NUTRITIONAL VALUES OF FISH-MEAL PROTEINS AND THEIR RELATION TO PROCESSING VARIABLES

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ABSTRACT

More than 100 commercial and experimental fish meals were evaluated as sole sources of amino acids in chick diets in an attempt to determine what variables, if any, influence the protein quality of fish meal. It was found that the quality is influenced by the temperature of drying and possibly by storage conditions of the meal and by moisture-plus-oil content of the meal.

INTRODUCTION

Many attempts have been made to relate quality of protein to variation in processing methods in the manufacture of fish meal. It is generally thought that spoilage, extremely high temperatures, or long times of drying and other similar treatments reduced quality. That no simple relationships are involved, however, is clear from the extensive older literature and from a recent survey (Grau and Williams 1955).

The purpose of the present study therefore was to attempt to discover what processing variables, if any, are related to the nutritional value of the protein in fish meal.

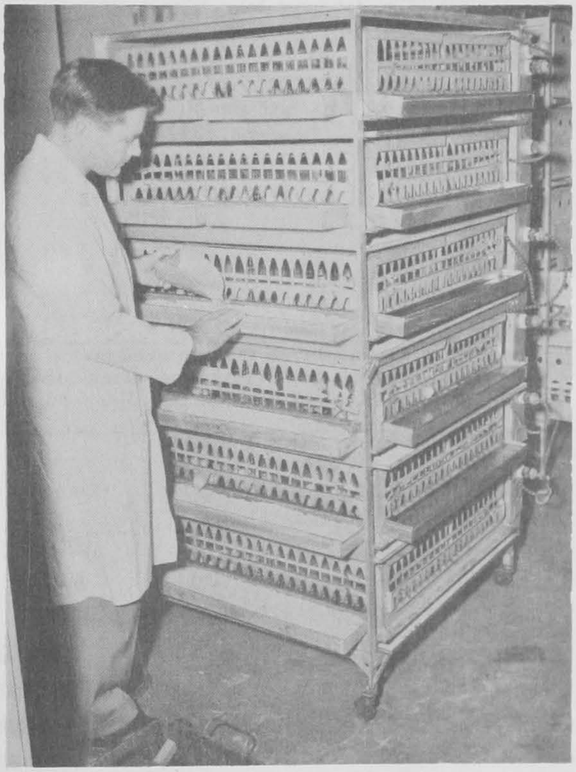

Fig. 1 - Battery brooder at the Poultry Husbandry Department, University of California. Chicks are being raised prior to feeding an experimental diet to study protein quality of fish meals.

PROCEDURE

The general approach to the problem was to study meals produced from one species of fish during one year, note processing variables of possible significance, determine composition of meals, estimate protein quality of the meals by measurement of the growth of chicks, and then study the data to see if there was correlation between the processing variables and quality.

The data taken included the following: date of capture of fish, condition of raw material, method of drying the press cake, type of meal produced, when sample was taken, and proximate composition of the meal. The effects of time and temperature of storage on the nutritive value of the meals also were studied.

MEAL SAMPLES: The fish meals used in the present work were obtained by the U. S. Bureau of Commercial Fisheries largely from commercial plants located along the Atlantic Coast and the Gulf of Mexico. Most of the meals were made from whole menhaden (Brevoortia tyrannus), but two samples of haddock (Melanogrammus aeglefinus) fillet waste and two of rosefish (Sebastodes marinus) fillet waste from

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New England also were included. Nearly all of the meals were from regular commercial sources, but a few (X-series) were produced experimentally in equipment of pilot-plant size that had been leased by the Bureau.

Table 1 - Composition of the Diets

Component	Level in Diet
	Percent
Mineral, choline, and glucose mixture (see below)	10
Vitamin mixture (see below)	6
Soybean oil, crude	5
Protein[1/], crude, from fish meal	20
Glucose, to a total of	100
Mineral, choline, and glucose mixture:	
Calcium phosphate, dibasic	3.30
Calcium carbonate	1.92
Magnesium sulfate · 7 H_2O	0.6
Potassium chloride	0.6
Sodium chloride (iodized)	0.5
Sodium silicate · 9 H_2O	0.2
Aluminum sulfate · 18 H_2O	0.1
Ferric citrate	0.074
Manganous sulfate · H_2O	0.03
Zinc sulfate · 7 H_2O	0.0063
Copper sulfate (anhydrous)	0.005
Cobaltous acetate · 4 H_2O	0.002
Choline chloride	0.20
Glucose to make a total of	10.00
Vitamin mixture:	
Vitamin A premix (1,000 IU per gram)	0.1
Vitamin D premix (1,500 ICU per gram)	0.1
Vitamin E premix (1 mg. per gram) (440 IU per gram)	0.1
Nicotinic acid	0.006
Calcium (d) pantothenate	0.003
Thiamine HCl	0.001
Riboflavin	0.001
Pyridoxin HCl	0.001
Folic acid	0.001
Menadione	0.001
Biotin	0.00001
Vitamin B_{12}	0.0000022
Glucose to make a total of	6.00

1/ The level of fish meal used is determined by the crude protein (N x 6.25) content; thus, if the meal contained 60 percent protein, the level of meal would be $\frac{20 \times 100}{60} = 33.3$ percent.

DETERMINATION OF PROTEIN QUALITY: A number of different methods of estimating the quality of protein have been developed; the method of choice for any particular product depends on the use to which the data are to be put (Grau and Carroll 1958). In earlier studies of fish meals (Grau and Williams 1955), a protein source supplied all the amino acids in a diet that otherwise was composed of purified materials. In this method, all nutrients except amino acids are contained in the basal diet. This method has the advantage that it yields rapid results and indicates deficiencies or imbalances of amino acids, but it has the disadvantages of not differentiating among meals that supply various amounts of amino acids above the required levels and of rating as poor those proteins that may be deficient in one or two amino acids but that could supply amino acids needed to supplement other proteins. A more accurate measure of quality could be obtained by estimating the amount of each amino acid that is available to the animal from a particular source of protein. Such a measure now is being developed, but work on it had not been started when this investigation was undertaken; hence the more general method of assessing quality was employed.

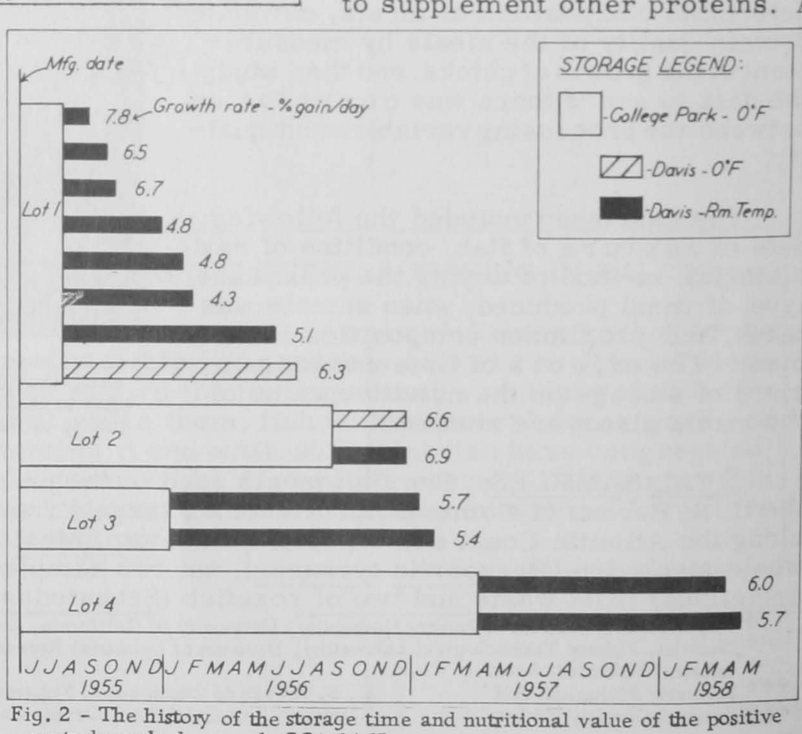

Fig. 2 - The history of the storage time and nutritional value of the positive control menhaden meal, GG1-3A65.

The chick-growth method used to determine quality of protein in the fish meals was as follows: Newly hatched white leghorn chicks were fed a commercial-type starter mash for 11 days, and then the heaviest and lightest birds (about 10 percent) were discarded. The remaining birds were placed at random into converted rat cages that housed four birds each. Four such

Table 2 - Data on Samples

Code1/	Catch Date2/	Condition of Raw Material3/	Drying Method4/	Meal Type5/	Samples Taken6/	Protein	Oil	Ash	Moisture	Growth Rate
						. . . . (Percent)				Percent Gain Per Day
EBA (haddock)	1953-54	G+	HA	–	–	59.3	4.9	26.0	7.9	7.8
GG2-2B75	7/13	G	D	FS	-	61.2	8.9	20.5	7.4	7.6
EBB (haddock)	1953-54	G+	-	-	-	53.3	18.9	20.9	7.3	7.5
GG3-3D75	7.7	G	S	FS	-	63.3	9.4	18.5	9.0	7.5
GG1-1B75	7/13	G	S	FS	FC	65.4	11.8	17.0	6.1	7.5
GG5-1B75	7/13	G	S	CS	EG	65.6	12.1	16.8	5.2	7.4
GG1-6C65	6/20	F	S	FS	FC	56.5	15.2	18.5	8.7	7.3
GH1 (rosefish)	6/21	G	HA	-	-	63.3	11.4	22.4	6.3	7.3
GG4-1B75	7/13	G	S	CM	BG	61.3	11.1	17.1	6.3	7.3
GG1-2B75	7/13	G	D	FS	-	65.8	10.6	18.7	6.4	7.3
GG2-1B75	7/13	G	S	FS	FC	66.5	10.6	18.3	4.7	7.1
GG8-2B75	7/13	G	D	CM	EG	62.5	10.4	19.3	6.7	7.1
GG11-3D115D	11/2	-	S	CS	-	64.9	9.6	18.4	6.6	7.1
CP70	1/8/54	-	HA	CM	-	58.3	6.5	23.2	9.5	7.0
GG7-3D85	8/30	-	S	FS	FC	63.2	7.9	18.1	10.8	7.0
CP50	8/6/52	-	HA	CM	-	59.5	6.1	21.2	8.2	6.9
GG4-2B75	7/13	G	D	CS	BG	62.6	10.7	18.4	7.3	6.9
GH3 (haddock)	9/28	G+	S	-	-	62.7	13.0	18.1	6.1	6.9
GG5-2B75	7/13	G	D	CM	BG	62.8	10.3	18.8	7.1	6.8
GG6-2B75	7/13	G	D	CD	EG	63.0	11.4	16.7	7.0	6.8
GG7-2B75	7/13	G	D	CS	EG	61.1	10.4	20.2	7.3	6.7
GH2 (rosefish)	9/15	-	HA	-	-	58.2	9.0	25.9	7.1	6.7
GG3-2B75	7/13	G	D	CD	BG	63.1	10.9	16.7	7.2	6.6
GG32-3A105	10/4	G	HA	CM	-	60.3	8.6	22.8	7.7	6.6
GG11-3D115B	11/2	-	S	CS	-	65.2	10.7	18.9	5.5	6.6
GGX23-105	10/18	G	D	FS	-	61.1	3.8	19.6	11.6	6.5
GG27-3A105	10/12	G	HA	FS	FC	58.5	6.8	24.8	8.7	6.4
GG11-3D115F	11/2	-	S	CS	-	64.3	9.8	19.1	6.4	6.4
GG11-3D115G	11/2	-	S	CS	-	64.5	10.3	16.2	8.6	6.4
CP71	10/26/54	G	S	FS	-	58.2	11.2	20.1	8.9	6.3
GG5-3D85	8/24	E	S	FS	FC	62.1	9.2	20.5	9.6	6.3
GG6-3D85	8/30	G	S	FS	H	63.6	9.2	17.5	11.6	6.3
GG9-3D105	10/18	F	S	CM	-	63.5	11.4	18.5	6.9	6.3
GGX24-105	10/18	G	D	FS	-	58.0	11.0	22.6	7.1	6.3
GG15-4D125	12/9	F	HA	FS	FC	60.2	8.6	22.3	7.4	6.3
CP73	6/16	-	HA	FS	-	58.4	9.8	21.6	8.0	6.2
GG3-3D85	8/24	E	S	FS	H	62.6	9.8	20.4	8.9	6.2
GG11-3A95	8/31	G	HA	FS	FC	54.5	9.8	23.5	9.5	6.2
GGX22-105	10/18	G	D	FS	-	57.5	9.7	23.4	7.9	6.2
GG33-3A105	10/20	G	HA	CM	-	61.1	8.4	21.5	8.9	6.2
GG13-3A95	8/31	G	HA	CM	-	59.2	9.5	21.4	10.3	6.1
GG20-3A95	9/27	G	HA	FS	FC	60.7	8.2	21.0	8.4	6.1
GG29-3A105	10/18	G	HA	FS	FC	58.7	8.4	23.4	9.0	6.1
GG31-3A105	10/20	G	HA	FS	FC	60.8	9.1	21.0	8.7	6.1
GG12-3A95	8/30	G	HA	CM	-	59.0	9.7	21.3	9.9	6.0
GG25-3A105	10/16	G	HA	FS	FC	60.4	7.8	23.2	7.8	6.0
GG4-3D85	8/24	E	S	FS	H	62.8	9.1	20.0	9.5	5.9
GG7-3A85	8/30	G	HA	FS	H	58.6	9.4	20.0	11.5	5.9
GG8-3A85	8/30	G	HA	FS	FC	61.2	10.3	20.3	9.7	5.9
GGX3-95	9/7	-	HA	FS	-	55.0	10.6	23.8	10.9	5.9
GG23-3A95	9/28	G	HA	CM	-	60.2	7.9	24.0	7.6	5.9
GGX27-105	10/20	G	D	FS	-	61.0	8.7	21.1	6.7	5.9
GG2-3D65	6/14	G	S	CM	-	60.7	11.5	21.2	6.5	5.8
GG9-3A85	8/31	G	HA	FS	H	61.3	9.3	18.6	10.5	5.8
GGX11-95	9/28	G	HA	FS	-	55.6	11.0	25.1	7.0	5.8
GG22-3A95	9/29	G	HA	FS	FC	61.0	7.9	22.0	8.6	5.8
GG26-3A105	10/11	G	HA	FS	FC	58.6	9.5	21.7	9.1	5.8
GG4-4D115	11/2	-	HA	FS	FC	62.0	9.6	20.3	6.5	5.8
GG1-3B85	8/31	G	HA	FS	H	59.4	9.4	18.5	12.7	5.7
GGX5-95	9/13	E	HA	FS	-	57.4	10.1	22.9	8.6	5.7
GG10-1B95	9/21	G	S	FS	FC	65.5	12.6	15.2	5.9	5.7
GGX12-95	9/29	G	HA	FS	-	59.7	9.3	21.7	8.7	5.7
GGX21-105	10/13	G	HA	FS	-	58.1	9.6	21.6	8.9	5.7
GG1-3C105	10/26	G	HA	CS	-	60.6	11.8	19.7	7.6	5.7
GG6-4D115	11/7	G	HA	FS	FC	62.7	13.4	14.7	7.6	5.7
GG10-3A85	8/31	G	HA	FS	H	62.2	9.3	17.5	10.5	5.6
GG3-3B85	8/31	G	HA	FS	FC	58.6	9.3	18.6	13.2	5.6
GG17-3A95	9/8	-	HA	CM	-	62.8	7.1	22.8	7.4	5.6
GGX18-105	10/11	G	HA	FS	-	59.3	14.0	18.6	7.1	5.6
GG24-3A105	10/4	G	HA	FS	FC	58.6	9.1	22.9	8.6	5.5
GG12-4D115	10/27	F	HA	CS	-	62.9	8.5	20.9	7.0	5.5
GG18-3A95	9/13	E	HA	FS	FC	61.1	9.4	21.6	7.2	5.4

Continued on next page.

Table 2 - Data on Samples (Contd.)

Code[1/]	Catch Date[2/]	Condition of Raw Material[3/]	Drying Method[4/]	Meal Type[5/]	Samples Taken[6/]	Protein	Oil	Ash	Moisture	Growth Rate
						. . . . . . (Percent)				Percent Gain Per Day
GG5-3A85	8/24	S	HA	FS	FC	53.6	11.1	24.9	10.2	5.3
GGX10-95	9/27	G	HA	FS	-	60.7	8.7	21.5	8.3	5.3
GG21-3A95	9/28	G	HA	FS	FC	59.2	7.9	24.8	7.9	5.3
GG30-3A105	10/18	G	HA	CM	-	61.3	9.9	19.8	8.3	5.3
GG10-3D105	10/26	G	S	FS	-	65.2	9.5	19.4	6.3	5.3
GG11-3D115	11/2	-	S	CS	-	65.3	9.6	19.2	5.5	5.3
GG5-4D115	11/2	-	HA	CS	-	62.2	10.2	19.8	6.9	5.3
GG8-3D95	8/30	G	S	CM	-	63.0	9.7	19.1	9.1	5.2
GG19-3A95	9/21	-	HA	FS	FC	62.0	9.1	20.4	7.4	5.2
GGX16-105	10/6	G	HA	FS	-	57.5	9.8	24.2	7.9	5.2
GG4-3A85	8/24	S	HA	FS	H	55.0	10.1	24.8	9.3	5.1
GG6-3A85	8/22	S	HA	CM	-	60.5	12.5	20.3	7.5	4.9
GGX6-95	9/14	G	HA	FS	-	59.1	8.5	21.9	8.7	4.9
GG4-3B95	8/31	G	HA	CM	-	59.3	11.3	19.8	11.2	4.8
GG16-3A95	9/7	-	HA	CM	-	62.6	7.3	21.8	7.7	4.7
GGX15-105	10/6	G	HA	FS	-	56.1	12.2	23.0	6.8	4.5
GG18-4D125	12/9	F	HA	CS	-	60.2	7.5	23.3	6.9	4.4
GGX19-105	10/12	G	HA	FS	-	54.7	11.4	25.1	7.8	4.3
GG13-4D115	11/7	G	HA	CM	-	62.9	13.4	14.8	7.2	4.3
GG14-4D115	11/9	-	HA	CM	-	64.3	13.0	14.7	6.4	4.3
GG19-4D125	11/16	E	HA	CM	-	62.9	11.7	17.1	6.5	4.2
GG28-3A105	10/14	G	HA	FS	FC	58.9	12.2	20.2	8.1	4.1
GG11-4D115	11/9	-	HA	FS	FC	65.0	13.5	14.7	5.5	4.1
GG3-3A85	8/24	S	HA	FS	H	53.6	12.3	27.0	8.6	3.9
GGX20-105	10/12	G	HA	FS	-	57.0	10.4	23.2	8.3	3.9
GGX14-105	10/4	G	HA	FS	-	55.2	16.2	22.1	6.1	3.4

1/ All meals processed from menhaden, unless noted otherwise.
2/ Catch date--all fish caught during 1955 unless marked otherwise.
3/ Condition of raw material--E - excellent, G - good, F - fresh, S - spoiled.
4/ Drying method--S - steam drier, HA - hot-air drier, D - dehydromat drier.
5/ Meal type--FS - fresh scrap, CS - cured scrap, CM - cured meal, CD - cured dust.
6/ Samples taken--FC - floor cooled two hours, H - hot, bagged immediately, BG - beginning of grinding, EG - end of grinding.

groups were randomized in racks in a room maintained at about 85° F. Twelve hours of artificial light was available each day.

The chicks were fed diets that contained the ingredients listed in table 1. The level of fish meal was adjusted to provide 20 percent crude protein to each diet. Feed and water always were available to the birds. The test period lasted 8 days, and the rate of growth was expressed as the percent gain per day. This value was calculated for each group by dividing the gain per day by the average of the initial and final weights and then multiplying by 100.

RESULTS AND DISCUSSION

The data for the chick-feeding tests are presented in table 2, together with proximate analyses and a condensed history of the fish-meal samples. The rate of growth varied from 7.8-percent gain per day for meals of highest quality down to 3.4-percent gain per day for those of lowest quality.

An examination of the data shows two trends. Both the drying method employed during manufacture of the meal and the composition of the meal affected its nutritive value.

The fish meals were prepared in driers of several types: in hot-air driers at high temperature and in steam driers and dehydromat driers at lower temperature.

In table 3, growth rates are tabulated according to the method of drying. All of the 15 meals that were of poor quality and resulted in low-growth rate were dried at high temperature, whereas 76 percent of the meals of good quality were dried at low temperature. These results indicate that high-temperature drying is associated with decreasing quality of the meals. They also indicate, however, that meals of good quality can be prepared in high-temperature driers. Accordingly, there must be factors other than temperature that affect meal quality.

Table 3 - Comparison of Protein Quality as Measured by Growth Rate and of Temperature Used to Dry Meals

Growth Rate	Low Temperature		High Temperature	
Percent Gain per Day	No. of Meals	Percent	No. of Meals	Percent
6.5 to 7.8 (good)	19	76	6	24
5.1 to 6.4 (intermediate)	16	28	41	72
3.4 to 5.0 (poor)	0	0	15	100

Materials making up fish meals are liquids (moisture and oil) and solids (protein and ash). The content of moisture plus oil, which gives a measure of the liquid-type constituents, has been used in table 4 as a means of classifying the meals. A comparison of the meals in three categories of moisture-plus-oil content with the meal quality is shown in table 4. Meals low in moisture plus oil tend to fall in the group yielding good growth rate (38 percent in the good category as compared to only 13 percent in the poor category). Meals having high moisture plus oil tend to fall in the group yielding poor growth rate (67 percent in the poor-growth-rate group as compared to only 12 percent in the high-growth-rate group). There thus seems to be some correlation between the composition of the meal as measured by moisture plus oil and the growth rate.

Table 4 - Comparison of Protein Quality and of Amounts of Moisture-Plus-Oil Contents

Growth Rate	Moisture-Plus-Oil Ranges					
	12.0 to 16.9 Percent		17.0 to 18.9 Percent		19.0 to 26.9 Percent	
Percent Gain Per Day	No. of Meals	Percent	No. of Meals	Percent	No. of Meals	Percent
6.5 to 7.8 (good)	10	38	13	50	3	12
5.1 to 6.4 (intermediate)	17	30	23	40	17	30
3.4 to 5.0 (poor)	2	13	3	20	10	67

A number of other possible correlations were investigated including those of growth rate with condition of raw material from which the meal was made, with protein content, with ash content, and with meal type, but no clear-cut trends could be found.

When the menhaden meals were manufactured, one carefully processed lot was set aside as a control. Samples of this meal (GG1-3A65) were kept at unregulated room temperature or at 0° F. in closed fiberboard drums until used for biological tests. The first tests, in which the meal was used as a positive control, revealed it to be an excellent source of protein. During the succeeding months, however, the quality decreased, as is shown in figure 1.

Table 5 - Effect of Storage on Protein Quality of Fish Meals

Code	Initial Value	Storage Time	Value After Storage	
	Percent Gain Per Day	Months	Percent Gain Per Day	
			0° F.	85° F.
GG2-2B75	7.6*	2*	6.7*	6.0*
GG1-1B75	7.5*	2*	7.1*	6.2*
GG3-3D75	7.5	7	6.9	6.2
GG5-1B75	7.4	7	5.9	5.9
GG4-1B75	7.3	7	6.7	5.3
GG1-6C65	7.3	7	6.1	6.7
GG1-2B75	7.3*	2*	6.7*	6.9*
GG2-1B75	7.1	7	6.9	6.4
GG8-2B75	7.1	7	7.0	5.2
CP70	7.0	7	6.7	7.0
GG4-2B75	6.9	7	6.8	5.3
GG6-2B75	6.8	7	7.0	5.9
GG5-2B75	6.8*	2*	6.6*	6.9*
GG7-2B75	6.7	7	7.1	6.1
GG3-2B75	6.6	7	5.3	5.1
CP71	6.3	7	6.1	5.9
CP73	6.2	7	5.7	5.5
Average	6.9	7*	6.5*	5.9*

*Two-months storage; omitted from average.

During the course of this research, four different lots of the standard menhaden meal (GG1-3A65) were used. The growth results with these four lots are shown in figure 2, together with data on time, temperature, and place of storage. Meals were not kept at 0° F. while being shipped from College Park, Md., to Davis, Calif. The results indicate that storage at unregulated room temperature was harmful to the first lot of meal. The other lots showed less adverse effect of storage, but those stored at room temperature were not as good as were those kept at 0° F. These data are only indicative, but they do suggest the advisability of testing further the effects of storage temperature on quality.

The possible adverse effects of storage on protein quality were studied directly by taking a series of meals that had been stored at 0° F. from the time of manufacture in June 1955 until June 1956, when the samples were divided. One-half of each sample was stored at 0° F.; and the second half, at a temperature of 85° F. Four of these pairs were fed after 2 months; the others, after 7 months. The growth results, which are presented in table 5, show that although some of the meals deteriorated at the elevated temperature, others either were not changed in value or, even after having deteriorated, contained protein of higher quality than the diet required. More critical tests are needed to establish the nature of the observed effect.

CONCLUSIONS

1. The results of using a large series of fish meals as the sole source of amino acids in chick diets revealed a variation in protein quality.

2. A correlation has been shown between higher drying temperature used in manufacturing meals and a lowering of protein quality, as measured by growth rate of chicks fed these meals; but other factors must be important because some meals dried at high temperature were of good quality.

3. There appears to be some correlation between growth rate of chicks and composition of meals as measured by moisture-plus-oil content. This indication needs further study.

4. There also appears to be a correlation between protein quality and the duration and temperature at which the meal was stored after manufacture. Again, this possible correlation must be confirmed by additional work before it can be considered as being definitely established.

SUMMARY

More than 100 fish meals were studied as sole sources of amino acids in chick diets in an attempt to determine if variables during processing are related to protein quality of the final product. For most of these variables, no correlation could be established. A relationship between drying temperature during the manufacture of the meal and the resulting growth rate when the meal was fed, however, was indicated. Some indication also was obtained that growth rate of fish meals may be related to meal-storage conditions after manufacture and also to the composition of the meal as measured by the moisture-plus-oil content.

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