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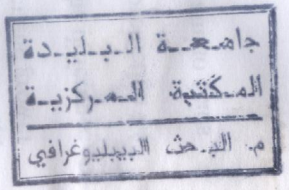

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DIET FORMULATION FOR BROILERS BASED ON TOTAL VERSUS DIGESTIBLE AMINO ACIDS

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SUMMARY

A number of true amino acid digestibility assays were conducted in adult roosters on a range of feedstuffs. Using these feedstuff batches, different broiler starters and growers were formulated. A corn-soy positive control diet with high amino acid digestibility (HD) was compared to another diet using various by-products to partially replace corn and soybean meal. This second diet with low amino acid digestibility (LD) was formulated to contain the same levels of total lysine and total sulfur amino acids as diet HD. A third diet (LD + AA) was similar to diet LD, but with L-lysine•HCl and DL-methionine added to obtain levels of true digestible amino acids equal to diet HD. All three treatments consisted of a starter diet fed to 21 days and a grower diet fed to 42 days of age. Diet LD significantly depressed growth, feed efficiency, and breast meat yield compared to control diet HD. Balancing digestible amino acid contents by additional L-lysine•HCl and DL-methionine essentially restored growth performance and carcass quality to the level of the control diet. This result demonstrates the potential benefit of switching diet formulation from total to digestible amino acids. The analysis of feed cost per kg broiler weight or per kg breast weight revealed considerable benefits from cheap by-products when diets were properly balanced in their digestible amino acid contents.

Key words: Breast meat, broilers, carcass, digestible amino acids, economics, growth, lysine, methionine

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DESCRIPTION OF PROBLEM

The concept of amino acid digestibility is widely accepted as a useful tool to estimate amino acid availability in poultry [1, 2, 3]. Although there are a variety of methods to assess amino acid digestibility in feedstuffs or compound feeds, the most frequently used assay is the balance study in adult roosters, usually referred to as the "Sibbald method" [4]. The

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assay is considered to be convenient, reproducible, and when caecectomized birds are used, not susceptible to hindgut fermentation. It has been repeatedly demonstrated that the digestibility of lysine or methionine in roosters reasonably reflects the availability of the respective amino acid in a chick growth assay [5, 6].

It is surprising that there appears to be very little work in the literature demonstrating the practical application of digestible amino acids in diet formulation. Green [7] compared broiler diets formulated to equal levels of either total or digestible lysine with different oilmeals. He could demonstrate the advantages of using digestible amino acids, but was unable to get identical performance with all oilmeals involved. Similarly, Jolly [8] could overcome most of the gap in performance between two layer diets with high or low digestibility when L-lysine and DL-methionine were added to make up for the difference in digestible lysine and methionine content. Better economic performance was also obtained with chick diets balanced in digestible amino acids as compared to diets formulated on a total amino acid basis [9].

The purpose of the present study, therefore, was to evaluate whether different broiler diets formulated to equal dietary contents of digestible lysine and sulfur amino acids would indeed support similar bird growth and carcass composition.

Materials and Methods

In order to approach this problem properly, amino acid digestibilities in several feedstuffs were determined in roosters. After that, the same feedstuff batches were used to formulate and mix starter and grower diets with equal content of either total or digestible amino acids. Those diets were fed to commercial strain broilers to 42 days of age, after which growth and carcass quality were measured.

EXPERIMENT 1: DIGESTIBILITY ASSAY

A balance study attempted to determine the true amino acid digestibilities of eight feedstuffs. This experiment used a total of twenty-four adult caecectomized Leghorn roosters with an average body weight of 2669±190 g. The procedure was a modified Sibbald method [10]. Caecectomy was performed by exteriorizing and removing the two caeca at the ileo-caecal junction following the surgical procedure described by Gurnsey *et al.* [11]. The feedstuffs evaluated were: corn, sorghum (low tannin variety), two batches of soybean meal, meat and bone meal, poultry by-product meal, feather meal, and rice bran. Two batches of soybean meal with different urease indexes were purchased in an effort to find soybean proteins of different digestibility.

The experiment was run in a completely randomized block design with eight feedstuffs, three blocks, and two replicates per block. Thus each feedstuff was tested in six roosters. The procedure adopted ensured that no bird was fed the same feedstuff twice. An additional six roosters were fasted throughout the experimental period to determine endogenous amino acid losses.

After a five-day adaptation period to the rooms and cages, the birds were fasted for 24 hr, and the feedstuffs were fed at 8:00 a.m. and 4:00 p.m. in two equal doses of 15 g via crop intubation. This procedure was adopted to avoid regurgitation of feed. Total collection of excreta was done twice daily for a period of 56 hr. The excreta produced by each rooster were weighed, freeze dried, and pooled in a single sample for each feedstuff for lab analysis.

The amino acid content in feed and excreta samples was determined using ion-exchange chromatography after preoxidation and acid hydrolysis [12].

EXPERIMENT 2: GROWTH STUDY

A total of 600 male broiler chicks of a commercial strain (Ross) received three dietary treatments over two experimental periods: from 1 to 21 days and from 21 to 42 days posthatch. The experiment had a complete randomized block design consisting of three treatments with ten replicates of twenty birds each. Birds were kept on the floor in pens of 1.5 x 1.5 m each.

The experimental treatments were as follows:

1) Corn-soybean control diet with high amino acid digestibility (HD).

2) Mixed diet including a range of by-products to partially replace corn and soybean meal, formulated to the same level of total lysine and total sulfur amino acids as

diet HD. This diet was of low amino acid digestibility (LD).

3) A diet similar to LD, but supplemented with L-lysine•HCl and DL-methionine to obtain the same level of true digestible lysine and sulfur amino acids as diet HD (LD + AA).

A set of three starter diets and three grower diets was formulated according to the above schedule. The composition of starter and grower diets appears in Table 1. L-Lysine•HCl and DL-methionine were considered as 100% digestible [10, 13, 14]. Diets were fed as mash *ad libitum*, and weight gain, feed intake, and feed conversion were recorded for the two sub-periods. At 42 days, ten birds/pen were selected at random after a 6 hr fast, leg banded, and weighed individually. They were then sacrificed and processed for carcass quality evaluation.

The results were subjected to analysis of variance, with treatment differences being tested for significance using a Student-Newman-Keuls test [15]. Economic evaluations were made by calculating the cost per ton of diet and determining the feed cost per kg of live broiler weight, per kg carcass, and per kg breast weight.

TABLE 1. Composition of experimental diets formulated on total or digestible amino acids

INGREDIENT	STARTER			GROWER		
%	HD	LD	LD + AA	HD	LD	LD + AA
Corn (8.1% CP)	51.0	29.2	29.2	57.2	33.1	33.1
Sorghum (8.8% CP)	–	25.0	25.0	–	23.6	23.6
Soybean meal 1 (45.0% CP)	–	14.0	14.0	–	12.0	12.0
Soybean meal 2 (45.2% CP)	40.9	14.9	14.9	35.3	11.0	11.0
Rice bran (12.5% CP)	–	4.0	4.0	–	7.0	7.0
Poultry by-products (49.2% CP)	–	4.0	4.0	–	4.0	4.0
Meat and bone meal (39.3% CP)	–	2.9	2.9	–	2.5	2.5
Feather meal (79.6% CP)	–	1.0	1.0	–	1.5	1.5
Starch	–	0.20	0.11	–	0.20	0.09
Dicalcium phosphate	1.80	–	–	1.65	–	–
Ground limestone	1.09	0.50	0.50	1.07	0.57	0.57
Salt	0.29	0.24	0.24	0.30	0.25	0.25
Soybean oil	3.99	3.13	3.13	3.64	3.54	3.54
Premix[A]	0.71	0.71	0.71	0.67	0.67	0.67
DL-methionine	0.23	0.19	0.22	0.17	0.12	0.16
L-lysine•HCl	–	–	0.063	–	–	0.065
CALCULATED ANALYSIS (%)						
ME (kcal/kg)	3050	3050	3050	3100	3100	3100
Crude protein	22.8	22.1	22.1	20.7	20.2	20.2
Lysine	1.12	1.12	1.17	1.00	1.00	1.05
Digestible lysine	1.02	0.97	1.02	0.90	0.85	0.90
Met + Cys	0.90	0.90	0.94	0.80	0.80	0.84
Digestible Met + Cys	0.81	0.77	0.81	0.71	0.67	0.71
Calcium	0.95	0.95	0.95	0.90	0.90	0.90
Available phosphorus	0.44	0.44	0.44	0.41	0.41	0.41

[A]Provided per kg of diet: Vitamin A, 10,000 IU; vitamin D_3, 2,000 IU; vitamin E, 30 IU; menadione, 3 mg; vitamin B_1, 2 mg; vitamin B_2, 6 mg; vitamin B_6, 4 mg; Ca pantothenate, 12 mg; niacin, 50 mg; vitamin B_{12}, 0.015 mg; biotin, 0.07 mg; folic acid, 1 mg; selenium, 0.25 mg; iron, 50 mg; manganese, 80 mg; zinc, 50 mg; copper, 10 mg; cobalt, 2 mg; iodine, 1 mg; propionic acid, 3 g; BHT, 0.1 g; zinc bacitracin, 50 mg; salinomycin, 60 mg; choline chloride, 500 mg (starter diets) or 300 mg (grower diets).

Results and Discussion

Table 2 reports the digestibility coefficients obtained from the assays in adult roosters. True amino acid digestibility varied considerably, with values as low as 54.6% for cystine digestibility in poultry by-product and higher than 92% for lysine and methionine in soybean meal. In general, digestibility coefficients were in the range of values reported elsewhere [4, 16]. Both batches of soybean meal revealed amino acid digestibilities superior to all other feedstuffs tested. Surprisingly, there was no obvious difference between the protein quality of the two batches, although batch 1 had 0.44 urease index, and batch 2 only 0.12. The urease index obviously was inappropriate to characterize different qualities of soybean meals in this case. In accordance with earlier estimates, cystine digestibility was rather low in by-products such as meat and bone, poultry by-products, feather meal, and rice bran.

Based on those predetermined digestibility figures, the experimental diets could be formulated very accurately. Amino acid supplementation, being of particular importance for this experiment, was verified by analysis of free amino acids in all diets (Table 3). Calculated additions of DL-methionine and L-lysine•HCl were almost exactly confirmed.

Table 4 summarizes growth and feed conversion data. Birds performed well during both starter and grower periods. To 21 days of age, birds on the LD diet were significantly inferior by 24 g body weight and 6 points in feed conversion compared to the HD diet. Thus, the lower contents of digestible lysine and sulfur amino acids resulted in lower bird performance. Adding DL-methionine and L-lysine•HCl to the LD diet to overcome the difference in digestible lysine and sulfur amino acids essentially equalized performance with diets HD and LD + AA. To 42 days of age, this picture remained unchanged.

The body weight of the birds sampled for carcass analysis reflected the average weight gain of the respective treatment groups (Table 4). Carcass yield as a percentage of live body weight was not affected by dietary treatment.

Breast meat yield, however, clearly responded to differences in digestible amino acid supply. Carcasses from birds on diet LD had only 29.0% breast portion including skin and bone, significantly less than the 30.1% for diet HD. Adding DL-methionine and L-lysine• HCl to diet LD compensated for about half of this difference, confirming the high sensitivity of the broilers to dietary levels of digestible amino acids. Carcass fatness, as measured by the abdominal fat pad, was

TABLE 2. True amino acid digestibility in the feed ingredients[A]

TRUE DIGESTIBILITY COEFFICIENT	FEEDSTUFFS							
%	Corn	Sorghum	Soybean Meal 1[B]	Soybean Meal 2[C]	Meat & Bone Meal	Poultry By-Product Meal	Feather Meal	Rice Bran
Methionine	89.1	86.8	90.4	92.3	85.6	78.9	72.0	75.5
Cystine	82.9	77.9	83.2	81.0	70.4	54.6	60.0	63.3
Met + Cys	86.0	82.3	87.2	85.9	79.9	70.4	60.5	69.2
Lysine	78.0	69.6	90.5	92.7	85.9	74.5	66.4	82.0
Threonine	77.1	71.0	87.3	87.2	83.4	73.3	66.0	72.5
Arginine	82.3	80.2	91.6	90.1	85.8	83.7	78.5	84.3
Valine	73.1	74.8	87.6	90.4	82.7	73.3	71.5	83.7
Leucine	90.6	93.5	91.1	91.8	85.4	77.6	74.9	80.0
Isoleucine	73.1	79.9	89.7	92.7	81.5	75.3	76.7	86.4

[A]Each figure represents the mean of six caecectomized cockerels.

[B]0.44 urease index

[C]0.12 urease index

TABLE 3. Comparison of analyzed vs. calculated addition of DL-methionine and L-lysine•HCl to the experimental diets

SUPPLEMENTED AMINO ACIDS	STARTER			GROWER		
%	HD	LD	LD + AA	HD	LD	LD + AA
DL-methionine						
Calculated	0.23	0.19	0.22	0.17	0.12	0.15
Analyzed	0.25	0.19	0.22	0.18	0.11	0.15
L-lysine•HCl						
Calculated	–	–	0.063	–	–	0.065
Analyzed	–	–	0.077	–	–	0.069

slightly higher in LD than in HD birds and remained unchanged by added amino acids.

The results show that starting birds negatively respond to dietary levels of 1.12% total lysine and 0.90% total sulfur amino acids when amino acid digestibility is not as good as in a corn-soy diet. Similarly, total levels of 1.00% lysine and 0.80% total sulfur amino acids were inadequate in a grower diet based on a mixed range of ingredients. Although the present study was not designed to yield estimates of amino acid requirements, it does indicate that recommendations such as the NRC's 1.00% lysine and 0.72% methionine and cystine [16] may be inadequate for grower diets.

The present data set gives further evidence that diet formulation on digestible amino acids will yield more consistent bird performance, especially if feedstuffs other than corn and soybean meal are included.

TABLE 4. Broiler performance as affected by diet composition

	TREATMENT			SEM
	HD	LD	LD + AA	
GROWTH DATA, 1–21 DAYS OF AGE[A]				
Weight gain (g)	697[a]	673[b]	706[a]	7.7
Feed intake (g)	1026[a]	1030[a]	1060[a]	13.5
Feed/gain	1.473[a]	1.532[b]	1.502[ab]	0.016
GROWTH DATA, 1–42 DAYS OF AGE[A]				
Weight gain (g)	2333[a]	2241[b]	2330[a]	18.5
Feed intake (g)	4165[a]	4140[a]	4190[a]	29.8
Feed/gain	1.786[a]	1.848[b]	1.799[a]	0.011
CARCASS DATA[B]				
Live weight at slaughter (g)	2309[a]	2229[b]	2301[a]	19.2
Carcass yield (%)[C]	72.4[a]	72.4[a]	72.6[a]	0.16
Breast (%)[D]	30.1[a]	29.0[c]	29.6[b]	0.15
Thighs (%)	14.2[a]	14.2[a]	14.2[a]	0.15
Drumsticks (%)	14.2[a]	14.0[b]	14.1[ab]	0.08
Abdominal fat (%)	1.48[a]	1.80[b]	1.90[b]	0.04

[A]Ten replicate pens of twenty male Ross broilers per treatment

[B]One hundred carcasses per treatment

[C]Carcass weight excluding head, feet, edible organs

[D]Breast weight including skin and bone, given as % of carcass weight

[a,b]Different superscripts indicate significant differences ($P < .05$).

Moreover, digestible amino acids might be considered as a necessary tool making possible the use of high portions of by-products without variability in performance or formulating with large safety margins.

The economic significance of the diet alterations evaluated in this study is considerable. Based on the performance data obtained, Table 5 calculates various cost ratios. Using typical prices for the feedstuffs included (Brazilian market, mid 1994), a large price difference between the corn-soy diets (HD) and the mixed diets (LD and LD + AA) was calculated. Feed cost per bird was lowest with the LD diet, but taking differences in weight gain and carcass composition into account, feed cost per kg carcass weight and per kg breast weight were lowest with the LD + AA diets. Thus, using cheap feed ingredients while balancing digestible amino acid contents with crystalline amino acids was the most profitable way to produce broiler meat in this study.

TABLE 5. Economic significance of growth and carcass quality responses under Brazilian conditions

	HD	LD	LD + AA
STARTER			
Cost/metric ton (US $)	227	213	216
Feed Consumption (g/bird)	1026	1030	1060
GROWER			
Cost/metric ton (US $)	216	205	208
Feed consumption (g/bird)	3139	3110	3130
COST CALCULATIONS			
Body weight at 42 days[A] (g)	2379	2287	2376
Carcass yield (%)	72.4	72.4	72.6
Carcass weight (g)	1722	1656	1725
Breast yield (%)	30.1	29.0	29.6
Breast weight (g)	518	488	511
Feed cost/bird (US $)	0.911	0.857	0.880
Feed cost/kg body weight (US $/kg)	0.383	0.375	0.370
Feed cost/kg carcass (US $/kg)	0.529	0.518	0.510
Feed cost/kg breast (US $/kg)	1.759	1.785	1.722
[A]Average chick weight at hatch = 46 g			

CONCLUSIONS AND APPLICATIONS

1. A negative growth and breast meat response occurred in broilers when ingredients with low amino acid digestibility partially replaced corn and soybean meal in starter and grower diets.
2. Added L-lysine•HCl and DL-methionine could essentially compensate for the difference in digestible lysine and sulfur amino acid content of the diets.
3. Formulating broiler diets based on digestible amino acids gives a better prediction of dietary protein quality and bird performance than total amino acids.
4. The use of cheap by-products with adequate supplementation of crystalline amino acids may offer considerable economic benefit to broiler meat production.

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