526	25.046
32-42 d	Starter	55.523[b]	35.069[a]	0.023	5.663	35.363
	Finisher	44.477[a]	64.931[b]	0.023	5.663	29.281
42-49 d	Starter	60.405[b]	37.160[a]	0.083	8.790	50.967
	Finisher	39.595[a]	62.840[b]	0.083	8.790	48.544
10-32 d	Starter	25.125	29.125	0.449	3.633	37.880
	Finisher	74.875	70.875	0.449	3.633	14.099
10-42 d	Starter	37.925	31.740	0.305	4.111	33.383
	Finisher	62.075	68.260	0.305	4.111	17.844
10-49 d	Starter	43.155	34.111	0.158	4.282	31.351
	Finisher	56.845	65.889	0.158	4.282	19.737

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

energy during the early growth period and a greater need for protein during the later period where breast meat was being formed. It is important to note that body weight gain and feed conversion by birds given the choice of starter and finisher diets did not differ significantly from that of birds given the normal diet series.

The effects of the different feeding systems on total protein consumption are shown in Table 8. There were significant effects of both treatment and strain for every growth period and a significant treatment by strain interaction for all periods other than 10-22 d of age. On both choice systems, significant differences for Energy-Protein diets and numerical differences for Starter-Finisher diets, the YIELD strain consumed more protein than did the GROWTH strain. 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 strain by protein interaction was due primarily to much higher protein consumption by the YIELD strain compared to the GROWTH strain birds that were given the choice of the high energy or high protein diets.

The effects of the different feeding systems on energy intake are shown in Table 9. Treatment differences were noted during the periods of 22-32 and 32-42 d of age but not during 10-22 or 42-49 d of age. Strain differences in energy intake were observed at every age, with the YIELD strain consuming more calories than did the GROWTH strain. In general, treatment by strain interactions were minimal, being significant only from the period of 22-32 d of age. During this period of time, the YIELD strain consumed considerably more calories when given the choice between high energy and high protein feed or between the starter and finisher feed than did the GROWTH strain birds.

The effects of the different feeding systems on total protein content of the consumed feed are shown in

Table 8: Effect of different feeding systems on protein intake (g/bird) by two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
10-22 d	186		205	118		157	167		196	7.81
		196^{c}			137^{a}			182^{b}		
22-32 d	264^{c}		277^{cd}	147^{a}		209^{b}	264^{cd}		282^{d}	7.24
		271^{b}			178^{a}			273^{b}		
32-42 d	331^{b}		346b^{c}	191^{a}		320^{b}	343^{bc}		375^{c}	11.97
		339^{b}			255^{a}			359^{b}		
42-49 d	233^{b}		248b^{c}	181^{a}		253^{bc}	263^{c}		276^{c}	11.96
		241^{b}			217^{a}			270^{c}		
Parameter		Treatment			Strain			Treat×strain		
10-22		<0.001			<0.001			0.13		
22-32		<0.001			<0.001			<0.001		
32-42		<0.001			<0.001			<0.001		
42-49		<0.001			<0.001			<0.001		

^{abc}Means within a row with common letters do not differ significantly ($p \leq 0.05$)

Table 9: Effect of different feeding systems on energy intake (ME Kcal/bird) by two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
10-22 d	3022		3329	2984		3420	3052		3493	5.53
		3176			3202			3273		
22-32 d	4661^{bc}		4884^{c}	3871^{a}		4657^{bc}	4435^{b}		4722^{c}	5.99
		4773^{c}			4264^{a}			4579^{b}		
32-42 d	5847		6100	4970		5686	5481		6318	8.58
		5973^{b}			5328^{a}			5900^{b}		
42-49 d	4361		4637	4221		4529	4149		4649	9.55
		4499			4375			4399		
Parameter		Treatment			Strain			Treat×strain		
10-22 d		0.30			<0.001			0.49		
22-32 d		<0.001			<0.001			0.01		
32-42 d		<0.001			<0.001			0.22		
42-49 d		0.68			0.005			0.72		

^{abc}Means within a row with common letters do not differ significantly ($p \leq 0.05$)

Table 10. Though the data were not run on SAS, there were numerical differences. Birds given choice of the energy and protein diets selected much less protein content than did birds fed the normal diets or the choice of starter and finisher diets. YIELD strain birds selected more protein content than did the GROWTH strain birds that were given the choice of the high energy or high protein diets.

The effects of the different feeding systems on energy level of the consumed feed are shown in Table 11. Though the data were not run on SAS, there were numerical differences. The selected energy level by birds given the choice of high energy or high protein feeds was higher than that of birds fed the other two systems. The GROWTH strain chose a higher energy level than did YIELD strain when offered a choice between the high energy and high protein feeds.

The effects of the different feeding systems and strain on mortality are shown in Table 12. There was considerably higher mortality among the GROWTH strain than the YIELD strain, most notably in the first 10 days of age and for the periods of 10-42 and 10-49 d of age. The two strains came from different locations and may not have been handled the same prior to being placed on feed in the research facility.

The effects of the different feeding systems and strain on various processing parameters are shown in Table 13. Treatment, strain and treatment by strain interactions were noted for every parameter. There were few differences between the performance of birds fed the normal diets and those given choice between starter and finisher diets for any parameter; however, in the birds given choice of Energy-Protein diets had significant lower values compared to those birds fed Normal or

Table 10: Effect of different feeding systems on protein level (% of consumed feed) by two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system								
	Normal			Energy-Protein			Starter-Finisher		
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD
11-22 d	19	19	19	12.9	13.8	14.8	17.3	17.5	17.7
22-32 d	18	18	18	12.4	13.5	14.5	18.5	18.5	18.5
32-42 d	18	18	18	12.6	15.2	17.7	19.2	18.8	18.4
42-49 d	17	17	17	13.9	15.7	17.5	19.4	19.0	18.5
11-32 d	18.4	18.4	18.4	12.6	13.6	14.6	18.0	18.1	18.2
11-42 d	18.3	18.3	18.3	12.6	14.3	15.9	18.5	18.4	18.3
11-49 d	18.1	18.1	18.1	12.9	14.6	16.3	18.7	18.5	18.4

Table 11: Effect of different feeding systems on energy level (ME Mcal/kg of the consumed feed) by two strains of male broilers at different feeding intervals (means of eight pens of 25 birds each)

	Feeding system								
	Normal			Energy-Protein			Starter-Finisher		
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD
11-22 d	3.083	3.083	3.083	3.271	3.250	3.229	3.162	3.153	3.143
22-32 d	3.176	3.176	3.176	3.283	3.259	3.235	3.105	3.105	3.104
32-42 d	3.176	3.176	3.176	3.279	3.219	3.160	3.071	3.090	3.110
42-49 d	3.176	3.176	3.176	3.248	3.206	3.164	3.061	3.084	3.106
11-32 d	3140	3140	3.140	3278	3255	3233	3128	3125	3121
11-42 d	3169	3169	3169	3279	3240	3202	3104	3110	3116
11-49 d	3194	3194	3194	3271	3232	3193	3094	3103	3111

Starter-Finisher diets for every parameter. The values for the YIELD strain tended to be higher than those for the GROWTH strain for breast weight and breast yield, as would be expected. The YIELD strain was better able to maintain breast weight and yield when given the choice of high energy or high protein diets, accounting for much of the treatment by strain interactions observed.

Discussion

The highest growth rate as shown by YIELD strains was not associated with the best feed conversion for those birds fed control and Starter-Finisher diets, despite the high relationship that exists between growth rate and feed conversion (Emmerson, 1997). Only the feed conversion of YIELD strain fed Energy-Protein diets was better than did the GROWTH strain. Lean strains have also had better feed conversion than did fat strains; moreover, this difference was shown for both choice feeding and control diets (Mastika and Cumming, 1981; Leclercq and Guy, 1991).

Many studies have shown that birds given a choice of high energy or high protein diets had worse performance than did birds fed control diets (Cowan and Michie, 1977; Cowan and Michie, 1978; Yokota and Sagawa, 1979; Sinurat and Balnave, 1986; Yo *et al.*, 1998; Zulkifli *et al.*, 2001; Munt *et al.*, 1995). Similar results have also been obtained in the present study in which the poor performance of birds given the choice of high energy or high protein diets was associated with dietary self-selection of higher energy content and lower protein content than those of control or Starter-Finisher diets. It seems that birds given the choice of the Energy-Protein diets, in the desire to first meet a high energy requirement, consequently select a lower protein

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

	Feeding system									
	Normal			Energy-Protein			Starter-Finisher			
Period (d)	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
0-10 d	9.000		0.500	4.000		3.500	7.000		1.500	111.19
		4.750			3.750			4.250		
10-22 d	1.000		1.000	3.000		2.000	0.000		1.500	165.18
		1.000			2.500			0.750		
10-32 d	3.500		1.500	4.000		3.000	1.500		1.500	139.65
		2.500			3.500			1.500		
10-42 d	9.500		3.500	6.500		3.500	5.000		2.000	112.46
		6.500			5.000			3.500		
10-49 d	15.500		5.500	8.500		4.000	7.500		5.000	88.92
		10.500			6.250			6.250		
Parameter		Treatment		Strain			Treat×strain			
0-10 d		0.82			0.001			0.06		
10-22 d		0.08			0.80			0.32		
10-32 d		0.28			0.32			0.72		
10-42 d		0.33			0.01			0.68		
10-49 d		0.14			0.007			0.28		

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

Parameter	Normal			Energy-Protein			Starter-Finisher			
	GROWTH		YIELD	GROWTH		YIELD	GROWTH		YIELD	CV
Body weight	3.323^{cd}		3.389^{d}	2.483^{a}		3.026^{b}	3.231^{c}		3.454^{d}	9.27
(kg)		3.356^{b}			2.754^{a}			3.342^{b}		
Carcass	2.381^{cd}		2.470^{de}	1.665^{a}		2.187^{b}	2.286^{bc}		2.544^{e}	10.12
weight (kg)		2.426^{b}			1.926^{a}			2.415^{b}		
Dressing	71.59^{bc}		72.88^{de}	66.90^{a}		72.18^{cd}	70.74^{b}		73.67^{e}	2.90
percentage		72.24^{b}			69.54^{a}			72.20^{b}		
Breast	0.677^{c}		0.776^{d}	0.353^{a}		0.630^{b}	0.645^{bc}		0.815^{d}	14.63
weight (kg)		0.726^{b}			0.492^{a}			0.730^{b}		
Wing	0.257^{d}		0.250^{cd}	0.198^{a}		0.224^{b}	0.245^{c}		0.253^{cd}	9.24
weight (kg)		0.253^{b}			0.211^{a}			0.249^{b}		
Leg quarter	0.738^{cd}		0.717^{cd}	0.569^{a}		0.669^{b}	0.703^{bc}		0.751^{d}	11.39
weight (kg)		0.727^{b}			0.619^{a}			0.727^{b}		
Breast %										
of carcass	28.36^{b}		31.39^{c}	21.01^{a}		28.60^{b}	28.17^{b}		32.03^{c}	8.31
		29.88^{b}			24.81^{a}			30.10^{b}		
Wings %										
of carcass	10.80^{c}		10.12^{ab}	11.94^{d}		10.30^{b}	10.75^{c}		9.95^{a}	6.09
		10.467^{b}			11.123^{a}			10.354^{b}		
Leg quarter	31.03^{b}		29.02^{a}	34.22^{c}		30.69^{b}	30.78^{b}		29.54^{a}	7.36
% of carcass		30.02^{a}			32.45^{b}			30.16^{a}		
Parameter		Treatment			Strain			Treat×strain		
Body weight		0.0001			0.0001			0.0001		
Carcass weight		0.0001			0.0001			0.0001		
Dressing percentage		0.0001			0.0001			0.0001		
Breast weight		0.0001			0.0001			0.0001		
Wing weight		0.0001			0.002			0.0001		
Leg quarter weight		0.0001			0.001			0.0001		
Breast % of carcass		0.0001			0.0001			0.0001		
Wings % of carcass		0.0001			0.0001			0.0001		
Leg quarter % of carcass		0.0001			0.0001			0.009		

^{abcd}Means within a row with common letters do not differ significantly ($p \leq 0.05$)

content. In this situation the deficiency of protein or amino acids may initiate a dietary protein stress in which the plasma levels of corticosterone increase (Weber *et al.*, 1990) and consequently cause an increment of energy intake by the preference for carbohydrate intake (Cosava and Forbes, 1995). Moreover, since the plasma ratio of tryptophan to large neutral amino acids (Trp:LNAA) and the selected protein intake have shown some inverse trends in birds (Elkin *et al.*, 1985) and rats (Ashley and Anderson, 1975), the high protein diet may not be preferred in the present study because this diet had higher dietary ratio of tryptophan to large neutral amino acids (Trp:LNAA) than that of high energy diet.

The similarity of performance between birds fed the Starter-Finisher diets and control diets was probably because the range of energy levels of starter and finisher diets was not too wide (2.896 to 3.176 Mcal/kg) which let these birds make an adequate self-formulation of energy and protein levels. Similar results have been reported in several studies which the birds were fed isocaloric diets varying in protein content (Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993), low energy levels of control diets (Cowan and Michie, 1978; Yokota and Segawa, 1979; Mastika and Cumming, 1981, 1985, 1987; Munt *et al.*, 1995), or a choice of very high energy or high protein diets (Sinurat and Balnave, 1986; Yo *et al.*, 1998; Olver and Jonker, 1997).

In both choice feeding systems in the present study the birds selected more of the high energy diets than high protein diets especially during the period of 10 to 22 d. Thus the selected energy levels were higher or equal than 3.15 Mcal/kg during this period. These choice-fed broilers had an elevated energy probably due to two possibilities 1) the energy requirement was high during this period or 2) the energy requirement of the previous phase (0 to 10 d) was deficient in energy content (2.986 Mcal/kg) and the birds compensated the previous deficiency selecting a higher amount of that nutrient as shown by Kirchgessner and Paulicks (1994) and Forbes and Shariatmadari (1996).

It seems that the lower energy requirement of YIELD strain fed the Energy-Protein diets allowed them to select a diet relatively high in protein and consequently a higher protein intake compared to the GROWTH strain. Similarly, strains of high growth rate have selected less energy level but higher protein level than did strains of low growth rate (Huey *et al.*, 1982; Brody *et al.*, 1984). Moreover, when the energy or protein consumption was expressed in function of body gain, lean strains have also chosen less energy and more protein compared to fat strains (Mastika and Cumming, 1981). Likewise the YIELD strains which had a higher breast yield than did GROWTH strain had less energy and more protein consumption for kg gain when given a choice of high energy or high protein diets. In this choice feeding the GROWTH strains probably had higher blood levels of corticosterone than did the YIELD strains and in turn incremented the selection of energy content by the preference of the high energy diet. Similarly a slow growth rate strain has shown a greater preference for a high energy diet than did the fast growth rate strain during the first 20 days (Siegel *et al.*, 1997). Thus greater adrenocortical cell sensitivity to corticotropin by slow growth rate strains compared to fast growth rate strains have been demonstrated (Weber *et al.*, 1990); corticotropin stimulates the synthesis of costicorterone (Siegel, 1968; Davison *et al.*, 1985) and therefore enhances the preference for carbohydrate intake.

Studies of choice feeding have shown that the selected protein level declines as the birds aged (Kaufman *et al.*, 1978; Kaminska, 1982; Picard *et al.*, 1997). In contrast, in the present study the selected protein level of both choice feeding systems tended to increase as the birds aged. It is likely that the tendency of this selected protein can be driven by the selection of energy since the energy level tended to decrease as the birds aged especially for the Starter-Finisher diet. Moreover, the low energy level used during the first 10 days suggests a possible energy deficiency which stimulated the birds to choose a higher energy level and consequently a lower protein level during the period of 10-22 d of age. Some studies without this previous energy deficiency have shown a decline of the selected protein level when the split diets were fed from 1 day old of age (Kaminska, 1982; Picard *et al.*, 1997). The selected energy levels of Energy-Protein diets shown a curvilinear trend with a tendency to decrease as the birds aged peaking at 22 to 32 d, whereas the selected energy levels of Starter-Finisher diet tended to decline as the birds aged. A choice feeding study has also shown a curvilinear tendency of selected energy levels but peaking later between 42 and 49 days of age (Kaminska, 1982).

The results of the present study demonstrates definite differences in the ability of two strains that differed in expected performance and nutritional selection when offered choices in diet selection. The greatest difference was observed when they were given a choice between a high energy and a high protein diet, but differences were also noted when given a choice between a starter and finisher diets. These results suggest that some type of choice feeding system might be used as a preliminary step in evaluating whether new or modified strains of birds might differ in their nutrient needs.

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