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Comparison of Nutrient Recommendations for Broilers[1]

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Abstract: Various recommendations exist for formulating broiler diets. In this study, diet specifications were compared for four different scenarios which included U.S. Poultry Industry average, recommendations by two major breeders and Brazilian recommendations. For each of these, amino acid specifications were adjusted to a percent per Mcal basis as the various recommendations utilize different energy levels. Performance of birds formulated to different nutrient recommendations varied depending primarily upon the relative levels of crude protein, amino acids and metabolizable energy. Feeding diets higher in crude protein and amino acids tended to result in faster growth, especially in early stages, but were less efficient in conversion of crude protein and amino acids into body weight gain. Feeding diets higher in metabolizable energy tended to result in better feed conversion, however effects of dietary energy on calorie conversion were somewhat variable. Over the entire 49 d feeding period there were no significant differences among the various treatments for caloric efficiency. No economic analysis was made of the present study, as relative costs of energy and amino acids vary over time. However it is obvious that when protein costs are high relative to energy, feeding systems which recommend lower protein and amino acid levels should be more economical, while perhaps resulting in a small sacrifice in body weight gain, while feeding systems that recommend higher protein and amino acid levels might be more economical when protein is relatively lower in comparison to dietary energy costs. Because overall calorie utilization was similar among nutrient programs at the conclusion of the study, this could be used as an overall indication of economic efficiency when comparing the different nutrient programs.

Key words: Broilers, feeding programs, nutrient specifications

INTRODUCTION

A number of different recommendations exist for nutrient requirements for formulating diets for broilers. These include recommendations from scientific groups such as NRC (1994), from various breeders and other sources. These often vary widely in nutrient content especially in relation to amino acid and metabolizable energy levels as well as the feeding intervals for the different diets. The objective of this study was to compare the performance of broilers when fed diets that were formulated to meet different nutrient recommendations commonly observed in the poultry industry.

MATERIALS AND METHODS

Diet formulation: Diets were formulated by linear programming using a commercially available program (Concept-5, Creative Formulation Concepts LLC, Annapolis MD). Corn and soybean meal of known protein and moisture content were used in the formulation. Total and digestible amino acids for these two ingredients are based on values suggested by a major amino acid producer (Ajinomoto Heartland, Chicago IL) adjusted to the CP and moisture content of the samples used. A blended animal protein known to be consistent in nutrient content (Johnson and Waldroup, 1983) was added at 2.5% to all diets. Supplements of lysine, methionine and threonine were provided to minimize levels of essential amino acids at or above minimum specifications. No minimum protein levels were specified, to place further pressure on amino acid requirements.

Diet specifications were developed for four different scenarios (Table 1) which included 1) U.S. Poultry Industry average (Agri-Stats, Fort Wayne IN) ; 2) Cobb recommendations (Anonymous, 2006); 3) Ross recommendations (anonymous, undated) and 4) Brazilian recommendations (Rostagno *et al.*, 2005). For each of these, amino acid specifications were adjusted to a percent per Mcal basis as the various recommendations utilize different energy levels. The Brazilian recommendations were based on Standard performance levels. Diets for Industry were formulated on the basis of total amino acids; diets for Brazilian standards were based on digestible amino acids and diets for Cobb and Ross utilized both total and digestible amino acid specifications in formulation as stated by the various recommendations. Calcium and nonphytate phosphorus values were those recommended in the various scenarios while sodium was kept constant at 0.20% for all diets. Calculations were made of the dietary electrolyte balance (DEB, meq/kg of (Na + K) -Cl)) including sodium provided by the defluorinated phosphate and chloride provided from the L-Lysine HCl supplement; however, no attempt was made to maintain a specific DEB.

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Table 1: Comparison of protein and amino acid requirements (% per Mcal/lb) for diets on different feeding programs

	Industry average				Brazilian feeding standards					Cobb recommendations				Ross recommendations			
Nutrient	0-14	14-35	35-42	42-49	0-7	8-21	22-33	34-42	43-46	0-10	11-22	23-42	42+	0-14	15-28	29-42	42+
Protein	15.98	14.07	12.30	11.84	16.47	15.27	13.80	12.69	11.87	15.50	13.58	12.49	11.79	15.94	14.03	12.06	11.30
Total amino acids																	
Met										0.339	0.315	0.298	0.285	0.384	0.323	0.290	0.288
Lys	0.947	0.820	0.700	0.660						0.885	0.786	0.729	0.694	0.978	0.828	0.731	0.692
Trp	0.187	0.160	0.133	0.127						0.148	0.136	0.132	0.125	0.159	0.133	0.124	0.116
Thr	0.640	0.560	0.487	0.460						0.583	0.529	0.500	0.479	0.630	0.533	0.482	0.473
Ile														0.659	0.554	0.490	0.486
Val														0.754	0.639	0.559	0.534
Arg										0.863	0.836	0.784	0.749	1.058	0.898	0.800	0.760
TSAA	0.700	0.633	0.533	0.526						0.657	0.600	0.569	0.541	0.703	0.596	0.538	0.527
Digestible amino acids																	
Met					0.388	0.328	0.305	0.285	0.267	0.303	0.286	0.271	0.257	0.333	0.288	0.255	0.253
Lys					0.994	0.842	0.763	0.712	0.668	0.797	0.708	0.659	0.625	0.877	0.737	0.655	0.623
Trp					0.159	0.134	0.129	0.121	0.114					0.138	0.112	0.103	0.103
Thr					0.646	0.547	0.496	0.462	0.435					0.558	0.470	0.428	0.418
Ile					0.646	0.547	0.511	0.476	0.448					0.587	0.491	0.428	0.418
Val					0.746	0.632	0.587	0.548	0.514					0.667	0.561	0.497	0.473
Arg					1.043	0.883	0.801	0.747	0.702					0.957	0.807	0.717	0.671
TSAA					0.705	0.598	0.550	0.512	0.480	0.590	0.536	0.514	0.486	0.623	0.526	0.475	0.466
Leu					1.073	0.909	0.832	0.776	0.728								
His					0.358	0.303	0.274	0.256	0.240								
Phe					0.626	0.530	0.480	0.448	0.420								
Phe+Tyr					1.143	0.968	0.877	0.818	0.769								

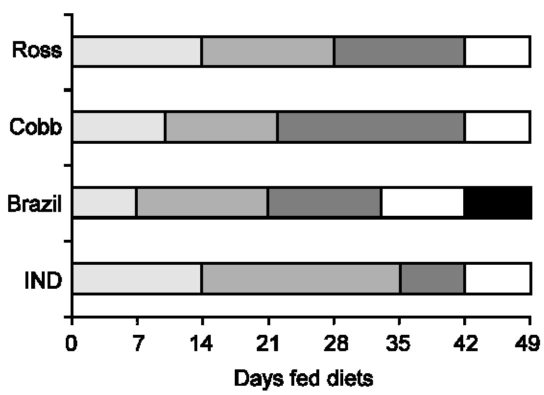

Fig. 1: Comparison of days fed each diet for different feeding programs

Because the time frame over which the diet recommendations are based varies (Fig. 1), it was not considered feasible to attempt to maintain a constant energy level in all diets. However, it was felt that having some common plane of nutrition was essential for a valid comparison. Therefore, all diets were formulated to have optimum nutrient density commensurate with 2% supplemental poultry oil, a level typically used in the U.S. poultry industry. All diets were fortified with complete vitamin and trace mineral mixes provided by commercial premixes, an anticoccidial, a growth promoting antibiotic and contained a pelleting aid. Composition of diets is shown in Tables 2, 3, 4 and 5 for Industry, Brazil, Cobb and Ross specifications, respectively.

The nutrient requirements and calculated nutrient composition are shown in Tables 6, 7, 8 and 9 for Industry, Brazil, Cobb and Ross diets, respectively. Values that met minimum specified levels are shown in bold face. It is apparent that the diets typically met minimum standards for many of the amino acids with total or digestible lysine, TSAA and threonine usually at or near minimum standards in most diets. All diets were analyzed for crude protein, calcium, total phosphorus, sodium and total amino acid content and were found to be in good agreement with calculated values (data not shown).

All diets were pelleted with steam, with the initial diets fed as crumbles. Each of the four diet series was fed to twelve replicate pens of 40 birds. Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated *in ovo* for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Forty chicks were randomly assigned to each of 48 pens in a steel truss house of commercial design. New softwood shavings over concrete floors served as litter. Temperature and air flow rates were controlled by thermostatically controlled gas brooders, exhaust fans and sidewall curtains. Each pen was equipped with two tube feeders and five nipple waterers. Supplemental feeder flats and water fonts were used for the first seven days. Daily care and management followed guidelines suggested by FASS (1999). All procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee.

Body weights by pen were obtained at 14, 28, 42 and 49 d of age. Feeds were changed at intervals specified by the feeding program, with the amount of feed consumed during the period recorded. Feed consumption was also determined at 14, 28, 42 and 49 d. Birds were monitored

Table 2: Composition (g/kg) of diets formulated to Industry specifications

Ingredient	0-14 d	14-35 d	35-42 d	42-49 d
Yellow corn	599.86	659.86	722.36	736.46
Soybean meal, dehulled	317.80	260.23	200.32	186.46
Pro-Pak[1]	25.00	25.00	25.00	25.00
Poultry oil	20.00	20.00	20.00	20.00
Limestone	7.58	6.41	6.40	7.81
Defluorinated phosphate	13.90	12.61	10.22	8.64
Salt	2.47	2.65	2.95	3.13
MHA-84	2.00	1.82	1.07	1.16
L-Threonine	0.35	0.30	0.35	0.21
L-Lysine HCl	1.29	1.37	1.58	1.38
Vitamin premix[2]	5.00	5.00	5.00	5.00
Coban 60[3]	0.75	0.75	0.75	0.75
BMD-50[4]	0.50	0.50	0.50	0.50
Mintrex P_Se[5]	1.00	1.00	1.00	1.00
Pel-Stik[6]	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00

[1]H.J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407.
[2]Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg.
[3]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825.
[4]Alpharma, Inc., Ft. Lee, NJ 07024.
[5]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg.
[6]Uniscope Inc., Johnstown CO 80534

Table 3: Composition (g/kg) of diets formulated to Brazilian standards (Standard performance)

Ingredient	0-7 d	8-21 d	22-33 d	34-42 d	43-46 d
Yellow corn	552.55	633.03	663.35	690.68	712.69
Soybean meal, dehulled	364.72	285.26	257.83	232.41	211.67
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00
Poultry oil	20.00	20.00	20.00	20.00	20.00
Limestone	4.84	4.93	4.98	4.98	4.86
Defluorinated phosphate	15.56	14.65	12.49	10.70	9.78
Salt	2.26	2.40	2.66	2.88	2.99
MHA-84	2.60	1.98	1.58	1.29	1.03
L-Threonine	0.75	0.72	0.46	0.39	0.35
L-Lysine HCl	1.97	2.28	1.90	1.92	1.88
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00
Coban 60[1]	0.75	0.75	0.75	0.75	0.75
BMD-50[1]	0.50	0.50	0.50	0.50	0.50
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00
Pel-Stik[1]	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 2

Table 4: Composition (g/kg) of diets formulated to Cobb standards

Ingredient	0-10 d	11-22 d	23-42 d	42+
Yellow corn	668.93	682.42	704.60	719.04
Soybean meal, dehulled	245.67	235.69	215.26	201.10
Pro-Pak[1]	25.00	25.00	25.00	25.00
Poultry oil	20.00	20.00	20.00	20.00
Limestone	4.96	5.13	5.02	5.10
Defluorinated phosphate	17.18	16.12	14.58	14.67
Salt	2.14	2.25	2.45	2.44
MHA-84	2.43	1.64	1.54	1.26
L-Threonine	0.88	0.30	0.26	0.21
L-Lysine HCl	3.06	1.70	1.54	1.43
Vitamin premix[1]	5.00	5.00	5.00	5.00
Coban 60[1]	0.75	0.75	0.75	0.75
BMD-50[1]	0.50	0.50	0.50	0.50
Mintrex P_Se[1]	1.00	1.00	1.00	1.00
Pel-Stik[1]	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 2

Table 5: Composition (g/kg) of diets formulated to Ross standards

Ingredient	0-14 d	15-28 d	29-42 d	42+
Yellow corn	594.66	659.83	700.00	716.35
Soybean meal, dehulled	322.77	260.81	222.20	208.17
Pro-Pak[1]	25.00	25.00	25.00	25.00
Poultry oil	20.00	20.00	20.00	20.00
Limestone	5.18	5.17	5.40	5.43
Defluorinated phosphate	16.65	14.27	12.85	10.16
Salt	2.16	2.46	2.64	2.95
MHA-84	1.97	1.19	0.81	0.85
L-Threonine	0.23	0.03	0.07	0.16
L-Lysine HCl	1.63	1.49	1.28	1.18
Vitamin premix[1]	5.00	5.00	5.00	5.00
Coban 60[1]	0.75	0.75	0.75	0.75
BMD-50[1]	0.50	0.50	0.50	0.50
Mintrex P_Se[1]	1.00	1.00	1.00	1.00
Pel-Stik[1]	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 2

Table 6: Specified (S) and calculated (C) nutrient content of diets formulated to industry recommendations adjusted to an energy value commensurate with 2% supplemental poultry oil. Values in bold are at minimum specified levels

	0-14 d		14-35 d		35-42 d		42-49 d	
Nutrient	S	C	S	C	S	C	S	C
ME (kcal/lb)	1398.80	1398.80	1427.10	1427.10	1456.77	1456.77	1462.82	1462.82
ME (kcal/kg)		3083.01		3145.39		3210.72		3224.06
Protein (%)		21.43		19.31		17.13		16.59
Protein (%) (analyzed)		23.10		20.50		17.50		16.20
Calcium (%)	1.00	1.00	0.90	0.90	0.80	0.80	0.80	0.80
Total P (%)		0.69		0.64		0.57		0.54
Nonphytate P (%)	0.45	0.45	0.42	0.42	0.37	0.37	0.34	0.34
Methionine (%)		0.58		0.54		0.44		0.44
Lysine (%)	1.32	1.32	1.17	1.17	1.02	1.02	0.97	0.97
Tryptophan (%)	0.26	0.26	0.23	0.23	0.19	0.19	0.19	0.19
Threonine (%)	0.90	0.90	0.80	0.80	0.71	0.71	0.67	0.67
Isoleucine (%)		0.91		0.80		0.69		0.67
Histidine (%)		0.60		0.54		0.48		0.46
Valine (%)		1.05		0.95		0.84		0.81
Leucine (%)		1.95		1.79		1.63		1.59
Arginine (%)		1.47		1.28		1.09		1.04
TSAA (%)	0.98	0.98	0.90	0.90	0.78	0.78	0.77	0.77
Sodium (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chloride (%)	0.15	0.20	0.15	0.22	0.15	0.24	0.15	0.25
DEB (meq/kg)		230.49		203.29		172.27		164.42
Dig Methionine		0.55		0.50		0.41		0.42
Dig Lysine		1.20		1.06		0.92		0.86
Dig Tryptophan		0.23		0.20		0.17		0.16
Dig Threonine		0.78		0.70		0.62		0.58
Dig Arginine		1.36		1.19		1.01		0.96
Dig TSAA		0.88		0.81		0.69		0.68

Table 7: Specified (S) and Calculated (C) nutrient content of diets formulated to Brazilian standards adjusted to an energy value commensurate with 2% supplemental poultry oil. Values in bold are at minimum specified levels

	0-7 d		8-21 d		22-33 d		34-42 d		43-49 d	
Nutrient	S	C	S	C	S	C	S	C	S	C
ME (kcal/lb)	1378.80	1378.80	1414.15	1414.15	1430.00	1430.00	1443.70	1443.70	1454.46	1454.46
ME (kcal/kg)		3038.92		3116.85		3151.76		3181.97		3205.69
Protein (%)		23.26		20.34		19.30		18.37		17.60
Protein (%) (analyzed)		25.8		21.7		21.5		19.0		18.70
Calcium (%)	0.97	0.97	0.92	0.92	0.84	0.84	0.77	0.77	0.73	0.73
Total P (%)		0.74		0.69		0.64		0.60		0.57
Nonphytate P (%)	0.49	0.49	0.46	0.46	0.42	0.42	0.38	0.38	0.36	0.36
Methionine (%)		0.65		0.56		0.51		0.48		0.45
Lysine (%)		1.51		1.31		1.21		1.14		1.08

Table 7 Cont.

	0-7 d		8-21 d		22-33 d		34-42 d		43-49 d	
Nutrient	S	C	S	C	S	C	S	C	S	C
Tryptophan (%)		0.29		0.24		0.23		0.21		0.20
Threonine (%)		1.01		0.88		0.81		0.77		0.73
Isoleucine (%)		1.00		0.85		0.80		0.75		0.71
Histidine (%)		0.65		0.56		0.54		0.51		0.49
Valine (%)		1.14		0.99		0.94		0.89		0.86
Leucine (%)		2.08		1.86		1.79		1.72		1.66
Arginine (%)		1.62		1.36		1.27		1.19		1.12
TSAA (%)		1.08		0.94		0.88		0.83		0.78
Sodium (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chloride (%)	0.15	0.20	0.15	0.22	0.15	0.23	0.15	0.24	0.15	0.25
DEB (meq/kg)		249.82		212.85		199.19		184.92		174.64
Dig Methionine	0.54	0.62	0.47	0.53	0.44	0.48	0.40	0.45	0.39	0.42
Dig Lysine	1.37	1.37	1.19	1.19	1.09	1.09	1.03	1.03	0.97	0.97
Dig Tryptophan	0.25	0.26	0.18	0.21	0.19	0.20	0.17	0.19	0.16	0.18
Dig Threonine	0.89	0.89	0.77	0.77	0.71	0.71	0.67	0.67	0.63	0.63
Dig Arginine	1.43	1.50	1.24	1.26	1.14	1.18	1.08	1.10	1.02	1.04
Dig TSAA	0.97	0.97	0.85	0.85	0.79	0.79	0.74	0.74	0.70	0.70
Dig Val	1.03	1.03	0.89	0.89	0.84	0.85	0.79	0.81	0.74	0.77
Dig Ile	0.90	0.91	0.78	0.78	0.73	0.73	0.69	0.69	0.65	0.65
Dig Leu	1.48	1.92	1.28	1.72	1.19	1.66	1.13	1.60	1.06	1.54
Dig His	0.50	0.58	0.42	0.50	0.39	0.48	0.38	0.46	0.35	0.44
Dig Phe	0.86	1.08	0.75	0.93	0.69	0.88	0.65	0.83	0.61	0.79

Table 8: Specified (S) and Calculated (C) nutrient content of diets formulated to Cobb standards adjusted to an energy value commensurate with 2% supplemental poultry oil. Values in bold are at minimum specified levels

	0-10 d		11-22 d		23-42 d		42+	
Nutrient	S	C	S	C	S	C	S	C
ME (kcal/lb)	1425.62	1425.62	1435.42	1434.52	1446.03	1446.03	1452.42	1452.42
ME (kcal/kg)		3142.08		3161.68		3187.05		3201.13
Protein (%)		18.93		18.42		17.65		17.12
Protein (%) (analyzed)		21.20		18.80		18.50		17.4
Calcium (%)	1.00	1.00	0.96	0.96	0.90	0.90	0.90	0.90
Total P (%)		0.72		0.69		0.66		0.65
Nonphytate P (%)	0.50	0.50	0.48	0.48	0.45	0.45	0.45	0.45
Methionine (%)	0.48	0.58	0.44	0.51	0.43	0.49	0.41	0.46
Lysine (%)	1.26	1.26	1.13	1.13	1.06	1.06	1.01	1.01
Tryptophan (%)	0.21	0.22	0.20	0.21	0.19	0.20	0.19	0.19
Threonine (%)	0.83	0.83	0.76	0.76	0.72	0.72	0.70	0.70
Isoleucine (%)		0.78		0.76		0.72		0.69
Histidine (%)		0.52		0.51		0.49		0.48
Valine (%)		0.92		0.90		0.86		0.84
Leucine (%)		1.75		1.72		1.67		1.63
Arginine (%)	1.23	1.23	1.20	1.20	1.13	1.13	1.09	1.09
TSAA (%)	0.94	0.94	0.86	0.86	0.83	0.83	0.79	0.79
Sodium (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chloride (%)	0.15	0.22	0.15	0.20	0.15	0.21	0.15	0.21
DEB (meq/kg)		196.62		197.84		187.16		181.98
Dig Methionine	0.42	0.55	0.42	0.48	0.39	0.46	0.38	0.43
Dig Lysine	1.15	1.15	1.02	1.02	0.95	0.95	0.91	0.91
Dig Tryptophan		0.19		0.19		0.18		0.17
Dig Threonine		0.73		0.66		0.63		0.60
Dig Arginine		1.14		1.11		1.05		1.01
Dig TSAA	0.84	0.84	0.77	0.77	0.74	0.74	0.71	0.71

twice daily; birds that died or were removed to alleviate suffering were weighed and the weight used to determine feed conversion. Both feed conversion (feed per gain) and calorie conversion (ME kcal per pound of

Table 9: Specified (S) and Calculated (C) nutrient content of diets formulated to Ross standards adjusted to an energy value commensurate with 2% supplemental poultry oil. Values in bold are at minimum specified levels

	0-14 d		15-28 d		29-42 d		42+	
Nutrient	S	C	S	C	S	C	S	C
ME (kcal/lb)	1396.12	1396.12	1427.27	1427.27	1446.40	1446.40	1456.02	1456.02
ME (kcal/kg)		3077.04		3145.70		3187.92		3209.07
Protein (%)		21.63		19.33		17.89		17.19
Protein (%) (analyzed)		23.8		21.0		19.6		17.8
Calcium (%)	1.00	1.00	0.90	0.90	0.85	0.85	0.76	0.76
Total P (%)		0.74		0.67		0.63		0.58
Nonphytate P (%)	0.50	0.50	0.45	0.45	0.42	0.42	0.37	0.37
Methionine (%)	0.53	0.58	0.46	0.48	0.42	0.43	0.42	0.43
Lysine (%)	1.37	1.37	1.18	1.18	1.06	1.06	1.01	1.01
Tryptophan (%)	0.22	0.26	0.19	0.23	0.17	0.21	0.17	0.20
Threonine (%)	0.88	0.89	0.76	0.77	0.69	0.72	0.68	0.70
Isoleucine (%)	0.92	0.92	0.78	0.81	0.71	0.73	0.71	0.71
Histidine (%)		0.60		0.54		0.50		0.49
Valine (%)	1.05	1.06	0.91	0.95	0.81	0.88	0.77	0.85
Leucine (%)		1.96		1.80		1.69		1.65
Arginine (%)	1.48	1.48	1.28	1.28	1.16	1.16	1.11	1.11
TSAA (%)	0.98	0.98	0.85	0.85	0.78	0.78	0.77	0.77
Sodium (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Chloride (%)	0.15	0.19	0.15	0.21	0.15	0.22	0.15	0.23
DEB (meq/kg)		236.09		206.15		188.27		177.72
Dig Methionine	0.46	0.55	0.41	0.45	0.36	0.40	0.36	0.40
Dig Lysine	1.24	1.24	1.06	1.07	0.94	0.95	0.91	0.91
Dig Tryptophan	0.20	0.23	0.16	0.20	0.14	0.18	0.15	0.17
Dig Threonine	0.78	0.78	0.67	0.67	0.62	0.62	0.61	0.61
Dig Isoleucine	0.82	0.84	0.70	0.74	0.62	0.67	0.61	0.42
Dig Arginine	1.34	1.37	1.16	1.19	1.04	1.07	0.97	1.03
Dig TSAA	0.88	0.88	0.76	0.76	0.68	0.69	0.68	0.68

gain) were calculated as measurements of feed utilization. Calculations were made of consumption of crude protein, lysine and TSAA on the different feeding programs and the utilization of these nutrients expressed as grams consumed per kg of gain. At the conclusion of the study five birds per pen were randomly selected for processing to determine dressing percentage and parts yield as described by Fritts and Waldroup (2006).

RESULTS AND DISCUSSION

The diets varied widely in both amino acid and metabolizable energy content, with some being particularly high in amino acids and crude protein and consequently lower in metabolizable energy, while others had lower amino acid and crude protein levels and consequently higher in metabolizable energy. It is difficult to directly compare the nutrient recommendations as some (Brazil) are based totally on the basis of digestible amino acids while the Cobb and Ross recommendations are based on both total and digestible amino acids. In addition, the recommendations cover different time periods. However, all of these do provide recommendations for digestible Met, TSAA and Lys. In general, the Brazil standards were highest in digestible Lys with Cobb recommendations the lowest with Ross and Industry levels intermediate between these two. From approximately 37-49 d of age, the digestible Lys levels for Cobb, Ross and Industry were similar with Brazil recommendations still higher. For TSAA recommendations, the Brazil standards were the highest initially and remained higher during the remainder of the study. Industry values tended to be higher than Cobb and Ross throughout most of the study, with similar values for industry, Cobb and Ross for 37-49 d. Cobb recommendations were generally lowest during the early part of the study but increased during the latter part of the study in comparison to the other recommendations. Because of the higher amino acid values, the Brazil diets were typically lowest in ME energy with Cobb diets typically highest. Ross and Industry diets were similar in ME for most of the study with industry diets being higher for the last 10-12 d of the study.

The effect of diets formulated to different nutrient standards on live performance is shown in Table 10. There were significant differences in body weight at every age related to the different diets. Birds fed the diets formulated to Brazilian standards and Ross standards typically had the highest body weight at every age while birds fed diets formulated to Cobb or industry standards were typically lower in body weight. At 42 and 49 d of age, there were no significant differences in body weight among birds fed diets formulated to Brazilian, Cobb, or Ross standards while those fed the industry standards had the lowest body weight at these times. Differences in average daily gain are presented to aid in calculating differences in time required to reach a specific target body weight.

Table 10: Effect of diets formulated to different nutrient standards on live performance of male broilers (means of 12 pens of 40 birds)

	Brazil	Cobb	Industry	Ross	p-value	Std. error	CV
Body weight (kg)							
14 d	0.490^{a}	0.468^{b}	0.466^{b}	0.482^{a}	<0.0001	0.004	2.62
28 d	1.481^{a}	1.435^{c}	1.454^{bc}	1.475^{ab}	0.0017	0.009	1.99
42 d	2.767^{a}	2.718^{ab}	2.664^{b}	2.747^{a}	0.0089	0.022	2.68
49 d	3.110^{a}	3.088^{ab}	3.013^{b}	3.165^{a}	0.0145	0.032	3.57
Average daily gain (g/d)							
0-14	35.00	33.42	33.28	34.42			
0-28	52.89	51.25	51.92	52.67			
0-42	65.88	64.71	63.42	65.40			
0-49	63.46	63.02	61.48	64.59			
Feed conversion (kg:kg)							
1-14 d	1.295^{b}	1.334^{a}	1.337^{a}	1.288^{b}	0.0034	0.012	2.86
1-28 d	1.458^{b}	1.507^{a}	1.463^{b}	1.473^{ab}	0.0503	0.014	2.92
1-42 d	1.755^{a}	1.715^{b}	1.716^{b}	1.733^{ab}	0.0328	0.011	2.07
1-49 d	1.927	1.897	1.895	1.904	0.4663	0.017	2.86
Feed efficiency (kg:kg)							
1-14 d	0.772^{a}	0.750^{b}	0.749^{b}	0.777^{a}	0.0028	0.007	2.77
1-28 d	0.686^{a}	0.663^{b}	0.684^{a}	0.680^{ab}	0.0541	0.006	2.97
1-42 d	0.570^{b}	0.583^{a}	0.583^{a}	0.577^{ab}	0.0275	0.003	2.05
1-49 d	0.519	0.528	0.528	0.525	0.4701	0.005	2.82
Feed intake (kg)							
1-14 d	0.577	0.568	0.566	0.566	0.5299	0.007	3.74
1-28 d	2.096	2.102	2.066	2.109	0.4418	0.020	3.25
1-42 d	4.785^{a}	4.591^{bc}	4.501^{c}	4.678^{ab}	<0.0001	0.039	2.78
1-49 d	5.909^{a}	5.783^{ab}	5.627^{b}	5.915^{a}	0.0029	0.063	3.42
Mortality (%)							
1-14 d	2.71	2.75	2.92	2.29	0.9648	0.96	1.47*
1-28 d	3.54	4.00	5.21	5.42	0.5814	1.22	1.83
1-42 d	5.42	5.00	7.29	6.88	0.5752	1.44	2.13
1-49 d	6.46	6.00	8.13	7.71	0.7089	1.56	2.30

*CV of transformed means. ^{abc}Means in rows with common superscripts do not differ significantly ($p \leq 0.05$)

Significant differences among birds fed the diets formulated to different nutrient standards were also observed for feed conversion at every age except 49 d of age. Birds fed diets formulated to Ross and Brazilian standards generally had the best feed conversion at early ages, probably related to the higher amino acid content of these diets, while birds fed diets formulated to Cobb and industry standards generally had the best feed conversion at later ages, probably related to the higher energy content of these diets. There were no significant differences in feed intake at early ages but at 42 and 49 d birds fed the diets formulated to Cobb and industry standards generally consumed less overall feed than did birds fed the diets formulated to Ross or Brazilian standards. The lower feed intake by birds fed the diets formulated to Cobb or industry standards was probably a reflection of the higher energy content of these diets. There were no significant differences among the various treatments for mortality during the study.

Because of differences in nutrient density among the various dietary treatments, a more effective means of comparing performance might be related to nutrient utilization. Calculations of consumption of calories, protein, lysine and TSSA are shown in Table 11. There were no significant differences in calorie consumption for the first 28 days; at 42 and 49 d significant differences were observed among the birds fed the various treatments. At 42 d, birds fed diets formulated to Cobb and industry standards consumed fewer calories than did birds fed diets formulated to Ross or Brazilian standards. At 49 d, there were no significant differences in calories consumed by birds fed diets formulated to Ross, Brazilian, or Cobb standards with significantly lower calorie consumption by birds fed the diets formulated to industry standards.

Significant differences in crude protein consumption were observed at every age. At 14, 28 and 42 d, birds fed diets formulated to Cobb standards consumed significantly less protein than birds fed diets formulated to Brazilian, Ross, or industry standards and at 49 d had numerically the lowest protein consumption among the various treatments. Birds fed the diets formulated to Brazilian standards had protein intake comparable to birds fed diets formulated to industry or Ross standards at 14 and 28 d and had significantly higher protein consumption than birds fed the other treatments at 42 and 49 d. Consumption of lysine and TSAA followed these same trends with birds fed diets to Cobb standards having the lowest lysine consumption and birds fed diets formulated to Brazilian standards having the highest lysine consumption throughout the study. Similar trends were observed for TSAA consumption with birds fed the diets formulated to Brazilian standards having the highest overall consumption of TSAA and birds fed diets to Cobb standards having the lowest overall consumption.

Table 11: Effect of diets formulated to different nutrient standards on nutrient consumption by male broilers (means of 12 pens of 40 birds)

	Brazil	Cobb	Industry	Ross	p-value	Std error	CV
Calorie consumption (ME kcal/bird)							
1-14 d	1788.00	1792.00	1744.00	1740.00	0.13	20.83	3.73
1-28 d	6555.00	6662.00	6463.00	6595.00	0.19	70.82	3.24
1-42 d	15087.00[a]	14595.00[b]	14127.00[c]	14781.00[ab]	<0.0001	117.12	2.65
1-49 d	18691.00[a]	18408.00[a]	17760.00[b]	18747.00[a]	0.001	197.20	3.39
Crude protein consumption (grams/bird)							
1-14 d	120.33[a]	105.26[b]	121.31[a]	122.38[a]	<0.0001	1.63	4.80
1-28 d	420.95[a]	379.06[b]	411.04[a]	420.82[a]	<0.0001	4.04	3.43
1-42 d	918.27[a]	811.51[c]	856.78[b]	878.71[b]	<0.0001	8.88	3.55
1-49 d	1119.79[a]	1023.35[b]	1039.19[b]	1093.35[a]	<0.0001	12.02	3.90
Lysine consumption (grams/bird)							
1-14 d	7.77[a]	6.67[b]	7.47[a]	7.75[a]	<0.0001	0.10	4.89
1-28 d	26.82[a]	23.29[d]	25.03[c]	25.97[b]	<0.0001	0.25	3.43
1-42 d	57.78[a]	49.27[c]	51.82[b]	53.13[b]	<0.0001	0.54	3.52
1-49 d	70.15[a]	61.78[c]	62.49[c]	65.76[b]	<0.0001	0.73	3.86
TSAA consumption (grams/bird)							
1-14 d	5.57[a]	5.04[b]	5.55[a]	5.55[a]	<0.0001	0.08	4.91
1-28 d	19.35[a]	17.87[b]	19.05[a]	18.67[a]	<0.0001	0.19	3.44
1-42 d	41.88[a]	38.21[c]	39.60[b]	38.64[bc]	<0.0001	0.41	3.60
1-49 d	50.82[a]	47.99[b]	48.07[b]	48.25[b]	<0.0015	0.55a	3.91

[abc]Means in row with common superscript do not differ significantly (P<0.05)

Table 12: Effect of diets formulated to different nutrient standards on nutrient utilization by male broilers (means of 12 pens of 40 birds)

	Brazil	Cobb	Industry	Ross	p-value	Std error	CV
Calorie:Gain (ME kcal:kg)							
1-14 d	4011.44[b]	4208.72[a]	4120.56[a]	3962.00[b]	<0.0001	36.62	2.84
1-28 d	4559.69[b]	4777.53[a]	4576.91[b]	4606.44[b]	0.002	42.51	2.91
1-42 d	5533.69[a]	5450.75[bc]	5385.74[c]	5475.36[ab]	0.005	28.41	1.73
1-49 d	6096.13	6038.00	5982.42	6035.97	0.47	55.46	2.90
Grams of crude protein per kg of gain							
1-14 d	268.69[b]	247.17[c]	286.42[a]	278.51[ab]	<0.0001	3.77	4.83
1-28 d	292.73[a]	274.02[b]	291.03[a]	293.89[a]	<0.0001	2.55	3.07
1-42 d	338.12[a]	303.25[c]	327.11[b]	326.63[b]	<0.0001	2.76	2.95
1-49 d	365.18[a]	336.25[c]	350.05[b]	350.30[b]	<0.0001	3.91	3.86
Grams of Lysine per kg of gain							
1-14 d	17.34[a]	15.68[b]	17.64[a]	17.64[a]	<0.0001	0.24	4.96
1-28 d	18.65[a]	16.84[c]	17.72[b]	18.14[b]	<0.0001	0.16	3.09
1-42 d	21.28[a]	18.41[c]	19.78[b]	19.75[b]	<0.0001	0.17	2.93
1-49 d	22.88[a]	20.30[c]	21.05[b]	21.07[b]	<0.0001	0.24	3.84
Grams of TSAA per kg of gain							
1-14 d	12.43[b]	11.83[c]	13.10[a]	12.62[ab]	0.0001	0.18	4.97
1-28 d	13.46[a]	12.92[b]	13.49[a]	13.04[b]	0.0013	0.12	3.06
1-42 d	15.42[a]	14.28[b]	15.12[a]	14.37[b]	<0.0001	0.13	3.02
1-49 d	16.57[a]	15.77[bc]	16.19[ab]	15.46[c]	0.0004	0.18	3.90

[abc]Means in row with common superscript do not differ significantly (P<0.05)

The effects of the different formulation methods on nutrient utilization are shown in Table 12. At 14 d, birds fed diets formulated to Cobb or Industry standards had the poorest calorie conversion (ME kcal/kg gain) as compared to birds fed diets formulated to Brazil or Ross standards. At 28 d, calorie conversion by birds fed Cobb standards again was the poorest among the various treatments, with no significant differences among the other treatments. This poorer conversion may be a reflection of the lower protein and amino acid intake by birds fed these diets, as calorie conversion actually reflects the conversion of the entire "nutrient package", i.e. the ratio of other nutrients to the dietary energy level. At 42 d, birds fed diets formulated on Cobb or Industry standards had numerically the most efficient calorie conversion; at 49 d there were no significant differences among the various treatment groups. Therefore, the cost per calorie of the entire diet could be used as an indication of overall economic benefits of a particular nutrient program.

At every age, birds fed diets formulated to Cobb standards were the most efficient in terms of protein utilization (g CP/kg gain), lysine utilization (g Lys/kg gain)and TSAA utilization (g TSAA/kg gain). Birds fed diets formulated to Ross or Industry standards were intermediate in utilization of protein, Lys and TSAA, while birds fed diets formulated to Brazilian standards tended to require more protein, Lys and TSAA than birds fed the other dietary treatments, especially after 14 d of age. The effect of the different formulation methods on processing characteristics of male broilers is shown in Table 13. No significant differences in dressing

Table 13: Effects of diets formulated on different nutrient standards on processing characteristics of male broilers (means of 12 pens of 5 birds)

	Brazil	Cobb	Industry	Ross	p-value	Std error	CV
Dressing (%)	70.84	71.26	70.49	71.11	0.2829	0.31	3.11
Breast							
Weight (kg)	0.607[a]	0.579[b]	0.589[ab]	0.604[a]	0.0467	0.009	10.26
Live weight (%)	18.81	18.34	18.61	18.48	0.3879	0.21	8.08
Carcass (%)	26.51	25.92	26.39	25.98	0.2392	0.26	7.01
Leg quarters							
Weight (kg)	0.724[ab]	0.721[b]	0.697[c]	0.742[a]	0.0002	0.007	7.21
Live weight (%)	22.47[ab]	22.76[a]	22.06[b]	22.69[a]	0.0098	0.16	5.25
Carcass (%)	31.78	31.95	31.31	31.93	0.1527	0.23	5.11
Wings							
Weight (kg)	0.257[ab]	0.252[b]	0.255[b]	0.263[a]	0.0079	0.002	6.47
Live weight (%)	8.00	8.01	8.09	8.05	0.6326	0.06	5.15
Carcass (%)	11.31	11.24	11.47	11.32	0.1456	0.07	4.68

[abc]Means in row with common superscript do not differ significantly (P<0.05)

percentage were observed among birds fed the different dietary treatments. Birds fed diets formulated to Brazilian and Ross standards had significantly higher breast meat weight than did birds fed the Cobb standards, with those fed the Industry diets being intermediate between these groups. However, when expressed as a percentage of live weight or carcass weight there were no significant differences among the various treatment groups. Leg quarter weight was highest for those fed diets formulated to Ross standards and lowest for those fed diets formulated to Industry standards with those fed diets formulated to Cobb or Brazilian standards intermediate in weight. When expressed as a percentage of live weight there were still significant differences among birds fed the various dietary treatments but not when expressed as a percentage of carcass weight. Significant differences in wing weight were observed among the treatments but not when expressed as a percentage of carcass weight.

In conclusion, performance of birds formulated to different nutrient recommendations varied depending primarily upon the relative levels of crude protein, amino acids and metabolizable energy. Feeding diets higher in crude protein and amino acids tended to result in faster growth, especially in early stages, but were less efficient in conversion of crude protein and amino acids into body weight gain. Feeding diets higher in metabolizable energy tended to result in better feed conversion, however effects of dietary energy on calorie conversion were somewhat variable. Over the entire 49 d feeding period there were no significant differences among the various treatments for caloric efficiency. No economic analysis was made of the present study, as relative costs of energy and amino acids vary over time. However it is obvious that when protein costs are high relative to energy, feeding systems which recommend lower protein and amino acid levels should be more economical, while perhaps resulting in a small sacrifice in body weight gain, while feeding systems that recommend higher protein and amino acid levels might be more economical when protein is relatively lower in comparison to dietary energy levels. Because overall calorie utilization was similar among nutrient programs at the conclusion of the study, this could be used as an overall indication of economic efficiency when comparing the different nutrient programs. Adjustments in time to market weight can be made utilizing the average daily gain data.

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