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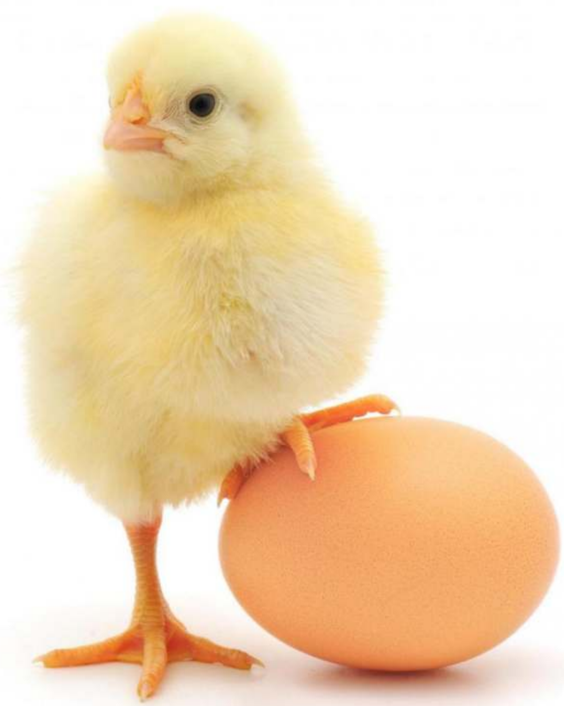

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Evaluation of Protein Choice Feeding Programs When Diets Have Constant Energy Level[1]

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Abstract: Male broilers of a commercial strain were grown to 10 d of age on a common starter diet and then from 11 to 49 days were offered single diets (control), a choice of starter and finisher diets, isoenergetic choices between 12 and 24 or 32% Crude Protein (CP) diets and isoenergetic choices between 15 and 24 or 32% CP diets. Birds fed the isoenergetic diets varying in protein content had almost similar body weight, feed intake, energy intake and carcass characteristics as did birds fed the control diets or the choice of starter and finisher diets. In general the feed and energy conversions by birds given the choice between 12 and 24 or 32% CP diets were worse than those of birds given the other feed systems; however, the protein consumption and conversion by birds fed the former diets were lower than those of birds fed the latter diets. There was a marked preference for the low protein diets (12 and 15% CP) over the high protein diets (24 and 32% CP), but this preference was reduced when the low protein diets were offered with the 24% CP diet. The levels of protein selected of the isoenergetic diets varying in protein content were lower than those of control diets or choice between finisher and starter diets and declined with age except for the last week of the experiment, possibly due to feed form variation. Birds given the choice between 15 and 24 or 32% CP diets had similar performance, except for slightly better protein conversion but slightly worse energy conversion, as those fed control diets or given a choice of starter and finisher diets; even though these choice-fed broilers chose lower protein contents than did birds fed the other two systems. These data indicate that choice of isoenergetic diets varying in protein content can be used to determine protein requirements of broilers, being more effective and efficient with a narrow range of two protein contents.

Key words: Broilers, choice feeding, self-selection, protein requirements

Introduction

Several experiments evaluating the use of choice feeding have maximized the performance as compared to control treatments when broilers were given the choice of isoenergetic diets varying in protein content. It appears that under such conditions birds can select appropriate protein density to meet the demand for optimum growth. Thus, some studies have shown that birds can select from wide (6.5 to 32%), medium (12 and 28%), or narrow (16.4 to 26%) ranges of two or four protein contents to meet their protein requirements for maximum growth (Shariatmadari and Forbes, 1993; Kaminska, 1982; Steinruck and Kirchgessner, 1993a). However, the selection of protein content can be affected by the strain of birds (Leclercq and Guy, 1991), the fixed energy density (Steinruck and Kirchgessner, 1993a), or the quality of the ingredients (Rose and Michie, 1984).

In addition, the selected protein contents are also influenced by the animal's age, decreasing as the broiler chicken aged (Kaufman *et al.*, 1978; Kaminska, 1982; Steinruck and Kirchgessner, 1993a; Forbes and Sharitmadari, 1994; Picard *et al.*, 1997). Further it has been observed in growing turkeys (Leeson and Summers, 1978; Cowan and Michie, 1979) and pigs (Kyriazakis, *et al.*, 1990; Bradford and Gous, 1991). Hence, a reduction in protein intake can be possible by the choice feeding system, in contrast the single-feed system where birds can overeat dietary protein for some period of time (Rose and Kyriazakis, 1991).

Another factor that affects the feed selection and, in turn, the choice protein content are the sensory properties of the birds. Forbes and Shariatmadari (1996) showed that it is important to compensate the selected protein in short-term (24 h). Moreover, the choice protein density is increased when the protein concentrate is offered as pellet compared to mash form (Yo *et al.*, 1997).

The objectives of this study were to estimate differences in nutritional needs of protein and evaluate performance by choice feeding system with isoenergetic diets varying in protein content.

Materials and Methods

Male Cobb 500 birds grown on five different choice feeding systems were compared to birds fed a commercial feeding schedule based on Cobb[3] recommendations. For the choice feeding systems, birds were allowed to choose between 1) a typical commercial starter diet and a finisher diet; 2) a diet containing 12% Crude Protein (CP) and a diet containing 24% CP; 3) a diet containing 12% CP and a diet containing 32% CP; 4) a diet containing 15% CP and a

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

	0-10 days	11-22 days	22-42 days	42-49 days	12% CP	15% CP	24% CP	32% CP
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	848.75	749.27	449.55	183.65
Soybean meal	304.21	254.26	230.59	203.65	98.31	184.57	439.21	664.15
Pro-Pak[1]	25.00	25.00	25.00	25.00	0.00	0.00	0.00	0.00
Poultry oil	0.62	10.21	23.36	18.46	5.00	19.60	66.63	108.63
Ground limestone	10.37	10.00	9.29	9.39	14.35	14.11	13.38	12.72
Dicalcium phosphate	16.25	15.52	14.12	14.27	19.05	18.56	17.13	15.88
MHA 84	1.81	1.81	2.00	1.81	0.62	0.92	1.85	2.72
L-Lysine HCl	0.21	0.72	1.02	1.25	1.67	0.72	0.00	0.00
L-Threonine	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
Constant ingredients[2]	12.25	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	1000.00
ME kcal/kg	2986.42	3083.00	3176.00	3176.00	3188.95	3184.85	3184.83	3184.78
CP (%)	21.00	19.00	18.00	17.00	12.00	15.00	24.00	32.00
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	0.26	0.33	0.52	0.70
Lys (%)	1.21	1.10	1.06	1.00	0.65	0.82	1.46	2.08
Thr (%)	0.84	0.76	0.72	0.69	0.46	0.59	0.98	1.33
TSAA (%)	0.90	0.84	0.83	0.79	0.51	0.62	0.95	1.25
Sodium (%)	0.24	0.23	0.23	0.24	0.22	0.22	0.22	0.23

[1]H. J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Contains (g kg^{-1}) 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 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); 1.0 trace mineral mix (provides per kg of diet: Mn (from $MnSO_4 \cdot H_2O$) 100 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 100 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 50 mg; Cu (from $CuSO_4 \cdot 5H_2O$) 10 mg; I from $Ca(IO_3)_2 \cdot H_2O$), 1 mg); 0.76 Coban 60 (Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825); 0.50 BMD 50 (Alpharma, Inc., Ft. Lee, NJ 07024).

diet containing 24% CP; or 5) a diet containing 15% CP and a diet containing 32% CP. Four 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: One series of diets (Normal) was formulated to provide diets that met nutrient standards for growing broilers suggested by Cobb 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 12 or 15 % CP (low protein series) 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 to 3 wk in relation to a 23% CP diet, with the exception that the lysine level was adjusted to 1.25% per 23% CP. These diets were similar in vitamins, trace minerals, sodium, calcium and available phosphorus as found in the normal diets.

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 ten days and then given a choice of diet 1 or diet 4. The third group of birds was fed Normal starter first ten days and then given a choice of diet 5 or diet 7. The fourth group of birds was fed the Normal starter diet for first ten days and then given choice of diet 5 or diet 8. The fifth group of birds was fed the Normal starter diet for first ten days and then given choice of diet 6 or diet 7. The sixth group of birds was fed the Normal starter diet for first ten days and then given choice of diet 6 or diet 8. Diets were fed as crumbles for the first ten days and as 3/16" pellets for the remainder of the trial except for the final week of the study. Feed mixed for this period of time was fed as mash due to the unavailability of pelleting equipment. Although no quantitative studies were done on pellet quality, visual examination of the pellets indicated that diets of high proteins (24 and 32% CP) had a very poor quality and the diet containing 32% CP had worse quality than that of 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 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 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. 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. 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 days of age, five 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 and the respective protein and energy contents of each diet. The selected energy and protein content were estimated by dividing the nutrient 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 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 2. Body weight gain at all intervals after ten days of age were not significantly influenced by the dietary treatment with the exception of the period between 22 to 32 days of age. In this feeding period, birds fed the choice of 12 and 32% CP had significantly lower body gain than did birds fed the normal diets, the choice of Starter-Finisher diets or the choice of 15 and 24% CP diets.

The feed intake was not significantly affected by dietary treatments at any age (Table 3). However, feed conversion was significantly affected by the feeding systems used (Table 4). There were significant treatment differences at all age periods except for 42 to 49 days of age. The feed conversion by birds given the choice between 12 and 24% CP or between 12 and 32% CP was significantly worse than that did birds fed the other four systems for the cumulative periods of 11 to 42 and 11 to 49 days of age. However, the feed conversion by birds given the choice of 12 and 24% CP was not significantly different from that of choice of Starter-Finisher diets at 11 to 22 days, the choice of 15 and 24% CP at 22 to 32 days and 32 to 42 days or the choice of 15 and 32% CP at 11 to 22 days, 22 to 32 days and 11 to 32 days of age. Further the feed conversion by birds given the choice of 12 and 32% CP was not different from that of the choice of Starter-Finisher diets at 11 to 22 days or the choice of 15 and 24% CP at 32 to 42 days. Birds fed the normal diets had a better feed conversion than did birds fed the choice between 15 and 24% CP or between 15 and 32% CP during the period of 22 to 32 days of age and for cumulative conversion from 11 to 32 and 11 to 42 days of age, but not during 11 to 22 days, 32 to 42 days, or 11 to 49 days of age. In general, the birds given the choice of starter and finisher diets had almost the same performance than did birds fed the normal diets and the choice of 15 and 24% CP or 15 and 32% CP.

Table 2: Effect of different feeding systems on body weight (kg) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	0.683	0.667	0.679	0.660	0.700	0.680	0.577	0.016	4.62
22-32	0.924[a]	0.918[a]	0.883[ab]	0.849b	0.901[a]	0.872[ab]	0.038	0.017	3.70
32-42	0.990	0.992	0.964	0.943	0.994	0.987	0.574	0.023	4.77
42-49	0.502	0.524	0.512	0.487	0.502	0.530	0.612	0.019	7.24
11-32	1.607	1.585	1.561	1.510	1.601	1.551	0.235	0.030	3.77
11-42	2.597	2.577	2.526	2.452	2.595	2.538	0.167	0.042	3.25
11-49	3.099	3.101	3.037	2.939	3.098	3.068	0.168	0.047	3.08

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

Table 3: Effect of different feeding systems on feed intake (kg/bird) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	1.040	1.056	1.065	1.065	1.054	1.055	0.953	0.020	3.80
22-32	1.571	1.589	1.645	1.627	1.630	1.603	0.507	0.030	3.67
32-42	1.898	1.908	1.988	1.959	1.992	1.923	0.431	0.040	4.13
42-49	1.368	1.358	1.342	1.285	1.298	1.336	0.627	0.040	5.93
11-32	2.611	2.644	2.707	2.693	2.682	2.656	0.700	0.046	3.43
11-42	4.507	4.549	4.690	4.651	4.667	4.578	0.488	0.076	3.29
11-49	5.852	5.901	6.020	5.927	5.957	5.900	0.860	0.094	3.19

Table 4: Effect of different feeding systems on feed conversion (feed:gain) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	1.523^{cd}	1.586^{ab}	1.569^{b}	1.614^{a}	1.505^{d}	1.552^{bc}	<0.001	0.014	1.77
22-32	1.701^{c}	1.734^{c}	1.863^{ab}	1.918^{a}	1.809^{b}	1.839^{b}	<0.001	0.023	2.51
32-42	1.920^{b}	1.923^{b}	2.062^{a}	2.082^{a}	2.003^{ab}	1.951^{b}	0.005	0.031	3.16
42-49	2.740	2.596	2.622	2.637	2.594	2.521	0.529	0.077	5.91
11-32	1.625^{d}	1.670^{cd}	1.733^{b}	1.784^{a}	1.676^{c}	1.712^{bc}	<0.001	0.016	1.88
11-42	1.736^{c}	1.766^{bc}	1.857^{a}	1.897^{a}	1.799^{b}	1.805^{b}	<0.001	0.015	1.64
11-49	1.889^{b}	1.904^{b}	1.982^{a}	2.017^{a}	1.923^{b}	1.923.	<0.001	0.016	1.65

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

Table 5: Relative intake (%) of different diets by male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Normal diet A	Normal diet B	Starter/ Finisher Fin.	Starter/ Finisher Star	12 vs 24 CP 12	12 vs 24 CP 24	12 vs 32 CP 12	12 vs 32 CP 32	15 vs 24 CP 15	15 vs 24 CP 24	15 vs 32 CP 15	15 vs 32 CP 32
11-22	56	44	79^{a}	21^{b}	56	44	75^{a}	25^{b}	62^{a}	38^{b}	84^{a}	16^{b}
22-32	50	50	58	42	64^{a}	36^{b}	86^{a}	14^{b}	85^{a}	15^{b}	90^{a}	10^{b}
32-42	45	55	52	48	71^{a}	29^{b}	86^{a}	14^{b}	83^{a}	17^{b}	89^{a}	11^{b}
42-49	46	54	55	45	59	41	72^{a}	28^{b}	61^{a}	39^{b}	73^{a}	27^{b}
11-32	53	47	67^{a}	33^{b}	61^{a}	39^{b}	81^{a}	19^{b}	76^{a}	24^{b}	88^{a}	12^{b}
11-42	49	51	61	39	65^{a}	35^{b}	83^{a}	17^{b}	79^{a}	21^{b}	88^{a}	12^{b}
11-49	49	51	59	41	64^{a}	36^{b}	81^{a}	19^{b}	75^{a}	25^{b}	85^{a}	150^{b}
Period (days)	**P diff**	**SEM**	**P diff**	**SEM**	**P diff**	**SEM**	**P diff**	**SEM**	**P diff**	**SEM**	**P diff**	**SEM**
11-22	0.56	9.24	0.002	2.86	0.050	1.83	<0.001	1.20	0.003	1.41	<0.001	1.24
22-32	0.96	5.22	0.23	5.78	0.039	4.11	<0.001	0.68	0.005	4.71	<0.001	0.70
32-42	0.24	3.69	0.90	13.02	0.003	2.34	<0.001	1.09	0.001	2.55	<0.001	1.08
42-49	0.52	5.63	0.74	14.10	0.054	2.99	<0.001	0.68	0.018	2.38	0.003	2.41
11-32	0.59	4.31	0.01	3.53	0.032	2.91	<0.001	0.66	0.003	2.79	<0.001	0.53
11-42	0.76	2.28	0.19	6.33	0.009	2.52	<0.001	0.32	<0.001	0.72	<0.001	0.31
11-49	0.63	2.84	0.32	7.86	0.013	2.60	<0.001	0.19	<0.001	0.53	<0.001	0.68

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

The relative intakes of the feeding systems are shown in Table 5. The relative intake of control diets was not significantly influenced by the position of the feeders. The relative intake of starter and finisher diets was significantly affected by the preference of the birds during the first feeding period of 11 to 22 days of age and for cumulative period from 11 to 32 days of age. These choice-fed broilers tended to consume a greater percentage of the lower protein, higher energy finisher diet than of the starter diet, but as the birds grew this preference tended to lessen. The relative intake of isoenergetic diets varying in protein contents was significantly affected by the preference of the birds at all age periods except between 11 to 22 days and 42 to 49 days of age for the choice between 12 and 24 % CP. The bird's choice was exclusively in favor to the low protein series (12 or 15 % CP); moreover, this preference for the low protein series was greater when these low protein diets were offered with the 32 % CP diet compared to the 24% CP diet. As the birds grew older, except for 42 to 49 days of age these choice-fed broilers tended to consume a lower percentage of the high protein diets than that of the low protein diets.

The effects of the different feeding systems on total protein consumption are shown in Table 6. There were significant effects for almost every growth period except for 11 to 22 days of age. Birds given the choice between starter and finisher diets consumed significantly more protein than did birds fed the other five feeding systems for the cumulative period of 11 to 49 days of age. However, the feed conversion of these choice diets was not different from that of the normal diets at 22 to 32 days, 32 to 42 days, 11 to 32 days and 11 to 42 days or the choice of 15 and 32% CP at 42 to 49 days of age. The protein intake was almost similar between birds fed the normal feed and given the choice between 15 and 24% CP diets; furthermore, this similarity was found between birds fed the normal diets and given choice between 15 and 32% CP diets for intakes between 22 to 32 days and 32 to 42 days of age and for cumulative intake from 11 to 49 days of age. On the other hand, the lowest protein consumption was found for birds fed the choice between 12 and 32 % CP diets followed by the choice between 12 and 24% CP diets.

The effects of the different feeding systems on protein conversion are shown Table 7. There were significant effects at all age periods except for 42 to 49 days of age.

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

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	0.198	0.188	0.184	0.181	0.194	0.187	0.088	0.004	4.36
22-32	0.283^{ab}	0.297^{a}	0.267^{bc}	0.242^{d}	0.267^{c}	0.267^{bc}	<0.001	0.005	3.88
32-42	0.342^{ab}	0.361^{a}	0.307^{cd}	0.291^{d}	0.329^{b}	0.326^{bc}	<0.001	0.007	4.20
42-49	0.233^{c}	0.256^{ab}	0.226^{c}	0.226^{c}	0.240^{bc}	0.262^{a}	0.005	0.007	5.66
11-32	0.480^{ab}	0.485^{a}	0.451^{c}	0.423^{d}	0.461^{bc}	0.454^{c}	<0.001	0.008	3.48
11-42	0.822^{ab}	0.845^{a}	0.758^{c}	0.714^{d}	0.789^{bc}	0.779^{c}	<0.001	0.011	2.89
11-49	1.051^{b}	1.099^{a}	0.982^{c}	0.938^{d}	1.027^{b}	1.038^{b}	<0.001	0.015	2.83

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

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 diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	0.289^{a}	0.283^{b}	0.272^{c}	0.274^{c}	0.277^{bc}	0.275^{c}	<0.001	0.002	1.57
22-32	0.306^{b}	0.324^{a}	0.302^{b}	0.285^{c}	0.296^{bc}	0.307^{b}	0.004	0.006	3.69
32-42	0.346^{b}	0.364^{a}	0.319^{cd}	0.309^{d}	0.331^{bc}	0.330^{bc}	<0.001	0.005	3.16
42-49	0.466	0.488	0.443	0.465	0.480	0.495	0.158	0.014	5.94
11-32	0.299^{ab}	0.306^{a}	0.289^{cd}	0.280^{d}	0.288^{cd}	0.293^{bc}	<0.001	0.003	2.24
11-42	0.317^{b}	0.328^{a}	0.300^{c}	0.291^{d}	0.304^{c}	0.307^{c}	<0.001	0.003	1.81
11-49	0.339^{b}	0.355^{a}	0.324^{cd}	0.319^{d}	0.331^{bc}	0.338^{b}	<0.001	0.003	1.83

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

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

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP
11-22	19.0	17.8	17.3	17.0	18.4	17.7
22-32	18.0	18.7	16.2	14.9	16.4	16.7
32-42	18.0	18.9	15.4	14.9	16.5	17.0
42-49	17.0	18.9	16.8	17.6	18.5	19.6
11-32	18.4	18.3	16.7	15.7	17.2	17.1
11-42	18.2	18.6	16.2	15.4	16.9	17.0
11-49	18.0	18.6	16.3	15.8	17.2	17.6

In general, the protein conversion by birds fed the isoenergetic diets varying protein content was better than in birds fed the other two systems. Within these free choice treatments the choice between 12 and 32% CP diets had the best protein conversion followed by the choice between 12 and 24% CP diets. For periods of 11 to 22 days and 11 to 42 days of age, the birds given the choice between 15 and 24% CP diets or between 15 and 32% CP diets appeared to have better protein conversion than did birds fed the normal diets. In contrast the birds fed the starter and finisher diets had generally worse protein conversion than did birds fed the other five systems except when these choice diets was compared with the normal diets at 11 to 22 days and 11 to 32 days or the choice of 15 and 24% CP at 11 to 22 days of age.

The effects of the different feeding systems on average protein content of the selected diets are shown in Table 8. The selected protein contents of birds fed the five choice feeding tended to slightly decrease as the birds aged except for 42 to 49 days of age. Birds fed the choices of 12% CP and 24 or 32% CP diets chose numerically a lower protein density than did birds fed the choices of 15% CP and 24 or 32% CP diets. The selected protein density of birds fed the choice of starter and finisher diets was numerically higher than that of birds fed the other choice feeding systems.

The effects of the different feeding systems on energy intake are shown in Table 9. There were no significant differences among the dietary treatments, indicating that birds were consuming feed primarily to meet energy needs regardless of the protein status of the diets.

Table 9: Effect of different feeding systems on energy intake (ME kcal/bird) of male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	3.206	3.313	3.394	3.395	3.356	3.359	0.313	63	3.76
22-32	4.990	4.923	5.243	5.189	5.189	5.104	0.174	95	3.73
32-42	6.028	5.886	6.336	6.246	6.344	6.125	0.146	132	4.30
42-49	4.346	4.198	4.276	4.096	4.133	4.255	0.730	125	5.92
11-32	8.194	8.231	8.627	8.584	8.541	8.458	0.210	146	3.46
11-42	14.218	14.108	14.948	14.829	14.865	14.581	0.116	247	3.38
11-49	18.486	18.287	19.189	18.897	18.972	18.790	0.365	307	3.27

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)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	4695^{c}	4974^{b}	5000b	5144^{a}	4793^{c}	4942^{b}	<0.001	45	1.82
22-32	5401^{d}	5371^{d}	5936^{ab}	6113^{a}	5763^{c}	5857^{bc}	<0.001	70	2.44
32-42	6098^{bc}	5933^{c}	6573^{a}	6637^{a}	6380^{ab}	6215^{bc}	0.001	106	3.36
42-49	8701	8027	8356	8404	8262	8030	0.436	252	6.08
11-32	5100^{e}	5199^{de}	5524^{b}	5689^{a}	5336^{cd}	5453^{bc}	<0.001	51	1.88
11-42	5476^{c}	5477^{c}	5918^{a}	6049^{a}	5728^{b}	5746^{b}	<0.001	49	1.71
11-49	5967^{bc}	5900^{c}	6317^{a}	6430^{a}	6125^{b}	6124^{b}	<0.001	54	1.77

^{abcde}Means within a row with common superscripts do not different significantly ($p \leq 0.05$)

Table 11: Effect of different feeding systems on energy density (ME kcal/kg of feed consumed) by male broilers at different feeding intervals (mean of four pens of 25 birds each)

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP
11-22	3083	3137	3187	3188	3184	3184
22-32	3176	3098	3187	3189	3183	3184
32-42	3176	3085	3187	3188	3185	3185
42-49	3177	3091	3186	3188	3184	3185
11-32	3138	3113	3187	3188	3185	3184
11-42	3155	3101	3187	3188	3185	3185
11-49	3159	3099	3188	3188	3185	3185

The energy conversion was significantly affected by the feeding systems used except for 42 to 49 days of age (Table 10). Birds fed the normal diets or the choice of starter and finisher diets had a better energy conversion than did birds fed the choice of 15% CP or 24 or 32 % CP diets for some periods. For the other periods, birds fed the normal diets had similar energy conversions to those of the choice of 15 and 24% CP at 11 to 22 days, 32 to 42 days and 11 to 49 days or the choice of 15 and 32% CP at 32 to 42 days and 11 to 49 days of age. Likewise, the energy conversion by birds given the choice of starter and finisher diets was not different from that of the choice of 15 and 24% CP at 11 to 32 days or the choice of 15 and 32% CP at 11 to 22 days and 32 to 42 days of age. Further, the choice-fed broilers given the 12 and 24 or 32% CP diets had worse energy conversion than did birds given the choice of 15% CP and 24 or 32 % CP for the 11 to 42 days and 11 to 49 days of age. For the other feeding periods, birds given the choice of 12 and 24% CP had similar conversion to those of the choice of starter and finisher diets at 11 to 22 days, the choice of 15 and 24% CP at 32 to 42 days or the choice of 15 and 32% CP at 11 to 22 days, 22 to 32 and 11 to 32d of age. The energy conversion of birds fed the choice of 12 and 32% CP was not different from the choice of 15 and 24% CP at 32 to 42 days of age. The selected energy densities of the birds fed choice of starter and finisher diets tended to wane as the birds aged (Table 11).

The effects of the different feeding systems on mortality are shown in Table 12. There were no significant differences between the treatments.

The effects of the different feeding systems on various processing parameters are shown in Table 13. There were no significant differences among treatments for all parameters except for breast yield. Birds fed the choice

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

Period (days)	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
11-22	1	0	0	1	0	1	0.701	0.707	283
22-32	1	3	2	0	1	1	0.564	1.155	173
32-42	1	0	1	0	2	0	0.654	1.000	300
42-49	3	2	3	1	2	1	0.842	1.414	141
11-32	2	3	2	1	1	2	0.874	1.269	139
11-42	3	3	3	1	3	2	0.911	1.546	124
11-49	6	5	6	2	5	3	0.302	1.434	64

Table 13: Effect of different choice feeding systems compared to Normal feeding on processing parameters of male broilers (mean of four pens of 25 birds each)

Parameters	Feeding system: Normal diet	Starter/ finisher	12 vs 24 CP	12 vs 32 CP	15 vs 24 CP	15 vs 32 CP	P diff	SEM	CV
Body weight (kg)	3.399	3.329	3.335	3.277	3.413	3.330	0.549	0.059	7.47
Carcass weight (kg)	2.554	2.468	2.473	2.452	2.526	2.476	0.550	0.046	7.86
Dressing percentage	75.160	74.150	74.150	74.840	73.990	74.33	0.097	0.350	1.99
Breast weight (kg)	0.736	0.723	0.677	0.696	0.685	0.688	0.196	0.020	12.28
Wing weight (kg)	0.268	0.265	0.266	0.259	0.271	0.265	0.568	0.005	7.65
Leg quarter weight (kg)	0.786	0.754	0.781	0.774	0.794	0.775	0.656	0.018	9.72
Breast (%) of carcass	28.760^{ab}	29.290^{a}	27.330^{bc}	28.340^{abc}	27.090^{c}	27.73^{bc}	0.024	0.541	8.17
Wings (%) of carcass	10.520	10.720	10.760	10.590	10.720	10.71	0.761	0.136	5.40
Leg quarter (% of carcass	30.810	30.610	31.630	31.580	31.420	31.32	0.672	0.555	7.54

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

of starter and finisher diets had the highest breast yield except by birds fed the normal diet series or the choice of 12 and 32% CP.

Discussion

The similarity of body weights between the choices of isoenergetic diets differing in protein content and the 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, 1993a). Moreover, although the high protein series (25 and 32% CP) had a lower pellet quality, the birds fed these choice feeding options responded similar to the birds fed control diets and choice of starter and finisher diets which both had a great pellet quality.

The lowest feed conversion found in the choices of 12 and 24 or 32% CP diets may be accounted for by the lower selected protein intake and pellet quality of the choice feed. It has been demonstrated in single diets that the feed conversion is improved by increasing the dietary protein (Leclerq, 1983; Pesti and Fletcher, 1984) or pelleting the feed (Pepper *et al*., 1960). Under a choice situation, Leclercq and Guy (1991) have also shown a better feed conversion when a single diet of 23% CP was compared to a choice of selected protein content of 18.9%. On the other hand, birds given the choice of 15 % CP and 24 or 32% CP diets selected a higher protein intake, had a slightly better pellet quality of the choice feed and had almost similar results in feed conversion as control diets or choice of starter and finisher diets. In the same way, several studies have shown a similarity in the feed conversion of single diets or choice feeding of isoenergetic diets varying in protein content (Engku Azahan and Forbes, 1989; Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993a).

The ability of birds to spare protein consumption in choice diets containing 12 % CP diets was also observed in other studies (Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993a). Further some reports have shown that birds offered choice feeding had equal or better protein conversion than did birds fed control diets (Leclercq and Guy, 1991; Shariatmadari and Forbes, 1993; Steinruck and Kirchgessner, 1993a). These observations are in agreement with the present study in which birds given the choice of 12 % protein series had the best efficiency of protein conversion, followed by birds given the choice with 15% CP. This greater protein efficiency may be accounted for the lower protein intake and the higher energy consumption as demonstrated by single diets (Jackson *et al*., 1982; Cheng *et al*., 1997).

The variation of choice protein density found in this study (14.9 to 19.6% CP) and other studies (17.6 to 22.6% CP) may be due to four reasons: (1) genetic; fat lines have selected lower protein content than that of lean lines (Leclercq and Guy, 1991) (2) feed textures; pellet concentrates were preferred to mash concentrates and therefore selecting more protein density (Yo *et al*., 1997) (3) the fixed energy level; when the fixed Metabolizable Energy level (ME) was low (2.892 Mcal kg^{-1}), the selected protein densities were higher than those of high fixed ME (3.203 Mcal kg^{-1}) and tended to increase as bird aged Steinruck and Kirchgessner, 1993a) and (4) quality of ingredients; when more fish meal was included in the choice diets, the selected protein content was lower (Rose and Michie, 1984). Moreover, the variable time affects the selected protein density, decreasing as the birds grew older (Kaufman *et al*., 1978; Kaminska, 1982; Steinruck and Kirchgessner, 1993a; Forbes and Shariatmadari, 1994; Picard *et al*., 1997). In this study as the birds aged a decreased protein density was also observed except for the last week during which the protein density increased because the low protein diets (12 and 15% CP) were supplied as mash instead of pellet, increasing the willingness for the high protein series (24 and 32% CP) as compared to previous periods.

It seems that the selection of the protein diets was partially affected by the feed textures. Thus the low protein diets (12 and 15% CP) probably were more attractive to the birds because these diets had a very good pellet quality compared to the high protein diets (24 and 32 % CP) which had a very poor pellet quality. Furthermore, the lower selected protein density of choices which included 12 % CP compared to that of choices that included 15 % CP diets may be explained by the physical form. Besides the physical forms, this preference may be accounted for the differences of net energy between the high and low protein diets; the diets with 12 and 15% CP probably had a lower heat increment and in turn more net energy compared to the diets with 24 and 32% CP. Moreover, it has been demonstrated that the metabolizability of dry matter decreases from 75% with 8% CP to 62% with 23 % CP in isoenergetic layer hen diets (Steinruck and Kirchgessner, 1993b). Hence a wide range of protein content is not recommended in choice feeding diets since it may have a great difference in heat increment or metabolizability.

The lower choice protein density (15.8 to 17.6% CP) by birds fed the isoenergetic diets varying in protein contain compared to birds fed the control diets or the choice of finisher and starter diets was also recommended for several studies in single diets especially in the growing periods (Proudfoot and Hulan, 1978; Salmon *et al*., 1983; Stilborn and Waldroup, 1988; Summer *et al*., 1992).

The poorer energy conversion observed in choice feeding diets containing 12% CP possibly happened because the birds fed these treatments had slightly lower body gain and slightly higher level of ME intake especially during the period of 11 to 22 days of age than did birds fed the normal diets or the choice of finisher and starter diets. In contrast, Steinruck and Kirchgessner (1993a) have showed similar results in energy conversion between the control diets and choice feeding which supplied the same energy levels for all the diets.

As the birds grew older, the selected energy density of birds given the choice of starter and finisher tended to decrease as reported by earlier studies (Cerrate *et al*., 2007a; Cerrate *et al*., 2007b). Further other reports have found similar tendency when the fixed ME was low (Steinruck and Kirchgessner, 1993a). However in this study the last week of feeding (42 to 49 days of age) these choice-fed broilers selected slightly greater energy content than the previous period (32 to 42 days). Probably this increment of energy density occurred because in this period the birds were affected by high summer temperature. Thus under high temperatures the higher protein, lower energy starter diet was not preferred because this diet presumably had higher heat increment than that of higher energy, lower protein finisher diet. In a choice feeding situation it has been demonstrated that birds under heat stress reject the high protein feed (Cheng, 1991).

The results of this study showed that the choice feeding method of constant energy levels with varying protein content is suitable to determine the protein requirement, especially for a pair of diets with a narrow range of protein concentrations. These choice feeding diets can spare the protein consumption without changes in performance, but the physical form of the feed can distort this effects.

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