FATS AND PROTEINS RESEARCH FOUNDATION, INC.

Director's Digest

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AREA CODE 813 — 463-4744

JANUARY 1991 No. 212

A COMPARISON OF SEVERAL ANIMAL BYPRODUCT AND PLANT PROTEINS AS SOURCES OF ESSENTIAL AMINO ACIDS FOR CATFISH[1]

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INTRODUCTION

NUTRITIONS IN MOST ANIMAL PRODUCTION FIELDS HAVE AT THEIR DISPOSAL, A VAST AMOUNT OF INFORMATION ON AVAILABILITY OF AMINO ACIDS IN FEED INGREDIENTS. PROTEINS WITH DEFICIENCIES OR LOW AVAILABILITIES OF ESSENTIAL AMINO ACIDS ARE CUSTOMARILY SUPPLEMENTED WITH SYNTHETIC FREE AMINO ACIDS, WHICH ARE GENERALLY CONSIDERED TO BE EFFICIENTLY UTILIZED BY MONOGASTRIC ANIMALS.

HOWEVER, IN THE RELATIVELY NEW AREA OF FISH NUTRITION, WE HAVE VERY LITTLE RESEARCH DATA ON THE RELATIVE VALUES OF FEED INGREDIENTS AS PROTEIN SOURCES OR ON THE UTILIZATION OF FREE AMINO ACIDS.

STUDIES FROM THIS LABORATORY HAVE SUGGESTED THAT FREE AMINO ACIDS ARE LESS EFFICIENTLY UTILIZED BY CATFISH THAN AMINO ACIDS IN THE FORM OF INTACT

1 - THIS STUDY WAS PARTIALLY FINANCED BY A GRANT FROM THE FATS AND PROTEINS RESEARCH FOUNDATION, INC.

PROTEINS (ANDREWS ET AL, 1977). IN ONE OF THESE STUDIES GROWTH AND FEED EFFICIENCY WERE IMPROVED BY THE ISONITROGENOUS SUBSTITUTION OF GELATIN (A RICH SOURCE OF ARGININE) INTO A DIET WHICH CONTAINED CASEIN AS THE SOLE PROTEIN SOURCE; WHEREAS, THE ADDITION OF FREE ARGININE, METHIONINE, CYSTINE OR TRYPTOPHAN TO CASEIN HAD NO EFFECT. IN THE SECOND STUDY (ANDREWS, 1977), THE ADDITION OF MENHADEN AND CORN GLUTEN MEAL TO DIETS WHICH WERE APPARENTLY LIMITING IN SULFUR AMINO ACIDS RESULTED IN ENHANCEMENT OF GROWTH AND FEED EFFICIENCY; WHEREAS, THE ADDITION OF L-METHIONINE, METHIONINE HYDROXY ANALOG OR L-CYSTINE DID NOT RESULT IN A SIGNIFICANT RESPONSE. IN THE THIRD STUDY (ANDREWS, 1977), MENHADEN MEAL OR SOYBEAN RESULTED IN INCREASED GROWTH WHEN ADDED TO A DIET WHICH APPEARED TO BE LIMITING IN LYSINE; WHEREAS, THE ADDITION OF L-LYSINE, PROVIDED NO BENEFIT. IN ANOTHER STUDY (ANDREWS AND PAGE, 1974), THE WATER SOLUBLE - NON ASH FRACTION OF FISH MEAL WAS SHOWN TO PROVIDE A GROWTH ENHANCING FACTOR IN CATFISH FEEDS. ALTHOUGH THE GROWTH ENHANCEMENT WAS PRESUMED TO BE RELATED TO AMINO ACID CONTENT, INCREASED GROWTH WAS NOT OBTAINED FROM THE ADDITION OF AN EQUIVALENT LEVEL OF FREE AMINO ACIDS.

SINCE INTACT PROTEINS APPEAR TO BE THE MOST IMPORTANT SOURCE OF ESSENTIAL AMINO ACIDS IN CATFISH FEEDS AND VERY LITTLE INFORMATION IS AVAILABLE ON THE RELATIVE ABILITY OF FEED INGREDIENTS TO SUPPLY AMINO ACIDS FOR CATFISH, THE FOLLOWING TWO STUDIES WERE CONDUCTED WITH ANIMAL BYPRODUCT AND PLANT PROTEINS.

METHODS

DESCRIPTION OF DIETS. IN EXPERIMENT 1, CORN GLUTEN MEAL WAS REPLACED ON AN ISONITROGENOUS BASIS BY SOYBEAN MEAL, POULTRY BYPRODUCT MEAL, HYDROLYZED FEATHER MEAL, PEANUT MEAL OR COTTON SEED MEAL (TABLE 1). CORN GLUTEN MEAL WAS CHOSEN AS THE CONTROL INGREDIENT BECAUSE IT IS A RELATIVELY RICH SOURCE OF SULFUR AMINO ACIDS (METHIONINE AND CYSTINE) WHICH HAS BEEN SHOWN TO PRODUCE A GROWTH ENHANCEMENT WHEN ADDED TO CATFISH DIETS WHICH APPEARED TO BE DEFICIENT IN SULFUR AMINO ACIDS (ANDREWS, 1977).

IN EXPERIMENT 2, SOYBEAN MEAL WAS REPLACED ON AN ISONITROGENOUS BASIS BY CORN GLUTEN MEAL, BLOOD MEAL, MEAT AND BONE MEAL, PEANUT MEAL OR COTTON SEED MEAL (TABLE 2). SOYBEAN MEAL WAS CHOSEN AS THE CONTROL INGREDIENT BECAUSE OF ITS

HIGH LYSINE CONTENT (ON A PERCENTAGE PROTEIN BASIS) AND THE FACT THAT HAS SHOWN TO HAVE A GROWTH PROMOTING EFFECT WHEN ADDED TO DIETS WHICH WERE APPARENTLY DEFICIENT IN LYSINE (ANDREWS, 1977).

CRUDE PROTEIN CONTENTS OF THE DIETS IN BOTH EXPERIMENTS WERE ANALYZED BY THE MICRO KJELDAHL PROCEDURE. THE CRUDE PROTEIN CONTENTS OF THE TEST DIETS WERE WITHIN 1% OF THE CALCULATED LEVELS.

AMINO ACID CONTENT OF EACH DIETARY INGREDIENT WAS ANALYZED BY ION EXCHANGE CHROMATOGRAPHY. GENERALLY, THE AMINO ACID PROFILES OF THE INGREDIENTS WERE IN AGREEMENT WITH TABLE VALUES. THE AMINO ACID CONTENT OF EACH INGREDIENT WAS USED TO CALCULATE A PROFILE FOR THE TEST DIETS. THIS PROFILE WAS USED TO CALCULATE AMINO ACID CONVERSIONS AND IN DISCUSSING LIMITING AMINO ACIDS.

EXPERIMENTAL CONDITIONS. THE DIETS DESCRIBED ABOVE WERE FED TO TRIPLICATE REPLICATES OF TWENTY CHANNEL CATFISH FINGERLINGS STOCKED IN 0.9M DIAMETER CULTURE TANKS. THE INITIAL INDIVIDUAL WEIGHTS OF FISH USED IN BOTH EXPERIMENTS WERE APPROXIMATELY 60G. FISH WERE FED TWICE DAILY (8:00 A.M. AND 4:00 P.M.) AT A RATE OF 4% BIOMASS DAILY. THE DURATION OF BOTH FEEDING TRIALS WAS 42 DAYS.

WATER QUALITY AND TEMPERATURE WERE CONTROLLED BY THE CONSTANT ADDITION OF 3.8 LITER/MINUTE OF PREHEATED WELL WATER. TEMPERATURE WAS MAINTAINED AT $26 \pm 1^{\circ}C$ THROUGHOUT THE EXPERIMENTAL PERIODS.

AT THE END OF THE FEEDING TRIALS, THE ENTIRE BIOMASS OF EACH REPLICATE WAS WEIGHED AND GROWTH WAS EXPRESSED IN TERMS OF AVERAGE INDIVIDUAL GAINS. FEED CONVERSIONS, AMINO ACID CONVERSION RATIOS AND GROWTH DATA WERE ANALYZED FOR STATISTICAL SIGNIFICANCE ($P>0.05$) BY THE METHOD OF DUNCAN (1955).

RESULTS AND DISCUSSION

EXPERIMENT 1. THERE WAS A SIGNIFICANT DECREASE IN GROWTH RATE AND FEED EFFICIENCY (FEED/GAIN) WHEN ONE-HALF OF THE CORN GLUTEN MEAL IN THE CONTROL DIET (TABLE 1, DIET 1) WAS REPLACED ISONITROGENOUSLY (22.5% OF TOTAL PROTEIN) WITH SOYBEAN MEAL (DIET 2). A FURTHER REDUCTION IN GROWTH AND FEED EFFICIENCY WAS OBTAINED WHEN ALL THE CORN GLUTEN MEAL PROTEIN (45% OF TOTAL PROTEIN) WAS

REPLACED WITH SOYBEAN MEAL (DIET 3). THE RATIOS OF TOTAL SULFUR AMINO ACIDS (METHIONINE PLUS CYSTINE) TO GAINS (G TSAA/G GAIN) WERE NOT SIGNIFICANTLY INFLUENCED BY THESE SUBSTITUTIONS.

SINCE THE TSAA LEVEL OF DIET 3 WAS 3.3% PROTEIN AND PAST RESULTS HAVE INDICATED THAT THE TSAA REQUIREMENT WAS GREATER THAN 3.6% OF PROTEIN FOR A 24% PROTEIN DIET (2), SULFUR AMINO ACIDS MAY HAVE BEEN THE GROWTH LIMITING FACTOR IN THESE DIETS.

WHEN ONE-HALF THE CORN GLUTEN MEAL WAS REPLACED WITH POULTRY BYPRODUCT MEAL (DIET 4), GROWTH AND FOOD CONVERSION RATES WERE ALMOST IDENTICAL TO THE CONTROL DIET (DIET 1). HOWEVER, WHEN ALL THE CORN GLUTEN MEAL PROTEIN WAS REPLACED BY POULTRY BYPRODUCT MEAL, BOTH GROWTH AND FOOD CONVERSION WERE SIGNIFICANTLY DECREASED. THE RATIOS OF G DIETARY TSAA/G GAIN WERE NOT AFFECTED BY EITHER LEVEL OF SUBSTITUTION.

WHEN HYDROLYZED FEATHER MEAL (DIET 6) WAS SUBSTITUTED ON AN ISONITROGENOUS BASIS FOR ONE-HALF THE CORN GLUTEN MEAL IN THE CONTROL DIET, GAINS WERE SLIGHTLY (BUT NOT SIGNIFICANTLY) REDUCED. HOWEVER, FOOD CONVERSION RATIOS (FEED/GAIN) WERE SIGNIFICANTLY HIGHER THAN THE CONTROL GROUP (DIET 1). THE RATIO OF TSAA/ GAIN WAS NOT SIGNIFICANTLY DIFFERENT FROM THE CONTROL DIET.

THE SIGNIFICANT REDUCTION IN FEED EFFICIENCY AND THE SLIGHT REDUCTIONS IN GROWTH AND TSAA/GAIN RATES SUGGESTS THAT FEATHER MEAL IS LESS EFFICIENTLY UTILIZED. THIS MAY BE DUE TO THE HIGH CYSTINE - LOW METHIONINE CONTENT OR TO LIMITING LEVELS OF OTHER AMINO ACIDS OR POOR DIGESTION AND ABSORPTION.

WHEN ONE-HALF THE CORN GLUTEN MEAL IN THE CONTROL DIET WAS REPLACED ON THE ISONITROGENOUS BASIS WITH PEANUT MEAL (DIET 7), GROWTH AND FOOD EFFICIENCY WERE SIGNIFICANTLY LESS THAN THOSE FROM THE CONTROL DIET. THE RATIO TSAA/GAIN WAS NOT AFFECTED.

WHEN ONE-HALF THE CORN GLUTEN IN THE CONTROL DIET WAS REPLACED BY COTTON SEED MEAL (DIET 8), GAINS, FEED EFFICIENCY AND TSAA/GAIN VALUES WERE POORER THAN THOSE OBTAINED FOR ALL OTHER DIETS EXCEPT FOR DIET 3.

THE POOR RESPONSE TO THE RELATIVE HIGH LEVELS OF SULFUR AMINO ACIDS IN COTTON SEED MEAL RAISES THE FOLLOWING POSSIBILITIES: (1) OTHER ESSENTIAL AMINO ACIDS MAY BE LIMITING IN THIS DIET; (2) THE SULFUR AMINO ACIDS OF COTTON SEED MEAL MAY HAVE A LOW BIOLOGICAL AVAILABILITY; (3) THE GOSSYPOL LEVELS IN THE COTTON SEED MEAL MAY HAVE BEEN HIGH ENOUGH TO HAVE A GROWTH INHIBITING EFFECT ON CATFISH; OR (4) COTTON SEED MEAL MAY BE POORLY DIGESTED AND ABSORBED PER SE.

WITH THE EXCEPTION OF THE DIETS WHICH CONTAINED COTTON SEED MEAL OR FEATHER MEAL, THE GROWTH AND FEED EFFICIENCY RESPONSES TENDED TO REFLECT THE SULFUR AMINO ACID CONTENT OF THE TEST DIETS. THIS CONCLUSION IS SUPPORTED BY THE FACT THAT THE TSAA/GAIN RATIOS WERE NOT SIGNIFICANTLY DIFFERENT AMONG THE CORN GLUTEN, SOYBEAN, POULTRY BYPRODUCT AND PEANUT MEAL TREATMENTS.

EXPERIMENT 2. THERE WERE SIGNIFICANT REDUCTIONS IN GROWTH RATE AND FEED EFFICIENCY WHEN CORN GLUTEN MEAL (TABLE 2, DIETS 2 AND 3) WAS SUBSTITUTED ON AN ISONITROGENOUS BASIS FOR 50% OF THE SOYBEAN MEAL (19% OF TOTAL PROTEIN) AND 100% (38% OF THE TOTAL PROTEIN) OF THE SOYBEAN MEAL IN THE CONTROL DIET (DIET 1). HOWEVER, LYSINE CONVERSION RATIOS (G LYSINE/G GAIN) FOR ALL THREE DIETS WERE ALMOST IDENTICAL. THESE DATA AND THE DIETARY AMINO ACID PROFILES SUGGEST THAT DIETS 2 AND 3 WERE LIMITING IN LYSINE.

WHEN ONE-HALF THE SOYBEAN MEAL OF THE CONTROL DIET WAS REPLACED ISONITROGENOUSLY BY BLOOD MEAL (DIET 4), WEIGHT GAINS AND FOOD AND LYSINE CONVERSION RATIOS WERE NOT SIGNIFICANTLY DIFFERENT FROM THE CONTROL DIETS.

WHEN ONE-HALF OF THE SOYBEAN MEAL IN THE CONTROL DIET WAS REPLACED BY MEAT AND BONE MEAL (DIET 5), GROWTH, FOOD AND LYSINE CONVERSION RATIOS WERE NOT AFFECTED. HOWEVER, WHEN ALL THE SOYBEAN WAS REPLACED BY MEAT AND BONE MEAL (DIET 6), SIGNIFICANT REDUCTIONS IN GROWTH, FOOD CONVERSION AND LYSINE CONVERSION RATES WERE NOTED.

THE POOR RESPONSE TO THE HIGHER LEVEL OF MEAT AND BONE MEAL MAY BE THE RESULT OF A LOW TRYPTOPHANE LEVEL (0.06% OF PROTEIN), AS TRYPTOPHANE IS THE AMINO ACID WHICH IS MOST AFFECTED BY THE ISONITROGENOUS SUBSTITUTION OF MEAT AND BONE MEAL FOR SOYBEAN MEAL.

ALTHOUGH GROWTH RATES AND FEED EFFICIENCIES WERE SIGNIFICANTLY LOWER IN DIETS IN WHICH PEANUT MEAL WAS SUBSTITUTED FOR SOYBEAN MEAL, LYSINE CONVERSION RATIOS WERE NOT SIGNIFICANTLY DIFFERENT FROM THE CONTROL DIET.

AS WAS THE CASE IN EXPERIMENT 1, POOR RESULTS WERE OBTAINED IN THE DIET IN WHICH COTTON SEED MEAL WAS USED (DIET 8). SINCE THE LYSINE CONVERSION RATIO WAS SIGNIFICANTLY HIGHER FOR DIET 8 THAN FOR THE CONTROL DIET, THE LYSINE CONTENT OF COTTON SEED MEAL PER SE DOES NOT SEEM TO BE A GROWTH LIMITING FACTOR.

WITH THE EXCEPTIONS OF THE DIET WITH HIGHER LEVELS OF MEAT AND BONE MEAL OR THE DIET WITH COTTON SEED MEAL, GROWTH AND FEED EFFICIENCY RESPONSES REFLECTED THE LYSINE CONTENT OF THE TEST DIETS. THIS IS EMPHASIZED BY AN ABSENCE OF A SIGNIFICANT DIFFERENCE IN LYSINE/GAIN RATIOS AMONG THE SOYBEAN, MEAT AND BONE (LOWER LEVEL), CORN GLUTEN AND PEANUT MEAL TREATMENTS.

IN SUMMARY, THESE DATA SUGGEST THAT AS IS THE CASE WITH OTHER MONOGASTRIC ANIMALS, AMINO ACID CONTENTS AS WELL AS PROTEIN LEVELS HAVE TO BE CONSIDERED WHEN DIETARY PROTEIN SOURCES ARE INTERCHANGED IN CATFISH FEED FORMULATIONS. DESPITE THE RELATIVE HIGH LEVELS OF PROTEIN IN CATFISH FEED, AMINO ACID BALANCE IS CRITICAL AND CAN BE EASILY UPSET. UNTIL ADDITIONAL INFORMATION IS AVAILABLE ON THE AMINO ACID REQUIREMENTS OF CATFISH (IN COMMERCIAL TYPE FEEDS), SUBSTITUTIONS FOR PROTEIN SOURCES IN CATFISH FEEDS SHOULD BE CAUTIOUSLY APPROACHED.

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able 1. Results from a study in which animal byproduct and plant protein sources were substituted on an isonitrogenous basis for corn gluten meal in catfish feeds (Experiment 1).

iet	Dietary Variable (%)		T-SAA[3]		Av gain[4]	feed/gain[4]	g TSAA/g gain[4]
	Corn gluten meal	Test ingredient[2]	(%)	% of protein	(g)		
1	20	Corn gluten meal (control)	1.02	3.9	42.6^{c}	2.09^{a}	0.021^{a}
2	10	12.0 Soybean meal (50P)	0.96	3.6	39.2^{b}	2.28^{b}	0.022^{a}
3	0	24.0 Soybean meal (50P)	0.86	3.3	36.9^{a}	2.51^{c}	0.021^{a}
4	10	10.3 Poultry byproduct meal (58P)	0.99	3.7	42.5^{c}	2.09^{a}	0.020^{a}
5	0	20.6 Poultry byproduct meal	0.96	3.6	39.8^{b}	2.27^{b}	0.021^{a}
6	10	7.1 Feather meal (85P)	1.02	3.9	40.7^{bc}	2.26^{b}	0.023^{ab}
7	10	12.0 Peanut meal (50P)	0.93	3.5	39.1^{b}	2.29^{b}	0.021^{a}
8	10	14.6 Cottonseed meal (41P)	0.98	3.7	37.0^{a}	2.54^{c}	0.025^{b}

[1]The basal diet contained the following ingredients (/kg diet): menhaden meal, 40g; soybean meal (50P),

200g; yellow corn, 250g; retinyl acetate, 3000 I.U.; cholecalciferol, 2000 I.U.; riboflavin, 40 mg; pantothenic acid, 55 mg; thiamin, 3 mg; niacin, 15 mg; vitamin B_{12}, 0.01 mg; dl-α-tocopheryl acetate, 25 mg; menadione sodium bisulfate, 4 mg; folacin, 0.5 mg; pyridoxine hydrochloride, 6 mg; biotin, 0.1 mg; ascorbic acid, 200 mg; ethoxyquin, 100 mg; choline, 100 mg; Cu, 5 mg; Fe, 100 mg; Mn, 10 mg; I, 0.3 mg; Zn, 25 mg; and Co, 0.05 mg.

[2]All diets were isonitrogenous at 26.5% protein and were formulated to contain 5% lipid, 1.5% calcium and 0.9% phosphorus. Levels were adjusted with animal fat, calcium carbonate and dicalcium phosphate, respectively. Cellulose was used to supplement all diets to 100%.

[3]Total sulfur amino acids (met + cys).

[4]Values followed by the same letter are not significantly different (>0.05).

Table 2. Results from a study in which animal byproduct and plant protein sources were substituted on an isonitrogenous basis for soybean meal in catfish feeds (Experiment 2).

Diet	Dietary Variable (%)		Lysine content		Avg gain[3]	Feed/gain[3]	g lys/g gain[3]
	Soybean meal (50P)	Test ingredient[2]	%	% of protein	(g)		
1	20	Soybean meal (control)	1.17	4.4	42.6[b]	2.09[a]	0.024[a]
2	10	8.3 Corn gluten meal (60P)	0.96	3.6	35.2[a]	2.59[b]	0.023[a]
3	0	16.6 Corn gluten meal	0.76	2.9	31.6[a]	2.91[b]	0.022[a]
4	10	6.2 Blood meal (80P)	1.28	4.8	41.5[b]	2.14[a]	0.027[ab]
5	10	10.0 Meat and bone meal (50P)	1.20	4.5	41.1[b]	2.18[a]	0.026[ab]
6	0	20.0 Meat and bone meal	1.23	4.6	33.9[a]	2.74[b]	0.034[c]
7	10	10.0 Peanut meal (50P)	1.03	3.9	34.9[a]	2.67[b]	0.027[ab]
8	10	12.2 Cotton seed meal (41P)	1.06	4.0	32.0[a]	2.83[b]	0.030[bc]

[1]The basal diet was the same as the one used in experiment 1 (Table 1, footnote 1) except it contained 200 g/kg of corn gluten meal and no soybean meal.

[2]See footnote 2, Table 1.

[3]Values followed by the same letter are not significantly different (P>0.05).