ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 7 (8): 726-737, 2008
ISSN 1682-8356

Choice Feeding of Two Different Broiler Strains Using Diets with Constant Energy Level[1]

S. Cerrate, C. Coto, Z. Wang, F. Yan, F.G. Costa and P.W. Waldroup[2]
Department of Poultry Science, University of Arkansas, Fayetteville AR 72701, USA

Abstract: Chicken 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 11-49 days were provided single diets (control) or isoenergetic choices between 15% and 24% or 15% and 32% crude protein (CP) diets. The Growth strain had greater body weight and intake of feed, protein and energy at all intervals except for 42-49 d of age as well as carcass characteristic in weight basis than did Yield strain. However, the latter strain had better feed, protein and energy conversion at 42-49 d of age and breast meat yield than did the former strain. Birds fed the isoenergetic diets varying in protein content had similar body weight, feed intake, feed conversion, energy intake, energy conversion and carcass characteristic expressed in relative term as did birds fed the control diets. Only for the last period of feeding (42-49 d of age), the protein consumption and conversion by birds fed choice of 15 and 24% CP were higher than those of birds fed the control diets. The Growth strain had a slightly greater preference for the high protein diet and consequently a higher protein intake compared to Yield strain. It seems that the selection of protein density was determined by the growth rate rather than the breast yield. There was a marked preference for the low protein diet (15% CP) over the high protein diets (24 and 32% CP), but this preference was reduced when the low protein diet was offered with the 24% CP diet. The levels of selected protein of birds given the choice diets were higher than those of control diets except for the period of 10-22 d of age and increased with age. These data indicate that these choice feeding systems can detect differences in protein requirement of two strains influenced by the growth rate.

Key words: Broilers, choice feeding, dietary self selection, protein intake

Introduction

Dietary self-selection or choice feeding has been suggested as a means of estimating nutrient needs of broilers (Hughes, 1984; Mastika and Cumming, 1987; Rose and Kyriazakis, 1991). As new strains of birds 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.

In previous studies from our laboratory (Cerrate *et al.*, 2007 a,b,c) it appeared the driving force in dietary self selection for broilers was the dietary energy level. Birds would consume diets based on meeting energy needs even if protein consumption was not sufficient to sustain adequate growth rates. Therefore, choice feeding programs to estimate the protein needs should have isoenergetic diets varying in protein content. This technique can detect differences in protein needs of new broiler strains according to the demand for optimum growth. Thus, heavy strains of fast growth rate have selected more protein and less energy density than did light strains of slow growth rate (Huey *et al.*, 1982; Brody *et al.*, 1984). Likewise, lean strains have chosen more protein content than did fat strains (Mastika and Cumming, 1981; Leclercq and Guy, 1991). It appears that the rate of growth of carcass protein determines the selected protein density in broilers. However, other factors can affect the selection of protein content such as the feed texture (Yo *et al.*, 1997), fixed energy level (Cheng, 1991; Steinruck and Kirchgessner, 1993), type of ingredient (Rose and Michie, 1984), time (Kaufman *et al.*, 1978; Kaminska, 1982; Steinruck and Kirchgessner, 1993; Forbes and Sharitmadari, 1994; Picard *et al.*, 1997; Cerrate *et al.*, 2007a,b,c) and temperature (Cowan and Michie, 1977; Mastika and Cumming, 1985, 1987; Hruby *et al.*, 1995). It seems that birds fed single diets try to decrease the protein density and energy content during heat stress compared to normal condition (Adams *et al.*, 1962b; Adams and Rogler, 1968; Kubena *et al.*, 1972; Dale and Fuller, 1978). However, in choice feeding studies with non-isocaloric diets the protein density has been increased as the temperature elevated (Cowan and Michie, 1977; Mastika and Cumming, 1985, 1987; Hruby *et al.*, 1995).

Although birds fed isoenergetic diets can select from wide, medium, or narrow ranges of two or four protein contents for maximum growth (Shariatmadari and Forbes, 1993; Kaminska, 1982; Steinruck and Kirchgessner, 1993), birds can efficiently select in term of energy conversion with a narrow range of two protein contents (15 vs 24 or 32% crude protein) (Cerrate *et al.*, 2007c).

The objective of the present study was to attempt to identify differences in nutritional needs for protein and evaluate performance of two different broiler strains by choice feeding system with isoenergetic diets varying in protein content.

Materials and Methods

Strain of birds: This experiment utilized a strain of birds generally selected for growth rate and feed conversion (Growth) and a strain of birds generally selected for high breast meat yield (Yield). Birds from the two different strains were obtained from breeder flocks of two different ages, obtained from two different hatcheries, transported different distances to the research facility, and held different times before being placed on feed. Therefore, comparison of performance of the two strains is focused primarily on response to the dietary treatments rather than differences in the two strains per se.

Birds grown on two different choice systems were compared to birds fed a commercial feeding schedule based on breeder[3] recommendations. Birds of each strain were allowed to choose between 1) a diet containing 15% CP and a diet containing 24% CP; or 2) a diet containing 15% CP and a diet containing 32% CP. Each treatment was fed to four pens of 25 birds. A low bird density (2 ft^2 per bird) was utilized 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: 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). Other diets were formulated to contain 15% CP (low protein) or 24 and 32% CP (high protein series) while remaining constant in metabolizable energy content. Within each protein level, a ratio of amino acids to dietary protein was maintained that had the same relationship as did the NRC (1994) recommendations for 0-3 week in relation to a 23% CP diet, with the exception that the lysine level was adjusted to 1.25% per 23% CP. The low and high protein diets were similar in content of supplemental vitamins, trace minerals, sodium, calcium and available phosphorus.

Dietary treatments: The combination of three feeding systems and two broiler strains resulted in a total of six experimental treatments. One group of birds of each strain was fed the Normal diets in chronological order (Diets 1 through 4). The second group of birds of each strain was fed the Normal starter diet for the first ten days and then given a choice between Diet 5 (15% CP) and Diet 6 (24% CP). The third group of birds of each strain was fed the Normal starter for the first ten days and then given a choice between Diet 5 (15% CP) and Diet 7 (32% CP). Diets were fed as crumbles for the first ten 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 the high protein diets (24 and 32% CP) had poor pellet quality, primarily because of the high dietary fat content; the diet containing 32% CP had worse pellet quality than did the diet containing 24% CP.

Measurements: For the first 10 days, all birds were fed the starter diet (Diet 1) in supplemental feeder flats and in two tube-type feeders. At the end of 10 d, feed and birds were weighted 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 two of the pens the "A" feeder was on the side of the pen facing west and in two of the pens the "A" feeder was on the side of the pen facing east for each treatment. All birds were weighed at each feed change interval indicated for the Normal feeding diets (10, 22, 42 and 49 days) and also at 32 days of age. In pens with choice or control feeds, consumption of feed from the two different feeders was determined. At 49 days of age, five males from each pen were processed to determine processing yield as described by Fritts and Waldroup (2006).

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

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 analysis; data are presented as natural numbers.

Results

The basic premise of this study was that birds would selectively choose between two different diets when offered a choice. When birds were offered the same feed in two different feeders (Normal), they consumed approximately equal amounts from either feeder (Table 2). This indicates that there was no innate selectivity as to which feeder that the birds might choose from. Therefore, when offered the choice of two different feeds

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

Ingredients	0-10 d Diet 1	11-22 d Diet 2	22-42 d Diet 3	42-49 d Diet 4	15% CP Diet 5	24% CP Diet 6	32% CP Diet 7
Yellow corn	629.28	670.23	682.37	713.80	749.26	449.54	183.65
Soybean meal	304.21	254.26	230.59	203.65	184.57	439.21	664.15
Pro-Pak[1]	25.00	25.00	25.00	25.00	0.00	0.00	0.00
Poultry oil	0.62	10.21	23.36	18.46	19.60	66.63	108.63
Ground limestone	10.37	10.00	9.29	9.39	14.11	13.38	12.72
Dicalcium phosphate	16.25	15.52	14.12	14.27	18.56	17.13	15.88
MHA 84	1.81	1.81	2.00	1.81	0.92	1.85	2.72
L-Lysine Hcl	0.21	0.72	1.02	1.25	0.72	0.00	0.00
L-Threonine	0.00	0.00	0.00	0.12	0.00	0.00	0.00
Constant ingreedients[2]	12.25	12.25	12.25	12.25	12.25	12.25	12.25
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/lb	1355.00	1398.82	1441.00	1441.00	1445.03	1445.02	1445.00
ME kcal/kg	2986.42	3083.00	3176.00	3176.00	3184.85	3184.83	3184.78
CP %	21.00	19.00	18.00	17.00	15.00	24.00	32.00
Ca %	1.00	0.96	0.90	0.90	1.00	1.00	1.00
Nonphytate P %	0.50	0.48	0.45	0.45	0.45	0.45	0.45
Met %	0.50	0.48	0.48	0.45	0.33	0.52	0.70
Lys %	1.21	1.10	1.06	1.00	0.82	1.46	2.08
Trp %	0.25	0.23	0.21	0.20	0.17	0.32	0.44
Thr %	0.84	0.76	0.72	0.69	0.59	0.98	1.33
Arg %	1.43	1.26	1.18	1.10	0.95	1.76	2.47
TSAA %	0.90	0.84	0.83	0.79	0.62	0.95	1.25
Dig Lys %	1.08	0.99	0.95	0.90	0.73	1.31	1.88
Dig Trp %	0.22	0.20	0.18	0.17	0.15	0.28	0.44
Dig Thr %	0.73	0.66	0.62	0.60	0.51	0.86	1.33
Dig Met+Cys %	0.80	0.75	0.74	0.70	0.55	0.85	1.12
Sodium %	0.24	0.23	0.23	0.24	0.22	0.22	0.23

[1]H.J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Contains (g /kg) 5.0 sodium chloride; 5.0 vitamin premix (provides per kg of diet: vitamin A 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B12 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); 1.0 trace mineral mix (provides per kg of diet: Mn (from $MnSO_4 \bullet H_2O$) 100mg; Zn (from $ZnSO_4 \bullet 7H_2O$) 100 mg; Fe (from $FeSO_4 \bullet 7H_2O$) 50 mg; Cu (from $CuSO_4 \bullet 5H_2O$) 10 mg; I from $Ca(IO_3)_2 \bullet H_2O$), 1 mg); 0.75 Coban 60 (Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825); 0.50 BMD 50 (Alpharma, Inc., Ft. Lee, NJ 07024).

Table 2: Relative intake of different feeding systems by two different strains of male broilers at different feeding intervals (means of four pens of 25 birds each)

	Feeding system											
	Normal diet				15 vs 24 CP				15vs 32 CP			
	Growth		Yield		Growth		Yield		Growth		Yield	
Period (Days)	A	B	A	B	15	24	15	24	15	32	15	32
10-22	49	51	46	54	65^{a}	35^{b}	59	41	79^{a}	21^{b}	84^{a}	16^{b}
22-32	50	50	53	47	54	46	65	35	82^{a}	18^{b}	84^{a}	16^{b}
32-42	51	49	49	51	58	42	58	42	73^{a}	27^{b}	82^{a}	18^{b}
42-49	54	46	51	49	51	49	52	48	70^{a}	30^{b}	79^{a}	21^{b}
10-32	50	50	50	50	58	42	63	37	81^{a}	19^{b}	84^{a}	16^{b}
10-42	50	50	50	50	58	42	61	39	78^{a}	22^{b}	83^{a}	17^{b}
10-49	51	49	50	50	56	44	59	41	76^{a}	24^{b}	82^{a}	18^{b}
Period (days)	P diff	SEM	P diff	SEM	P diff	SEM	P diff	SEM	P diff	SEM	P diff	SEM
10-22	0.638	2.31	0.078	1.66	0.041	4.33	0.363	8.64	0.004	3.44	<0.001	1.50
22-32	0.977	8.52	0.787	9.34	0.179	2.08	0.146	7.74	0.008	5.16	0.003	3.75
32-42	0.838	6.41	0.867	6.27	0.346	7.30	0.265	5.94	0.042	6.74	<0.001	0.45
42-49	0.626	6.52	0.876	7.38	0.874	6.93	0.544	2.97	0.050	6.36	0.021	6.53
10-32	0.935	6.01	0.953	5.79	0.051	2.44	0.195	7.86	0.006	4.51	<0.001	1.93
10-42	0.945	5.18	0.959	4.12	0.138	3.97	0.213	7.01	0.013	5.26	<0.001	1.06
10-49	0.849	5.20	0.968	4.05	0.262	4.61	0.185	5.20	0.018	5.50	<0.001	2.01

^{ab}Means within a row with common superscripts do not differ significantly ($P \leq 0.05$).

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

Period (days)	Feeding system: Normal Growth	Normal Yield	15 vs 24 CP Growth	15 vs 24 CP Yield	15 vs 32 CP Growth	15 vs 32 CP Yield	All systems Growth	All systems Yield	CV
10-22	0.584	0.535	0.607	0.547	0.594	0.533	0.595[a]	0.538[b]	5.59
	0.559		0.577		0.563				
22-32	1.025	0.939	1.023	0.925	1.020	0.891	1.023[a]	0.918[b]	2.88
	0.982		0.974		0.956				
32-42	1.085	1.017	1.087	1.047	1.062	1.026	1.078[a]	1.030[b]	4.78
	1.051		1.067		1.044				
42-49	0.740	0.771	0.737	0.785	0.730	0.733	0.736	0.763	7.85
	0.755		0.761		0.731				
10-32	1.609	1.474	1.630	1.472	1.614	1.407	1.618[a]	1.451[b]	3.09
	1.541		1.551		1.510				
10-42	2.694	2.490	2.717	2.519	2.676	2.461	2.696[a]	2.490[b]	3.06
	2.592		2.618		2.569				
10-49	3.434	3.261	3.454	3.304	3.406	3.196	3.431[a]	3.254[b]	3.16
	3.347		3.379		3.301				

Period (days)	Treatment	Strain	Treat x Strain
10-22	0.517	0.0004	0.913
22-32	0.214	< 0.001	0.340
32-42	0.673	0.037	0.795
42-49	0.604	0.288	0.771
10-32	0.261	< 0.001	0.366
10-42	0.475	< 0.001	0.976
10-49	0.351	0.0006	0.851

[ab]Means within a row with common superscripts do not differ significantly ($P \leq 0.05$).

it would further suggest that any deviation from equal amounts of feed consumed would be due to some desire of the bird to meet its nutritional needs.

When offered the choice between diets with 15 and 24% CP, both the Growth strain and the Yield strain consumed more feed from the feeder with 15% CP than from the feeder with 24% CP; however this was significantly different only with the Growth strain and only during the period of 10-22 d. When offered the choice between diets with 15 and 32% CP, however, there was a greater degree of difference in choice between the two feeders. Both the Growth strain and the Yield strain consumed a significantly greater amount of feed from the feeder with 15% CP than from the feeder with 32% CP over all age periods. These data indicate that the birds in fact selectively chose from the two different feeds when offered a choice.

The effects of the different feeding systems on body weight of two strains of male broilers are shown in Table 3. The Growth strain had significantly greater body weight than did the Yield strain at all age periods except for 42-49 d of age. Body weight gains at all intervals after ten days of age were not significantly influenced by the dietary treatment or by an interaction between dietary treatment and strain. This indicates that the birds of either strain were able to select between the diets with different crude protein levels sufficiently to meet their needs for growth.

The feed intake by birds of the Growth strain was significantly greater than that of birds of the Yield strain at all periods except from 42-49 d of age (Table 4). However, there was no significant effect of dietary treatment on feed intake, nor was there any significant interaction between strain of bird and dietary treatment on feed intake. This indicates that with diets calculated to be isocaloric that birds were able to selectively choose their desired protein level without overconsumption of the overall diet.

There were no significant differences in feed conversion (grams feed per gram gain) due to dietary treatment (Table 5). This indicates that birds offered their choice between diets with widely different levels of crude protein were able to selectively consume the proper balance of diets to allow the birds to meet their needs for nutrients without overconsumption of energy or protein. Strain differences in feed conversion were noted during the periods of 22-32 days and 42-49 days; however, these were not consistent as the Growth strain had lower feed conversion during the period of 22-32 days while the Yield strain had lower feed conversion during the period of 42-49 days. There were no significant differences between strains for cumulative feed conversion to 32, 42, or 49 days of age. There were no significant treatment by strain interactions for feed conversion.

The effects of different feeding systems and genetic strains on protein intake is shown in Table 6. In general,

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

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	0.913	0.831	0.948	0.827	0.928	0.860	0.930[a]	0.839[b]	5.87
	0.872		0.887		0.894				
22-32	1.633	1.576	1.675	1.576	1.645	1.510	1.651[a]	1.554[b]	5.29
	1.605		1.625		1.578				
32-42	2.005	1.891	2.038	1.876	1.903	1.939	1.982	1.902	5.57
	1.948		1.957		1.921				
42-49	1.484	1.499	1.589	1.513	1.515	1.427	1.529	1.480	6.38
	1.491		1.551		1.471				
10-32	2.546	2.407	2.621	2.401	2.573	2.335	2.580[a]	2.381[b]	4.62
	2.476		2.511		2.454				
10-42	4.531	4.294	4.639	4.265	4.468	4.269	4.546[a]	4.276[b]	4.06
	4.413		4.452		4.368				
10-49	5.999	5.783	6.191	5.758	5.958	5.695	6.049[a]	5.745[b]	3.93
	5.891		5.975		5.826				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.688		0.0005		0.594				
22-32	0.574		0.015		0.682				
32-42	0.807		0.096		0.219				
42-49	0.268		0.240		0.534				
10-32	0.634		0.0007		0.674				
10-42	0.674		0.002		0.614				
10-49	0.480		0.006		0.626				

[ab] Means within a row with common superscripts 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 four pens of 25 birds each)

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	1.566	1.553	1563	1.513	1.567	1.612	1.565	1.559	4.02
	1.559		1.538		1.589				
22-32	1.592	1.680	1.639	1.704	1.612	1.697	1.614[b]	1.694[a]	5.23
	1.636		1.671		1.655				
32-42	1.846	1.867	1.876	1.791	1.793	1.890	1.838	1.849	4.73
	1.857		1.833		1.842				
42-49	2.012	1.959	2.155	1.929	2.077	1.951	2.081[a]	1.946[b]	5.68
	1.985		2.042		2.014				
10-32	1.581	1.633	1.610	1.631	1.595	1.660	1.595	1.641	4.15
	1.607		1.621		1.627				
10-42	1.681	1.726	1.709	1.693	1.670	1.755	1.687	1.725	3.46
	1.703		1.701		1.712				
10-49	1.746	1.774	1.793	1.743	1.750	1.800	1.763	1.772	2.51
	1.760		1.768		1.775				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.283		0.815		0.331				
22-32	0.717		0.044		0.960				
32-42	0.864		0.760		0.160				
42-49	0.623		0.012		0.338				
10-32	0.835		0.120		0.807				
10-42	0.927		0.136		0.273				
10-49	0.817		0.630		0.095				

[ab]Means within a row with common superscripts do not differ significantly ($P \leq 0.05$).

protein consumption was similar for all treatments with the exception of the period between 42-49 d. During this time, birds given the choice between diets with 15 and 24% CP consumed significantly more crude protein than those birds given the normal diet, with birds given the choice between diets with 15 and 32% being intermediate in protein consumption. Birds of the Growth strain consumed significantly more crude protein than did birds of the Yield strain except for the period of 42-49 d of age. Cumulative crude protein consumption was

Table 6: Effect of different feeding systems on protein intake (kg/bird) by two strains of male broilers at different feeding intervals (means of four pens of 25 birds each)

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	0.174	0.158	0.172	0.155	0.173	0.154	0.173^{a}	0.156^{b}	8.31
	0.166		0.163		0.163				
22-32	0.294	0.284	0.321	0.286	0.296	0.273	0.304^{a}	0.281^{b}	6.86
	0.289		0.304		0.285				
32-42	0.361	0.341	0.381	0.352	0.373	0.347	0.372^{a}	0.347^{b}	7.48
	0.351		0.367		0.360				
42-49	0.252	0.255	0.308	0.292	0.306	0.264	0.289	0.270	10.33
	0.254^{b}		0.300^{a}		0.285^{ab}				
10-32	0.468	0.441	0.493	0.441	0.469	0.419	0.477^{a}	0.434^{b}	6.43
	0.454		0.467		0.444				
10-42	0.826	0.782	0.871	0.791	0.839	0.765	0.845^{a}	0.779^{b}	6.44
	0.804		0.831		0.802				
10-49	1.076	1.035	1.171	1.078	1.139	1.030	1.129^{a}	1.048^{b}	6.50
	1.056		1.124		1.084				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.922		0.006		0.967				
22-32	0.182		0.016		0.491				
32-42	0.515		0.040		0.956				
42-49	0.016		0.152		0.366				
10-32	0.347		0.003		0.636				
10-42	0.497		0.008		0.768				
10-49	0.181		0.015		0.623				

[ab] Means within a row with common superscripts do not differ significantly ($P \leq 0.05$).

always significantly greater for birds of the Growth strain. However, there were no significant interactions between dietary treatment and genetic strain for crude protein consumption.

The efficiency of protein utilization, expressed as kg protein/kg gain, is shown in Table 7. With the exception of the period of 42-49 d, there were no significant differences related to either dietary treatment or genetic strain of birds. During this time, birds fed the normal diet used less protein per kg gain than did those given the choice of diets with 15 and 24 or 32% CP. Birds of the Yield strain used less protein per kg gain than did birds of the Growth strain. No treatment by strain interactions were observed at any time during the study. The effects of different feeding systems and genetic strain on the actual protein level (% of consumed feed) is shown in Table 8. The amount of protein consumed by birds fed the Normal series was of course predetermined and based on recommendations of the breeder. It is interesting that, after the period of 10-22 d, protein consumption by the birds given their choice of diets was greater than that of birds given the Normal series. Again, this indicates that given a choice, birds may be able to select the protein/amino acid level that best sustains their productivity.

The effects of different feeding systems and genetic strain on energy intake is shown in Table 9. There were no significant differences in average ME intake by birds related to the different dietary treatments. While the Choice diets with 15 and 24 or 32% CP were formulated to be isocaloric, the Normal series of diets gradually increased in energy content as the birds aged. Therefore, it suggests that the primary factor that drives the birds to consume feed is the energy needs of the bird. The Growth strain birds consumed significantly more energy than did the Yield strain birds during the periods of 10-22 d and from 22-32 d. From 32-42 and 42-49 d the Growth strain birds consumed more energy than the Yield strain but the difference was not statistically significant. However, cumulatively over the entire period the Growth strain consumed significantly more energy than did the Yield strain. There were no treatment by strain interactions for energy intake.

The effects of the different feeding systems and genetic strain on energy utilization (ME kcal/kg gain) is shown in Table 10. There were no significant effects of dietary treatment on energy utilization at any time, although during the initial period of 10-22 d the difference neared statistical significance ($P = 0.058$). During that period, birds given the choice between diets with 15 and 32% CP did not consume energy as efficiently as did birds consuming the Normal diets or the birds given the choice between diets with 15 and 24% CP. However, at all other time periods and cumulatively over the study, there were no statistically significant differences in energy utilization among the birds fed the different

Table 7: Effect of different feeding systems on protein conversion (kg protein/kg gain) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal Growth	Normal Yield	15 vs 24 CP Growth	15 vs 24 CP Yield	15 vs 32 CP Growth	15 vs 32 CP Yield	All systems Growth	All systems Yield	CV
10-22	0.298	0.295	0.283	0.282	0.291	0.287	0.290	0.288	5.59
	0.296		0.283		0.289				
22-32	0.287	0.303	0.314	0.309	0.290	0.307	0.297	0.306	6.97
	0.295		0.312		0.299				
32-42	0.332	0.336	0.351	0.336	0.351	0.339	0.345	0.337	6.09
	0.334		0.344		0.345				
42-49	0.342	0.333	0.419	0.373	0.419	0.360	0.393[a]	0.355[b]	9.39
	0.338[b]		0.396[a]		0.389[a]				
10-32	0.290	0.300	0.302	0.299	0.291	0.298	0.294	0.299	5.65
	0.295		0.301		0.294				
10-42	0.306	0.314	0.321	0.314	0.313	0.315	0.313	0.314	5.41
	0.310		0.317		0.314				
10-49	0.313	0.318	0.339	0.326	0.334	0.325	0.329	0.323	4.99
	0.315		0.333		0.330				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.274		0.700		0.980				
22-32	0.267		0.304		0.531				
32-42	0.560		0.394		0.643				
42-49	0.008		0.020		0.385				
10-32	0.723		0.521		0.725				
10-42	0.708		0.911		0.689				
10-49	0.109		0.400		0.551				

[ab] Means within a row with common superscripts do not differ significantly ($P \leq 0.05$).

Table 8: Effect of different feeding systems on protein level (% of consumed feed) by two strains of male broilers at different feeding intervals (means of four pens of 25 birds each)

Period (days)	Normal	Feeding system: 15 vs 24 CP Growth	15 vs 24 CP Yield	15 vs 32 CP Growth	15 vs 32 CP Yield
10-22 d	19.0	18.1	18.7	18.6	17.9
		18.4		18.2	
22-32 d	18.0	19.2	18.1	18.0	18.1
		18.7		18.1	
32-42 d	18.0	18.7	18.8	19.6	17.9
		18.8		18.7	
42-49 d	17.0	19.4	19.3	20.2	18.5
		19.3		19.4	
10-32 d	18.4	18.8	18.4	18.2	17.9
		18.6		18.1	
10-42 d	18.2	18.8	18.5	18.8	17.9
		18.7		18.4	
10-49 d	18.0	18.9	18.7	19.1	18.1
		18.8		18.6	

dietary treatments. Significant strain differences in energy utilization were noted during the study but these were not consistent; the Yield birds were less efficient in energy conversion during the period of 22-32 d but more efficient during the period of 42-49 d. Cumulatively during the study, there were no differences between the two strains in energy utilization. There were no strain by treatment interactions for energy utilization.

Mortality during the study is shown in Table 11. There were no significant differences in mortality related to dietary treatment or to genetic strain, with no interactions between dietary treatment and genetic strain.

The effects of the different feeding programs and genetic strain on various carcass characteristics is shown in Table 12. The dietary treatment on which the birds were produced resulted in some significant effects on processing yields and carcass parts. Although the final live weight of birds at 49 d did not differ significantly among the various feeding treatments (Table 3), the birds that had been given the choice between diets with 15 and 32% CP were numerically smaller than birds given the Normal diet or the choice between diets with 15 and 24% CP; as a result, birds selected for processing from this group weighed significantly less and had a significantly lower carcass weight than birds from the other dietary treatments. In addition, birds given the choice of diets with 15 and 32% CP had a significantly lower dressing percentage, less breast weight and less wing weight than did birds fed the Normal diets or a choice between 15 and 24% CP. When expressed as a percentage of the carcass, however, there were no significant differences in breast yield, wing yield, or leg quarter yield among the birds fed the various dietary treatments.

Because there were significant differences in body weight between strains at 49 d (Table 3) there were also significant strain differences in the body weight and carcass weight of the birds selected for processing

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 four pens of 25 birds each)

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	2816	2561	3017	2634	2957	2740	2930^{a}	2645^{b}	5.88
	2688		2826		2848				
22-32	5186	5005	5333	5018	5239	4810	5253^{a}	4944^{b}	5.29
	5096		5176		5024				
32-42	6366	6007	6492	5973	6060	6175	6306	6052	5.57
	6186		6233		6118				
42-49	4712	4759	5059	4819	4824	4545	4865	4708	6.38
	4736		4939		4685				
10-32	7999	7567	8347	7646	8194	7435	8180^{a}	7549^{b}	4.61
	7783		7997		7814				
10-42	14301	13559	14775	13585	14229	13596	14435^{a}	13580^{b}	4.05
	13930		14180		13912				
10-49	18960	18289	19718	18339	18975	18138	19218^{a}	18255^{b}	3.92
	18624		19029		18556				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.136		0.0005		0.578				
22-32	0.570		0.015		0.681				
32-42	0.815		0.096		0.219				
42-49	0.255		0.238		0.533				
10-32	0.467		0.0007		0.650				
10-42	0.593		0.002		0.605				
10-49	0.413		0.006		0.613				

[ab]Means within a row with common superscripts do not differ significantly ($P \le 0.05$).

Table 10: Effect of different feeding systems on energy conversion (ME kcal/kg gain) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	4828	4787	4977	4817	4989	5134	4931	4913	4.05
	4808		4897		5062				
22-32	5056	5335	5220	5426	5135	5403	5137^{b}	5388^{a}	5.23
	5195		5323		5269				
32-42	5862	5930	5973	5705	5710	6021	5848	5885	4.74
	5896		5839		5866				
42-49	6390	6221	6864	6142	6616	6213	6623^{a}	6192^{b}	5.68
	6306		6503		6414				
10-32	4967	5135	5128	5195	5080	5286	5058	5205	4.16
	5051		5161		5183				
10-42	5304	5451	5442	5393	5317	5590	5354	5478	3.46
	5378		5418		5454				
10-49	5519	5610	5711	5550	5572	5732	5601	5631	2.51
	5565		5631		5652				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.058		0.821		0.327				
22-32	0.656		0.044		0.961				
32-42	0.918		0.757		0.161				
42-49	0.566		0.012		0.337				
10-32	0.447		0.119		0.808				
10-42	0.740		0.134		0.270				
10-49	0.468		0.617		0.092				

[ab]Means within a row with common superscripts do not differ significantly ($P \le 0.05$).

(Table 12). Birds of the Yield strain had higher dressing percentage (P = 0.07) and lower wing and leg quarter weight than did birds of the Growth strain. No significant difference in breast weight was observed between the two strains, but the Yield strain had a greater percentage of breast meat and a smaller percentage of wings than the Growth strain with no significant difference in yield of leg quarters. There was no interaction of dietary treatment and genetic strain for any processing parameter.

Table 11: Effect of different feeding systems on mortality (%) by two strains of male broilers at different feeding intervals (means of four pens of 25 birds each)

	Feeding system								
	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Period (days)	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
10-22	3.0	0.0	0.0	1.0	3.0	0.0	2.0	0.3	1.15
	1.5		0.5		1.5				
22-32	2.0	0.0	3.0	3.0	1.0	2.0	2.0	1.7	1.32
	1.0		3.0		1.5				
32-42	8.0	3.0	7.0	10.0	4.0	4.0	6.3	5.7	2.78
	5.5		8.5		4.0				
42-49	2.0	3.0	6.0	4.0	2.0	1.0	3.3	2.7	1.61
	2.5		5.0		1.5				
10-32	5.0	0.0	3.0	4.0	4.0	2.0	4.0	2.0	1.47
	2.5		3.5		3.0				
10-42	13.0	3.0	10.0	14.0	8.0	6.0	10.3	7.7	2.80
	8.0		12.0		7.0				
10-49	15.0	6.0	16.0	18.0	10.0	7.0	13.7	10.3	3.02
	10.5		17.0		8.5				
Period (days)	Treatment		Strain		Treat x strain				
10-22	0.627		0.100		0.176				
22-32	0.329		0.767		0.541				
32-42	0.334		0.789		0.421				
42-49	0.125		0.630		0.663				
10-32	0.809		0.126		0.174				
10-42	0.254		0.302		0.101				
10-49	0.056		0.248		0.297				

Discussion

The higher body weight of Growth strain in this study is in contrast to that found in the first trial from this laboratory (Cerrate *et al.*, 2007a) in which the Yield strain had superior growth rate. However, it should be again mentioned that birds from the two different strains were obtained from breeder flocks of two different ages, obtained from two different hatcheries, transported different distances to the research facility and held different times before being placed on feed. It is important to note, however, that the differences in growth rate were reflected in the choice of diets by the two strains. Birds of the Growth strain were significantly heavier and had a significantly higher feed intake with a concomitantly higher intake of both energy and protein. However, the efficiency of utilization of both energy and protein did not differ significantly between the two strains. It appears that the growth rate was a primary determinant in the selection of choice diets. Only for the last period, 42-49 days of age, was the feed conversion of YIELD strain better than that of Growth strain. It has been shown that lean strains had better feed conversion than did fat strains (Mastika and Cumming, 1981; Leclercq and Guy, 1991).

The lack of difference in body weights and feed conversion between birds fed choice diets and control diets found in this study is in agreement with previous observations (Engku Azahan and Forbes, 1989; Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993; Cerrate *et al.*, 2007c). Further, although the high protein series (25 and 32% CP) had a lower pellet quality, the birds fed these choice feeding options responded in the same way as did the birds fed control diets which had a great pellet quality.

The similarity of protein intake or conversion between the choice diets and control diets except for the last period (42-49 d) found in this study is in agreement with other studies; moreover, some studies have showed that birds offered choice feeding had better protein conversion than did birds fed control diets (Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993; Cerrate *et al.*, 2007c). However, the degree of difference in protein intake in the cited studies may have been due to higher crude protein levels in the control diets. The higher protein intake found herein for the last period (42-49 d) is probably caused because these choice birds tended to increase the selected protein density as they grew older and at this last period, the difference was more pronounced between birds given the control and choice diets.

It seems that higher selected protein density by Growth strain than did Yield strain was influenced for the higher growth rate instead of the breast yield. Similarly, strains of high growth rate had selected higher protein content

Table 12: Effect of different choice feeding systems compared to normal feeding on processing parameters of two strains of male broilers (means of four pens with five birds per pen each)

	Normal		15 vs 24 CP		15 vs 32 CP		All systems		
Parameter	Growth	Yield	Growth	Yield	Growth	Yield	Growth	Yield	CV
Body weight (kg)	3.809	3.563	3.747	3.631	3.647	3.415	3.734^{a}	3.536^{b}	7.63
	3.686^{a}		3.689^{a}		3.531^{b}				
Carcass weight (kg)	2.817	2.661	2.755	2.679	2.657	2.515	2.743^{a}	2.618^{b}	8.10
	2.739^{a}		2.717^{a}		2.586^{b}				
Dressing percentage	73.95	74.68	73.51	73.82	72.80	73.64	73.42	74.05	2.55
	74.31^{a}		73.66^{ab}		73.22^{b}				
Breast weight (kg)	0.850	0.835	0.819	0.820	0.777	0.774	0.815	0.810	13.38
	0.842^{a}		0.820^{ab}		0.775^{b}				
Wing weight (kg)	0.298	0.274	0.289	0.272	0.283	0.260	0.290^{a}	0.269^{b}	7.28
	0.286^{a}		0.280^{ab}		0.271^{b}				
Leg quarter weight (kg)	0.839	0.762	0.793	0.787	0.797	0.729	0.810^{a}	0.759^{b}	9.62
	0.800		0.790		0.763				
Breast % of carcass	30.12	31.30	29.68	30.53	29.05	30.64	29.62^{b}	30.82^{a}	7.59
	30.71		30.10		29.85				
Wings % of carcass	10.62	10.29	10.51	10.15	10.69	10.36	10.61^{a}	10.27^{b}	5.52
	10.45		10.33		10.53				
Leg quarter % of carcass	29.77	28.68	28.81	29.42	30.00	29.07	29.53	29.06	6.62
	29.23		29.12		29.54				
Parameter	Treatment		Strain		Treatment x Strain				
Body weight	0.021		0.0002		0.518				
Carcass weight	0.005		0.002		0.682				
Dressing percentage	0.040		0.074		0.806				
Breast weight	0.026		0.778		0.943				
Wing weight	0.008		< 0.0001		0.692				
Leg quarter weight	0.092		0.0004		0.076				
Breast % of carcass	0.237		0.005		0.779				
Wings % of carcass	0.326		0.002		0.993				
Leg quarter % of carcass	0.623		0.191		0.103				

^{ab}Means within a row with common superscripts do not differ significantly ($P \le 0.05$).

than did strains of low growth rate (Huey *et al.,* 1982; Brody *et al.,* 1984). Moreover, Cerrate *et al.,* (2007a) had found that the Yield strain which had higher growth rate than did the Growth strain had chosen the highest protein density, in contrast to this study; even though, for both studies the Yield strain had greater breast yield than did the Growth strains.

The variability of the selected protein density found in this study (17.9-20.2% CP) and other studies (14.9-22.6% CP) may be due to several reasons:

(1) Genetic Lean lines have selected higher protein content than that of fat lines (Leclercq and Guy, 1991) and birds of fast growth rate have chosen a higher protein density than did birds of slow growth rate (Huey *et al.,* 1982; Brody *et al.,* 1984; Cerrate *et al.,* 2007a).

(2) Feed texture Pellet concentrates were preferred to mash concentrates and therefore selecting more protein content (Yo *et al.,* 1997)

(3) Fixed energy level When the fixed metabolizable energy level (ME) was reduced (from 3.250-3.050 kcal/g), the selected protein density was also decreased (17.4-16.4% CP) keeping a constant energy/protein ratio (Cheng, 1991); however, when the ME was severely reduced (from 3.203-2.892 kcal/g), the selected protein density was increased (18.8-21.3% CP) (Steinruck and Kirchgessner, 1993).

(4) Type of ingredient When more fish meal was included in the choice diets, the choice protein density was reduced (Rose and Michie, 1984)

(5) Time As the birds aged the selected protein content was decreased or increased depending of the environmental condition (Kaufman *et al.*, 1978; Kaminska, 1982; Steinruck and Kirchgessner, 1993; Forbes and Sharitmadari, 1994; Picard *et al.,* 1997; Cerrate *et al.,* 2007a, b, c)

(6) Temperature In free choice diets, as the temperature was elevated the selected protein contents were increased (Cowan and Michie, 1977; Mastika and Cumming, 1985, 1987; Hruby *et al.,* 1995).

However, this reduction of protein density may be strongly influenced by the reduction of the selected energy content as the temperature increased since these choice diets were not isocaloric and the birds may have selected the high protein diets for the low energy content instead of the high protein density. On the other hand, in single diets it has been demonstrated that increasing protein density did not improve the body weight as the temperature elevated (Adams *et al.*, 1962a; Adams and Rogler, 1968; Cowan and Michie, 1978; Kubena *et al.*, 1972). Moreover, it seems that the dietary protein tended to be reduced at heat stress compared to normal conditions (Adams and Rogler, 1968; Kubena *et al.*, 1972). Furthermore, it appears that birds under heat stress select a lower energy content compared to thermoneutral condition. Thus it has been shown that choice-fed birds given isocaloric diets in term of ME had selected a lower fat diet in a hot environment than did birds in a cool environment (56 vs 65%) and consequently the energy content was reduced in term of net energy at heat stress (Dale and Fuller, 1978). In single diets increasing the energy content improved the body weight in both normal and heat stress conditions; this effect was less marked during heat stress compared to thermoneutral condition (Adams *et al.*, 1962b; Adams and Rogler, 1968).

In the present study, it appears that the choice of protein diets was partially affected by the feed texture. The low protein diet (15% CP) was more attractive to the birds because this diet had a very good pellet quality compared to the high protein diets (24 and 32% CP) which had a poor pellet quality especially for the 32% CP diet. Thus the lower selected protein content of the choice that included 32% CP diet compared to that of choice that included 24% CP diet may be accounted for in part by the physical form. Besides the physical forms, this preference may be explained by the differences of net energy between the three protein diets; the diet with 15% CP probably had a lower heat increment and in turn more net energy compared to the diets with 24 and 32% CP. This difference would have been more marked between the choice of 15 and 32% CP diets.

The similarity of energy conversion shown in the control diets and choice feeding in this study was also observed by Steinruck and Kirchgessner (1993) who supplied the same energy levels for all the choice diets.

As the birds grew older, the selected protein density tended to increase in this study, as compared to the typical decrease in dietary protein level used in the poultry industry. Other studies have found similar results (Cerrate *et al.*, 2007a, b). In contrast, in other reports of choice feeding the selected protein level tended to decrease as the birds aged (Kaufman *et al.*, 1878; Kaminska, 1982; Picard *et al.*, 1997; Cerrate *et al.*, 2007c). It is likely that the tendency of this selected protein may be accounted for the temperature condition under which the study was conducted. For example, in previous research of similar treatments done in this laboratory (15 vs 24 or 32% CP diets) conducted during the summer (Cerrate *et al.*, 2007c), the birds had selected a lower protein content than that of the present study carried out during the winter (17.4 vs 18.7% CP). Further, in isocaloric choice feeding diets it has been demonstrated that birds under heat stress reject the high protein feed (Cheng, 1991).

The results of the present study demonstrated the ability of two distinctly different strains of birds to selectively consume diets to provide for their nutrient needs when offered choices in diet selection. The choice feeding method using diets of constant energy levels with varying protein content appears suitable to determine the protein needs of different genetic strains.

References

Adams, R.L. and J.C. Rogler, 1968. The effects of environmental temperature on the protein requirements and response to energy in slow and fast growing chicks. Poult. Sci., 47: 579-586.

Adams, R.L., F.N. Andrews, E.E. Gardiner, W.E. Fontaine and C.W. Carrick, 1962b. The effects of environmental temperature on the growth and nutritional requirements of the chicks. Poult. Sci., 41: 588-594.

Adams, R.L., F.N. Andrews, J.C. Rogler and C.W. Carrick, 1962a. The sulfur amino acid requirement of the chick from 4-8 weeks of age as affected by temperature. Poult. Sci., 41: 1801-1806.

Brody, T.B., J.A. Cherry and P.B. Siegel, 1984. Responses to dietary selection and calories in liquid form by weight selected lines of chickens. Poult. Sci., 63: 1626-1633.

Cerrate, S., Z. Wang, C. Coto, F. Yan and P.W. Waldroup, 2007a. Choice feeding as a means of identifying differences in nutritional needs of broiler strains differing in performance characteristics. Int. J. Poult. Sci., 6: 713-724.

Cerrate, S., Z. Wang, C. Coto, F. Yan and P.W. Waldroup, 2007b. Choice feeding as a means of identifying differences in nutritional needs with two methods of amino acid formulations. Int. J. Poult. Sci., 6: 846-854.

Cerrate, S., Z. Wang, C. Coto, F. Yan and P.W. Waldroup, 2007c. Evaluation of protein choice feeding programs when diets have constant energy level. Int. J. Poult. Sci., 6: 916-924.

Cheng, T.K., 1991. Self-selection of diets varying in protein content by broilers under heat-stress. Ph.D. Thesis, University of Minnesota, St. Paul, MN.

Cowan, P.J. and W. Michie, 1977. Environmental temperature and choice feeding of the broiler. Br. J. Nutr., 40: 311-315.

Cowan, P.J. and W. Michie, 1978. Environmental temperature and broiler performance: the use of diets containing increased amounts of protein. Br. Poult. Sci., 19: 601-605.

Dale, N.M. and H.L. Fuller, 1978. Effect of ambient temperature and dietary fat on feed preference of broilers. Poult. Sci., 57: 1635-1640.

Engku Azahan, E.A. and J.M. Forbes, 1989. Growth, food intake and energy balance of layer and broiler chickens offered glucose in the drinking water and the effect of dietary protein content. Br. Poult. Sci., 30: 907-917.

Fritts, C.A. and P.W. Waldroup, 2006. Modified phosphorus program for broilers based on commercial feeding intervals to sustain live performance and reduce total and water-soluble phosphorus in litter. J. Appl. Poult. Res. 15: 207-218.

Forbes, J.M. and F. Sharitmadari, 1994. Diet selection for protein by poultry. World's Poult. Sci. J., 50: 7-24.

Hruby, M., M.L. Hamre and C.N. Coon, 1995. Free-choice feeding and three temperature treatments. J. Appl. Poult. Res., 4: 356-365.

Huey, D.F., J.A. Cherry, P.B. Siegel, D.M. Denbow and H.P. Van Krey, 1982. Self-selection of dietary protein and energy by diverse populations of chickens. Nutr. Behav., 1: 55-64.

Hughes, B.O., 1984. The principles underlying choice feeding behavior in fowls-with special reference to production supplements. World's Poult. Sci. J., 40: 141-150.

Kaminska, B., 1982. Dietary selection of protein and energy and its effect on performance of broilers. Zootecnica Int., 5: 27-29.

Kaufman, N.W., G. Collier and R.L. Quibb, 1978. Selection of an adequate protein-carbohydrate ratio by the domestic chick. Physiol. Behav., 20: 339-344.

Kubena, L.F., J.W. Deaton, F.N. Reece, J.D. May and T.H. Vardaman, 1972. The influence of temperature and sex on the amino acid requirements of the broiler. Poult. Sci., 51: 1391-1396.

Leclercq, B. and G. Guy, 1991. Further investigations on protein requirement of genetically lean and fat chickens. Br. Poult. Sci., 32: 789-798.

Mastika, I.M. and R.B. Cumming, 1981. Performance of two strains of broiler chickens offered free choice from different ages. Pages: 79-85 in: Proc. 4th Australasian Poultry and Stock Feed Convention, Perth, Australia.

Mastika, I.M. and R.B. Cumming, 1985. Effect of nutrition and environmental variations on choice feeding of broilers. Paper 19 in: Recent Advances in Animal Nutrition in Australia. University of New England, Armidale, Australia.

Mastika, M. and R.B. Cumming, 1987. Effects of previous experience and environmental variations on the performance and pattern of feed intake of choice fed and complete fed broilers. (D.J. Farrell, ed.) Pages: 260-282, in: Recent Advances in Animal Nutrition in Australia.

NRC, 1994. Nutrient requirements of poultry. 9th Revised ed. National Academy Press, Washington, DC.

Picard, M., P.B. Siegel, P.A. Geraert, G. Uzu and P.E.V. Williams, 1997. Five genetic stocks of broilers of different growth rate potential choose the same protein/energy balance. Anim. Choices, 20: 117-118.

Rose, S.P. and I. Kyriazakis, 1991. Diet selection of pigs and poultry. Proc. Nutr. Soc., 50: 87-98.

Rose, S.P. and W. Michie, 1984. Meat and bone and fish meals in balancer feeds for choice-fed broilers. Anim. Feed Sci. Technol., 11: 221-229.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 ed. SAS Institute, Inc., Cary, NC.

Shariatmadari, F. and J.M. Forbes, 1993. Growth and food intake responses to diets of different protein contents and a choice between diets containing two concentrations of protein in broilers and layer strains of chicken. Br. Poult. Sci., 34: 959-970.

Steinruck, U. and M. Kirchgessner, 1993. Comparison of feeding systems with different dietary protein and energy levels during long fattening of male and female broilers. Arch. Geflugelk, 57: 145-154.

Yo, T., P.B. Siegel, H. Guerin and M. Picard, 1997. Self-selection of dietary protein and energy by broilers grown under a tropical climate: effect of feed particle size on the feed choice. Poult. Sci., 76: 1467-1473.

[1]Published with approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville AR 72701. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable. This research was supported by a grant from Cobb-Vantress Inc., Siloam Springs AR.
[2]To whom correspondence should be addressed. Waldroup@uark.edu,
[3]Cobb-Vantress, Inc. Siloam Springs AR.