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The Growth-Promoting Qualities of Various Protein Concentrates for Leghorn Chickens.

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THE by-products of slaughter houses and of the fishing industry form very important ingredients in poultry rations. Not only is the protein supplement an expensive item, but it is extremely important in its influence on growth and reproduction, and may thus hold the balance between success and failure.

Most of the abattoirs in larger centres manufacture meat meal. In addition the fishing industry places various products on the market. Protein supplements from plant sources are not used as extensively for poultry as those from animals.

As yet nothing has been done to determine whether any marked differences exist between these South African products, which of them are most suitable, and if there is any way in which the quality of the products can be improved. One naturally expects that the materials used for protein supplements will differ widely, coming as they do from different sources, and the manufacturing processes being by no means uniform.

The literature on the biological value of proteins is enormous and it is not intended to give an extensive review, but rather to select a few articles with a direct bearing on the subject.

Hoagland and Snider (1926) reported poor growth on dried blood and serum protein, as compared with muscle protein. Ox palates, hog snouts, and pork cracklings also contained insufficient proteins for normal growth. In general, connective tissue seemed to be deficient in certain amino acids. Mitchell, Beadles and Kruger (1927) confirmed the statement that connective tissue seemed to be definitely inferior as far as the amino acid make-up was concerned.

Plimmer, Rosedal, Raymond and Lowndes (1934) reported on the relative values of various proteins, judged by the growth of chicks from 15-25 weeks of age.

THE GROWTH-PROMOTING QUALITIES OF PROTEIN CONCENTRATES FOR CHICKENS.

In a series of experiments, Prange, Hauge, and Carick (1927, 1928a, 1928b, 1928c) tested the efficacy of various protein supplements. One sample of meat meal was found to be definitely lacking in tryptophane, and commercial meat and bone scraps from different manufacturers did not give the same rates of growth when fed at the same protein level with mineral variations equalized. Tankage gave very poor growth with high mortality.

Titus, Byerly, Ellis and Nestler (1936) were of the opinion that the material used in the manufacture of good meat scraps and similar products was relatively more important than the temperature and the time of processing, as long as the temperature did not exceed 200 degrees F. or the time 8 hours. Higher temperatures were not studied.

Wilgus, Norris and Ringrose (1933) reported on the relative merits of various protein supplements, and placed them in the following descending order:—vacuum- and drum-dried fish meals, dried skim milk, domestic sardine meal, flame dried white fish meal, expeller process soybean oil meal, Asiatic sardine meal, steam dried menhaden meal, meat scrap, flame dried menhaden meal, hydraulic process soybean oil meal, whale meat, corn gluten, and blood. The vitamin G complex in these studies was of no account as the rations were all supplemented.

Daniel and McCullum (1931) emphasized the fact that general statements could not be made regarding the values of white and menhaden fish meals, since the values depended both on the raw materials and the methods of processing.

Maynard, Bender and McCay (1932), in balance experiments with rats found vacuum dried white meal to be superior to steam dried menhaden meal, and the latter superior to flame dried menhaden meal as regards growth promotion. The results suggested that differences in heat treatment were at least partially responsible for the nutritive differences found.

Almquist, Stokstad and Halbrook (1935) obtained their best results with vacuum dried beef and whale meat meal; meat scraps and cracklings were poorer and the tankages decidedly inferior. The authors suggested a formula, based on the analyses of intact protein, protein decomposition products, indigestible protein and hot water soluble protein, for the rapid laboratory determination of the quality of protein in a commercial concentrate.

Boas-Fixsen and Jackson (1932) mentioned the fact that caseinogen suffers a marked decline in biological value as the result of prolonged heating at 112° C.

Chick, Boas-Fixsen and Hutchinson (1935) gave further evidence regarding the heat injury of proteins. Heating caseinogen at 150° C. for 66 hours decreased the biological value from 66 to 44 per cent. and also decreased the digestibility from 93 to 73 per cent. The biological value of lactalbumen was only slightly reduced by heating at 120° C. for 72 hours, but the digestibility was lowered from 95 to 69 per cent.

Fairbanks and Mitchell (1935) also found a decrease in biological value of the best roller process milk powder due to preheating. This decrease is due to a partial destruction of cystine. If the temperature is increased further until scorching results, a further decrease takes place. The scorched products are improved by the addition of lysine. Digestibility is also impaired by scorching.

Further evidence concerning the effect of heat on proteins was given by Greaves and Morgan (1934). Heating casein for 30 minutes at 140° C. produced a definite change in the lysine and hystidine fraction of the protein, which resulted in a measurable lowering of its nutritive value for rats.

Morgan (1931) submitted cereal and casein proteins to toasting at approximately 150° C. for thirty minutes. In all cases a significant decrease in biological value was found. The digestibility of the toasted proteins was but little different from that of the raw, particularly when fed to older animals, and the inexplicable loss of N occurred chiefly in the urine, indicating that the change produced by the heat treatment lies probably in the assortment or availability of the amino acids absorbed.

In a later article, Morgan and Kern (1934) concluded that there appeared to be a heat injury to beef muscle protein, increasing in severity with the length of exposure and the height of the temperature reached.

Allerdyce, Henderson and Asmundson (1933) found that the results on four samples of Pilchard meals varied widely. The weight of the chicks at two weeks varied inversely with the fat content, but showed no relation to the protein and ash content. Putrefaction and high temperatures have a detrimental effect on the feeding values of fish meals, and this probably accounts for the differences which were found.

From an analysis of fish meals, Ingvaldson (1929) concluded that high temperatures (195° C.) caused an increase in humin and volatile basic N and a diminution in arginine N and cystine. The other constituents in the hydrolysates were unaffected. Since arginine and cystine are essential amino acids, and the amounts of these therefore help to determine the biological values of fish meals, heating to such high temperatures as 195° C. should be avoided in the preparation of these meals.

Maynard and Tunison (1932) prepared haddock waste and menhaden fish by both flame drying and vacuum drying, and the four resulting products were studied on rats by the N balance method. The protein of the vacuum-dried haddock proved superior to that of the flame dried product, in both digestibility and biological value. In the case of the menhaden products, a marked superiority in digestibility was shown for vacuum-drying, but the difference in biological value in favour of vacuum-drying was too small to be statistically significant. The big decrease in digestibility of menhaden products was explained by their high oil content, and the effect of the oil on the proteins present. The authors concluded that both heat and the source of the material influence the nutritive values of protein supplements.

THE GROWTH-PROMOTING QUALITIES OF PROTEIN CONCENTRATES FOR CHICKENS.

Record and Bethke (1933) concluded that the fish meals commonly available on the market varied greatly in their nutritive values. These differences in nutritive value are probably due to variations in the biological values of the proteins, and in the vitamin G content of the meals as affected by the different methods of manufacture.

In a later paper, Record, Bethke and Wilder (1934) tested nine different samples of haddock and a sample of cod meat against meat scraps. Some samples were deficient in certain vitamins, which affected growth and gave rise to leg paralysis. When the samples were supplemented with liver extract or dried whey to supply the vitamin G complex, the differences disappeared. The protein values of the different fish meal samples were similar but both haddock and cod meal were superior to meat scraps.

In balance experiments with pigs, Schneider (1932) ranked fish meals in the following order, as regards the digestibility of their proteins: vacuum-dried white fish meal, steam-dried menhaden meal, flame-dried menhaden meal. In both experiments, the flame-dried meal was significantly inferior to the vacuum-dried meal.

Experimental.

Experiment I.

Single Comb White Leghorn chicks were used as experimental animals. In Experiments I and II, the chicks were taken from the pedigree baskets and wingbanded, and the chicks from each female were then distributed to successive lots, so that no full brothers or sisters were in the same lot, except in cases where a hen gave more than five chicks. The chicks for Experiment III were not pedigreed.

After banding, all chicks were placed in an electrically heated battery brooder, where they stayed for three weeks. They were then removed to another battery without artificial heat. Weekly records of food consumption and individual chick weights were kept. The first experiment comprised five lots, each lot getting their meat meal protein supplement from a different source. The analysis of the meat meals are given in Table 1.

Table I.

Supplement.	Moisture.	Ash.	Ether Extract.	Protein.
I	6·9	30·8	10·4	46·9
II	4·1	20·6	20·8	45·4
III	3·9	19·9	23·1	47·4
IV	6·9	20·8	11·2	62·1
V	4·7	27·5	15·3	45·1

The basal ration comprised yellow mealie meal, wheat bran, pollard and lucerne meal. The maize meal content was altered to make up the required amount after the addition of the protein supplement. Table II gives the actual rations fed, supplement I being given to Lot I and so on. The analyses of the rations are presented in Table III.

TABLE II.

Food.	Lot I.	Lot II.	Lot III.	Lot IV.	Lot V.
Yellow maize	49·0	48·0	49·5	55·5	48·0
Wheat bran	15·0	15·0	15·0	15·0	15·0
Pollard	10·0	10·0	10·0	10·0	10·0
Lucerne meal	5·0	5·0	5·0	5·0	5·0
Meat meal	20·0	21·0	19·5	13·5	21·0
Oyster shell	1·0	1·0	1·0	1·0	1·0
Salt	0·5	0·5	0·5	0·5	0·5
	100·5	100·5	100·5	100·5	100·5

TABLE III.

	Moisture.	Ash.	Ether Extract.	Protein.
Lot I	9·2	9·6	4·9	19·1
Lot II	8·5	7·3	7·9	19·0
Lot III	8·7	6·6	8·7	18·9
Lot IV	9·6	5·8	3·9	19·1
Lot V	8·7	9·0	6·6	19·5

TABLE IV.

Average Weekly Weights (in grams).

	Lot I.	Lot II.	Lot III.	Lot IV.	Lot V.
Day old	41·5	42·0	41·2	41·4	41·2
1 week	55·2	56·6	57·6	56·0	57·6
2 weeks	83·0	97·0	96·8	89·0	96·7
3 weeks	124·5	150·3	150·1	134·0	149·4
4 weeks	182·3	217·0	215·0	186·9	217·2
5 weeks	246·4	291·6	284·7	250·9	290·3
6 weeks	323·0	364·1	351·6	331·8	376·7
7 weeks	388·8	428·4	409·7	391·4	453·9
8 weeks Males	509·5	569·9	524·8	531·2	577·9
Females	441·1	454·5	443·1	431·2	486·3

TABLE V.

Food Consumption and Growth.

Week.	Lot I.			Lot II.			Lot III.			Lot IV.			Lot V.		
	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.
1st.....	2,125	2·36	2·22	2,080	2·36	2·23	1,725	2·35	2·25	2,035	2·23	2·35	2,115	2·09	2·45
2nd....	4,793	2·50	2·11	5,504	2·27	2·32	4,110	2·33	2·27	4,798	2·35	2·23	5,345	2·24	2·29
3rd.....	7,398	2·65	1·98	5,985	2·47	2·13	6,145	2·56	2·07	5,315	2·41	2·17	8,386	2·61	1·97
4th.....	11,227	2·94	1·78	11,381	2·93	1·79	8,398	2·88	1·84	9,574	2·97	1·76	11,597	2·80	1.83
5th.....	14,418	3·40	1·54	13,437	3·31	1·59	10,055	3·21	1·65	11,933	3·05	1·71	14,383	3·16	1·62
6th.....	18,267	3·62	1·45	15,752	3·54	1·49	11,068	3·68	1·44	14,919	3·14	1·67	17,152	3·32	1·55
7th.....	19,265	4·51	1·16	14,935	4·10	1·28	12,075	4·61	1·15	16,090	4·50	1·16	18,240	4·06	1·26
8th.....	20,425	3·82	1·37	17,300	4·11	1·28	13,035	4·18	1·26	18,540	3·44	1·52	19,390	4·24	1·21
TOTAL..	97,818	3·46	1·515	86,374	3·33	1·583	66,611	3·38	1·565	83,204	3·20	1·636	96,608	3·27	1·584

TABLE VI.

Health and Mortality.

Lot.	No. of chicks started.*	Paralysis.†	Mortality.	Percentage Mortality.	Percentage Paralysis.
I	67	1	3	4·5	1·5
II	62	0	7	11·3	—
III	45	1	1	2·2	2·2
IV	64	4	4	6·3	6·3
V	64	2	3	4·7	3·1

* The first night the chicks were in the electrically heated battery, a fuse blew, resulting in heavy mortality. The chicks that died due to chilling are not included in this column, and are treated as if they never started the experiment. This mortality accounts for the unequal numbers in the various groups.

† Paralysis means the paralysis of Norris (toes curled up and invariably turned inwards).

TABLE VII.

Differences in Mean Weight at Eight Weeks.

Lots.	Males.			Females.		
	Diff. grms.	T.	P.	Diff. grms.	T.	P.
1–2	60·4	3·50	<·01	13·4	·79	>·4
1–3	15·3	·81	>·4	2·0	—	—
1–4	21·7	1·29	>·2	9·9	·60	—
1–5	60·4	3·92	<·01	45·2	2·84	<·01
2–3	45·1	2·33	<·05	11·4	·62	>·6
2–4	38·7	22·2	<·05	23·3	1·35	>·1
2–5	8·0	·44	>·6	31·8	2·06	<·05
3–4	6·4	·34	>·7	11·9	·66	·5
3–5	53·1	2·27	<·05	43·2	2·48	<·02
4–5	46·7	2·65	<·01	55·1	3·37	<·01

Table IV gives the average weekly weights of all chicks, and the average male and female weights at eight weeks of age. These data are presented graphically in Fig. 1.

Table V gives food consumption and growth data for the five lots, during the entire experimental period. The first column is the actual amount of food consumed, the second column, the amount of food required in grams to produce one gram of gain in live weight, and the third column, the gain in weight resulting from the ingestion of one gram of protein.

Tables VI and VII give the health and mortality records, and the differences between corresponding sexes, T values and probabilities, respectively.

Table VIII gives the average weights of chicks and the standard errors of chicks at eight weeks of age.

Fig. I
Experiment I Growth Curves.

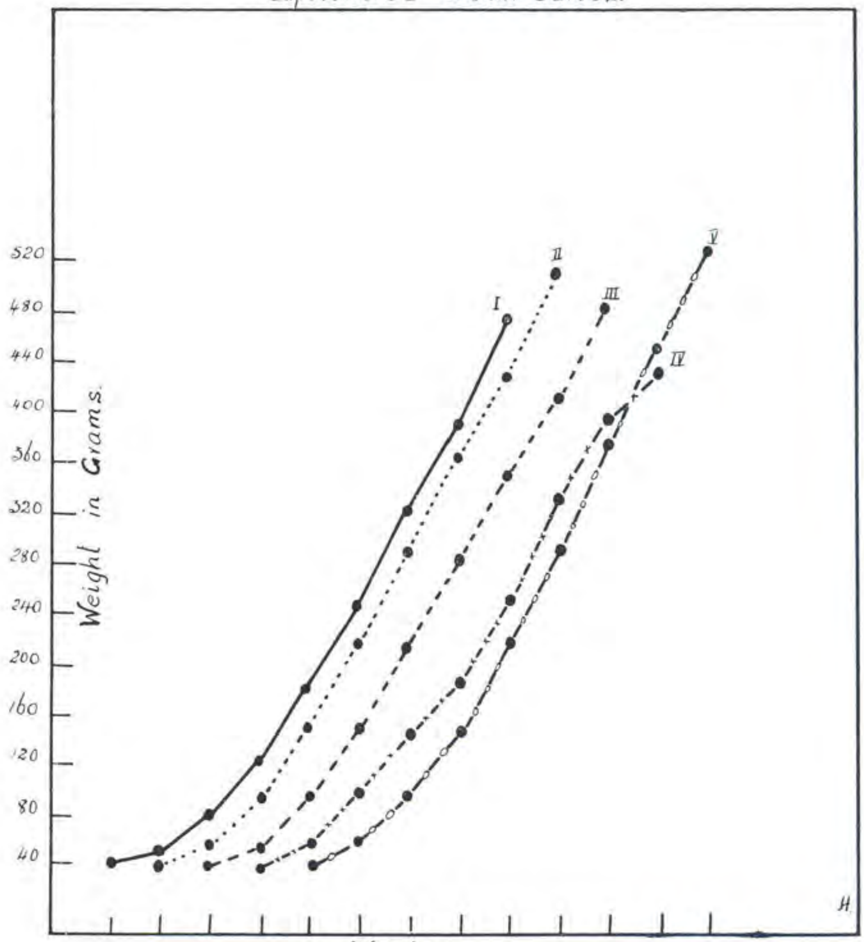


TABLE VIII.

Mean Weights and Standard Errors of Chicks at Eight Weeks of Age.

Lot.	Males.	Females.	Males and Females.*	No. of males.	No. of females.	Totals.
I....	509·5 ± 11·78	441·1 ± 11·42	474·2 ± 8·21	31	33	64
II....	569·9 ± 12·63	454·5 ± 12·40	511·1 ± 8·85	27	28	55
III....	524·8 ± 14·67	443·1 ± 13·39	480·2 ± 9·93	20	24	44
IV....	531·2 ± 11·98	431·2 ± 11·98	481·1 ± 8·47	30	30	60
V....	577·9 ± 12·87	486·3 ± 11·09	525·3 ± 8·49	26	35	61

* S.E. of unweighted mean live weight of males and females.

Discussion of Results.—This first experiment comprised four samples of meat and bone meal, of which the analyses were very similar as regards protein; the other sample, Lot IV, was considerably higher.

Samples II and III were from the same source as reflected by the similar ash and the very high ether-extract contents. Sample I was rather high in its ash content, and this was reflected in the composition of the ration; sample V was very similar in this respect.

The growth curves in Fig. 1 indicate the superior growth of lot V, lots I and IV revealing much slower growth, and lots II and III more moderate growth. From an inspection of differences and probabilities in Table VII, it can be seen that for the males, significant differences exist between lot V and all other lots except II, this lot in its turn being significantly superior to all others except V. The better growth of lot V is also reflected in the females, there being significant differences between the females in lot V and all others including lot II. The superiority of the males of lot II is not duplicated by the females in this group. It would thus appear that lot V was outstanding as far as growth was concerned, with lots, II, III, I and IV following in order.

In interpreting the results on the basis of food consumption per gram gain, and gain per gram protein ingested (Table V), a somewhat different picture is obtained. On this basis, lot IV appears to be best and lot I worst, while the rest are more or less similar.

The slight depression in the biological value of group V, which showed the best growth, when compared with group IV may be the result of the lower utilization due to the high food, and consequent protein, intake.

This method of estimating the biological value is used by Osborne, Mendel and Ferry (1919). The explanation of the slow growth of lot IV is probably to be found in the absence in the protein supplement of some growth promoting factor, not protein.

Table VI gives the mortality figures and incidence of leg paralysis of nutritional origin. It will be noticed that the incidence of paralysis was highest in lot IV; a sub-clinical manifestation of this deficiency might thus have been the cause of the slower growth, notwithstanding the higher biological value exhibited by this group as judged by the method of Osborne, Mendel and Ferry.

On the basis of the evidence presented, it is concluded that significant differences exist among the protein supplements tested. These differences may be due to the materials which are used in the manufacture of these products, or they may be due to differences in the manufacturing processes. The similarity in biological value for growth as measured by the method of Osborne, Mendel and Ferry, and marked differences in total growth would suggest that the manufacturing processes involving time and temperature of cooking, and temperature and duration of the drying process, play a very important part in the ultimate values of the finished products.

Experiment II.

The second experiment comprised one sample each of fish meal, crayfish meal, whale meal, pure meat meal, and meat and bone meal.

The analyses of these feeds are given in Table IX and the whole rations in Table X. The basal ration was the same as in Experiment I.

TABLE IX.

Analysis of Supplements.

Supplement.	Moisture.	Ash.	Ether Extract.	Protein.
I Fish meal	12·3	16·9	6·6	69·7
II Crayfish meal	6·9	30·3	4·8	40·5
III Whale meal	10·8	11·8	12·4	72·1
IV Pure meat meal	7·2	16·8	5·8	78·9
V Meat and bone meal	7·6	35·5	4·1	53·3

TABLE X.

Feed.	Lot I. Fish meal.	Lot II. Crayfish meal.	Lot III. Whale meal.	Lot IV. Meat meal.	Lot V. Meat and bone meal.
Protein supplement	11·5	23·0	11·0	10·0	16·0
Yellow maize meal	56·0	45·5	55·5	57·5	52·5
Wheat bran	15·0	15·0	15·0	15·0	15·0
Wheat pollard	10·0	10·0	10·0	10·0	10·0
Lucerne meal	5·0	5·0	5·0	5·0	5·0
Oyster shell	1·0	1·0	1·0	1·0	1·0
Salt	·5	·5	·5	·5	·5
Bonemeal	1·0	—	2·0	1·0	—
	100·0	100·0	100·0	100·0	100·0
Actual percentage protein	19·4	18·8	18·4	18·3	18·5

TABLE XI.

Average Weekly Weights.

	Lot I.	Lot II.	Lot III.	Lot IV.	Lot V.
Day old	40·4	40·8	39·9	39·9	40·3
1 week	51·3	53·2	54·4	55·0	52·5
2 weeks	63·8	71·2	85·0	80·0	74·9
3 weeks	80·5	97·4	126·9	114·1	100·7
4 weeks	101·3	132·6	173·9	150·0	137·2
5 weeks	128·5	180·7	228·5	194·0	184·0
6 weeks	155·3	231·7	280·6	237·0	232·0
7 weeks	191·6	293·1	345·0	294·6	296·7
8 weeks	242·4	378·2	420·8	365·7	376·9
Males	244·1	382·1	453·3	385·6	404·2
Females	240·2	372·2	392·5	355·0	356·4

TABLE XII.

Food Consumption and Growth

Week.	Lot I.			Lot II.			Lot III.			Lot IV.			Lot V.		
	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.	Total food consumed. Grams.	Grams food per gr. gain.	Grams gain per gr. protein.
1 week.	1,465	2·97	1·74	1,470	2·70	1·97	1,475	2·25	2·42	1,490	2·25	2·42	1,640	2·92	1·85
2 weeks	2,475	4·42	1·17	2,670	3·46	1·54	3,040	2·30	2·37	3,090	2·80	1·95	3,060	2·97	1·82
3 weeks	2,975	3·96	1·30	3,665	3·26	1·63	4,510	2·44	2·23	4,210	2·81	1·95	4,175	3·51	1·54
4 weeks	3,795	4·20	1·23	5,080	3·35	1·59	6,055	2·93	1·86	5,420	3·43	1·59	5,565	3·31	1·63
5 weeks	4,300	3·72	1·39	6,600	3·19	1·67	7,135	2·97	1·83	6,785	3·48	1·57	7,065	3·45	1·57
6 weeks	5,185	4·49	1·15	8,005	3·65	1·46	8,245	3·84	1·42	7,625	4·06	1·34	8,860	4·11	1·32
7 weeks	4,990	4·42	1·17	9,913	3·95	1·34	9,525	3·44	1·57	9,000	3·80	1·44	10,310	3·67	1·47
8 weeks	6,380	4·19	1·23	12,060	3·37	1·58	10,825	3·32	1·64	10,875	3·59	1·54	12,165	3·50	1·53
TOTAL..	31,565	4·116	1·252	49,463	3·458	1·538	50,810	3·084	1·762	48,495	3·440	1·599	52,840	3·542	1·526

Table XIII.

Health and Mortality.

Lot.	No. of Chicks.	Paralysis.	Mortality.	Percentage mortality.	Percentage paralysis.
I	47	1	4	8·5	2·1
II	48	2	5	10·4	4·2
III	45	5	2	4·4	11·1
IV	45	8	2	4·4	17·8
V	45	4	1	2·2	8·9

Table XIV.

Differences in Mean Weight at Eight Weeks of Age.

Lots.	Males.			Females.		
	Difference in grams.	T.	P.	Difference in grams.	T.	P.
1–2	138·0	7·17	< ·01	132·1	6·55	< ·01
1–3	209·2	10·73	< ·01	152·3	7·63	< ·01
1–4	141·6	6·68	< ·01	114·8	6·00	< ·01
1–5	160·1	8·10	< ·01	116·3	5·85	< ·01
2–3	71·2	3·54	< ·01	20·2	1·05	·3
2–4	3·6	0·16	> ·8	17·3	0·94	·4
2–5	22·1	1·10	·3	15·8	0·85	·4
3–4	67·6	3·08	< ·01	37·5	2·07	·05
3–5	49·1	2·38	·05	36·0	1·96	slightly > ·05
4–5	18·5	0·83	·4	1·5	0·08	> ·9

Table XV.

Lot.	Males.	Females.	Males and Females.	No. of males.	No. of females.	Totals.
I	244·1 ± 13·142	240·2 ± 14·770	242·4 ± 9·885	24	19	43
II	382·1 ± 14·050	372·3 ± 13·726	377·1 ± 9·821	21	22	43
III	353·3 ± 14·396	392·5 ± 13·424	420·8 ± 9·842	20	23	43
IV	385·7 ± 16·623	355·0 ± 12·167	365·7 ± 10·300	15	28	43
V	404·2 ± 14·770	356·5 ± 12·626	376·6 ± 9·716	19	26	45

The average weekly weights and the mean weights of males and females are given in Table XI. A graphic representation of the growth of different groups is given in Fig. 2.

Table XII gives the weekly food consumption, efficacy of food utilization, and the gains per unit of protein ingested.

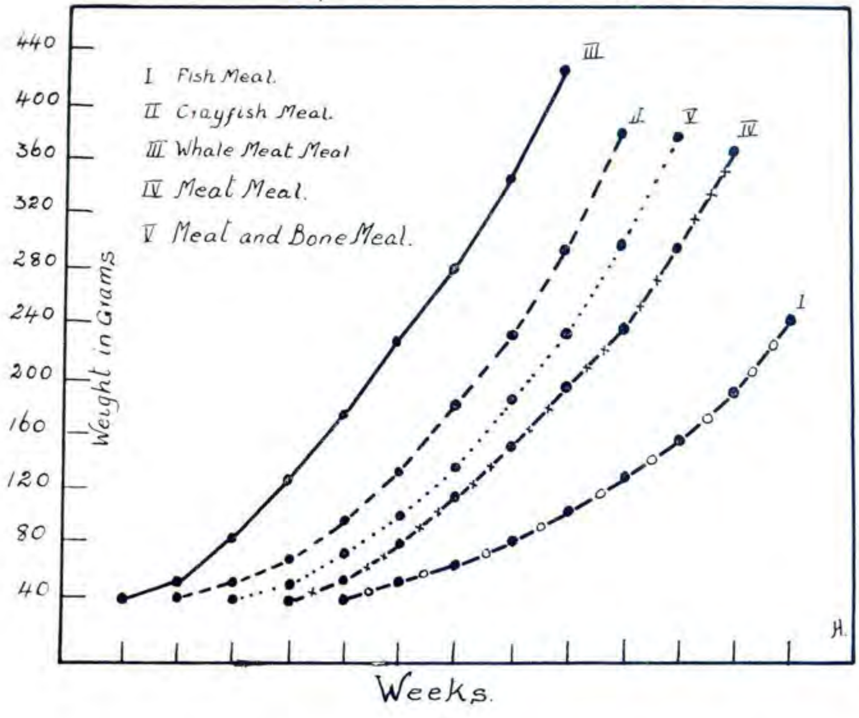
The health and mortality records are given in Table XIII, and the differences in mean weight at eight weeks of age, together with T values and probabilities, are given in Table XIV.

The mean weights and standard errors of males and females are given in Table XV.

Discussion of Results.—An attempt was made to stabilize the percentage protein at 19·0. Due to variations in the composition of the ingredients in the basal ration, lots III, IV, and V fell rather below this figure, notwithstanding the fact that every precaution was taken in sampling.

The most striking fact emerging from the average weekly weights (Table XI) and the growth curves (Fig. 2) is the extremely poor growth of chicks on fish meal.

Fig II.
Experiment II. Growth Curves.



This slow growth was evident from the first week, but during the last two weeks there was slightly better growth. Most of the chicks on this diet feathered poorly, and were very much given to cannibalistic habits. Table XIV illustrates further that the fish meal group was significantly poorer than all the others.

The whale meat meal gave good growth for the entire period. The growth could not be considered quite normal, but this was probably due to very hot weather experienced during the time the chicks were in the experiment. The males on the whale meal supplement were significantly heavier than those on crayfish meal, meat meal, and meat and bone meal, while the females showed no superiority over those in the crayfish meal group, and were only just significantly heavier than the females on the two different kinds of meat supplement.

The growth of all chicks (male and female) on crayfish meal, meat meal and meat and bone meal was almost identical.

Chicks which died during the first two days of the experiment were disregarded; this procedure accounts for the differences in numbers shown in Table XIII. All groups showed some degree of paralysis, those with the two meat meal supplements and whale meat meal being the worst in this respect. Only one case of paralysis was observed among the chicks on fish meal.

The mortality was highest on the crayfish meal supplement. The chicks on the crayfish meal diet drank much more water than the others, and the droppings were much softer, amounting in some cases to a mild diarrhoea. This physiological disturbance was probably due to the higher salt content of the crayfish meal.

The poor growth of chicks on fish meal could not be explained at this stage. The lack of some essential amino acid, or of some growth promoting factor of the B complex was suspected. With this in view the next experiment was planned.

Experiment III.

This experiment was designed to explain the poor results obtained with fish meal in the previous experiment. Lots I and II were used as controls, I containing fish meal alone and II meat and bone meal. In lot III, the fish meal was supplemented with 3 per cent. dried brewers' yeast. If the fish meal was deficient in a growth promoting factor of the B complex, the yeast ought to supply it, and thus improve growth.

In lot IV, one half of the protein supplied by fish meal was replaced by the quivalent amount of protein from casein, the latter being low in cystine.

In lot V, one half of the protein was replaced by peanut meal.

To test any supplementary action between fish meal and meat meal, an extra lot VI was included, each supplying half the protein supplement.

The actual rations fed are given in Table XVI.

TABLE XVI.

Rations.

	Lot I.	Lot II.	Lot III.	Lot IV.	Lot V.	Lot VI.
Wheat bran.......	15·0	15·0	15·0	15·0	15·0	15·0
Pollard...........	10·0	10·0	10·0	10·0	10·0	10·0
Lucerne meal.....	5·0	5·0	5·0	5·0	5·0	5·0
Yellow maize meal.	57·5	51·5	56·5	58·5	55·0	56·0
Fish meal.........	10·0	—	8·0	5·0	5·0	5·0
Meat and bone meal	—	17·0	—	—	—	7·5
Casein............	—	—	—	4·0	—	—
Peanut meal......	—	—	—	—	7·5	—
Brewers' yeast....	—	—	3·0	—	—	—
Bonemeal.........	1·0	—	1·0	1·0	1·0	1·0
Limestone flour...	1·0	1·0	1·0	1·0	1·0	1·0
Salt..............	·5	·5	·5	·5	·5	·5
Per cent. Protein..	18·4	18·0	17·8	17·5	17·5	17·3

TABLE XVII.

Average Weekly Weights.

	Lot I.	Lot II.	Lot III.	Lot IV.	Lot V.	Lot VI.
Day old..........	35·7	35·6	36·3	35·5	36·4	36·6
1 week...........	46·9	47·1	46·9	50·4	47·9	44·9
2 weeks..........	63·5	69·1	68·8	73·8	66·7	62·6
3 weeks..........	81·4	98·7	97·9	102·5	90·3	85·7
4 weeks..........	106·5	130·9	132·0	139·0	120·5	114·6
5 weeks..........	139·6	173·9	190·3	188·9	161·3	153·0
6 weeks..........	171·7	224·7	254·5	243·8	208·1	198·1
7 weeks..........	218·6	286·4	323·3	315·0	272·7	254·3
8 weeks..........	264·2	347·6	414·9	391·2	345·5	313·8
Males.............	271·9	372·9	409·6	410·0	360·3	332·0
Females..........	259·8	324·4	425·5	371·3	331·5	305·2

TABLE XIX.

Health and Mortality.

Lot.	No. of chicks started.	Paralysis.	Mortality.	Percentage Paralysis.	Percentage Mortality.
I........................	36	2	7	5·6	19·4
II.......................	36	5	9	13·9	25·0
III......................	36	—	5	—	13·9
IV.......................	36	24	3	66·7	8·3
V........................	36	11	3	30·6	8·3
VI.......................	37	3	3	8·1	8·1

TABLE XVIII.

Food Consumption and Growth.

Age.	Lot I.			Lot II.			Lot III.			Lot IV.			Lot V.			Lot VI.		
	Total food consumed. Grams	Grams food per gram grain.	Grams gain per gram protein.	Total food consumed. Grams	Grams food per gram gain.	Grams gain per gram protein.	Total food consumed. Grums	Grams food per gram gain.	Grams gain per gram protein.	Total food consumed. Grams	Grams food per gram gain.	Grams gain per gram protein.	Total food consumed. Grams	Grams food per gram gain.	Grams gain per gram protein.	Total food consumed. Grams	Grams food per gram gain.	Grams gain per gram protein.
1 week...........	1,055	3·05	1·78	1,010	2·93	1·89	943	2·88	1·94	1,180	2·33	2·37	1,060	2·64	2·17	895	3·17	1·83
2 weeks..........	1,685	3·27	1·66	1,780	2·41	2·33	1,860	2·73	2·06	2,080	2·56	2·06	2,000	3·04	1·88	1,980	3·29	1·75
3 weeks..........	2,055	3·70	1·47	2,390	2·89	1·92	2,905	3·22	1·74	2,710	2·87	1·93	2,630	3·16	1·81	2,890	3·68	1·57
4 weeks..........	2,650	3·41	1·58	3,315	3·67	1·51	3,670	3·47	1·61	3,715	3·05	1·81	3,525	3·34	1·71	3,485	3·54	1·63
5 weeks..........	3,940	4·07	1·34	4,335	3·60	1·54	5,900	3·27	1·73	5,325	3·26	1·69	5,130	3·59	1·59	5,125	3·93	1·47
6 weeks..........	4,372	4·65	1·17	5,285	3·98	1·39	7,305	3·67	1·53	6,382	3·52	1·57	5,895	3·76	1·52	6,000	3·90	1·48
7 weeks..........	5,233	3·84	1·41	6,065	3·63	1·53	8,075	3·78	1·49	7,713	3·28	1·68	7,170	3·40	1·68	7,235	3·79	1·53
8 weeks..........	6,125	4·63	1·17	7,510	4·55	1·22	11,055	3·90	1·44	9,060	3·60	1·53	8,675	3·61	1·58	8,385	4·15	1·39
	27,115	3·996	1·360	31,690	3·658	1·519	41,713	3·555	1·580	38,165	3·238	1·702	36,075	3·453	1·655	35,995	3·819	1·510

TABLE XX.

Differences in Mean Weight at Eight Weeks of Age.

Lots.	Males.			Females.			Unweighted means of males and females.		
	Difference.	T.	P.	Difference.	T.	P.	Difference.	T.	P.
1 & 2	100·7	3·6321	< ·01	64·6	2·5394	·01	82·65	4·3985	< ·01
1 & 3	137·7	6·1024	< ·01	165·7	7·0488	< ·01	151·70	8·1410	< ·01
1 & 4	138·1	5·2858	< ·01	111·5	4·5520	< ·01	124·80	6·9703	< ·01
1 & 5	88·4	3·3413	< ·01	71·7	2·9711	< ·01	80·05	4·4709	< ·01
1 & 6	60·1	2·2386	< ·02	45·4	1·8813	> ·05	52·75	2·9235	< ·01
2 & 3	37·0	1·3035	> ·05	101·0	4·1431	< ·01	69·05	3·6896	< ·01
2 & 4	37·4	1·4628	> ·05	46·9	1·8499	> ·05	42·15	2·3431	·03
2 & 5	12·3	·4753	> ·05	7·1	·2840	> ·05	2·60	·1445	> ·05
2 & 6	40·6	1·5691	> ·05	19·2	·7678	> ·05	29·90	1·6495	> ·05
3 & 4	·4	·015	> ·05	54·2	2·3056	·03	26·90	1·5089	> ·05
3 & 5	49·3	1·839	> ·05	94·0	4·0640	< ·01	71·65	4·0190	< ·01
3 & 6	77·6	2·8217	< ·01	120·3	5·2010	< ·01	98·95	5·5072	< ·01
4 & 5	49·7	2·0584	·05	39·8	1·6493	> ·05	44·75	2·6225	·01
4 & 6	78·0	3·1738	< ·01	66·1	2·7391	·01	72·05	4·1866	< ·01
5 & 6	28·3	1·532	> ·05	26·3	1·1067	> ·05	27·3	1·5863	> ·05

TABLE XXI.

Mean Weights and Standard Errors of Chicks at Eight Weeks.

Lot.	Males.	Females.	Unweighted Males and Females.	No. of Males.	No. of Females.	Total.
I....	271·9 ± 20·00	259·8 ± 17·32	265·8 ± 13·23	12	16	28
II....	372·6 ± 19·22	324·4 ± 18·52	348·5 ± 13·34	13	14	27
III....	409·6 ± 20·89	425·5 ± 15·90	417·6 ± 13·13	11	19	30
IV....	410·0 ± 16·81	371·3 ± 17·32	390·7 ± 12·07	17	16	33
V....	360·3 ± 17·32	331·5 ± 16·81	345·9 ± 12·07	16	17	33
VI....	332·0 ± 17·89	305·0 ± 16·81	318·6 ± 12·27	15	17	32

The weekly average live weights of all chicks, and the average of male and female chicks at eight weeks of age are presented in Table XVIII. The growth curves are presented in Fig. 3. The total food consumption, the food requirement per unit gain, and the gain per unit protein ingested, are presented in Table XVIII.

Fig. III.
Experiment III. Growth Curves.

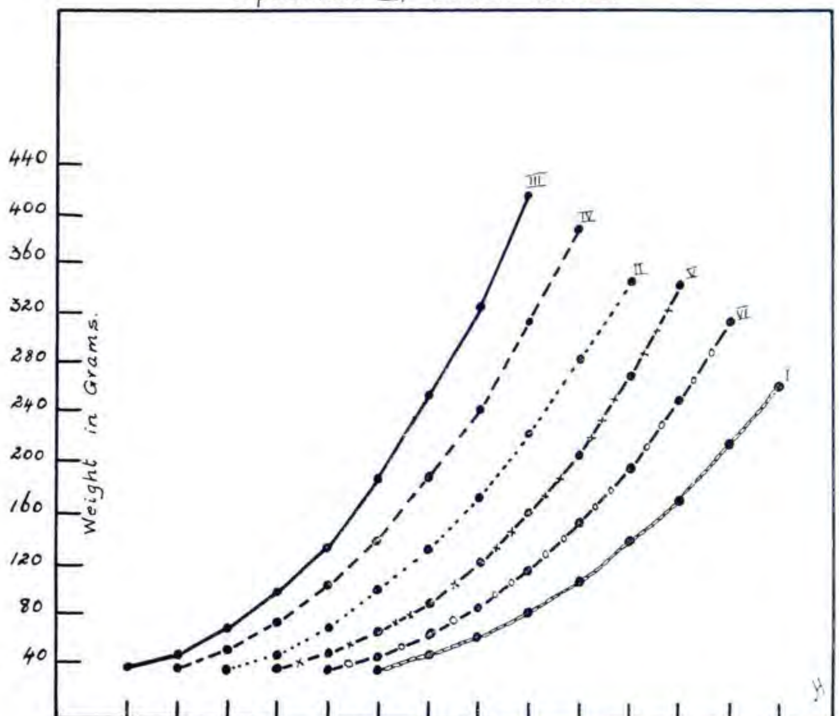


Table XIX gives the health and mortality records of chicks in the different groups.

The differences in mean weight at eight weeks of age, together with Fisher's T values and approximate probabilities are presented in Table XX.

Discussion.—The poor results with fish meal as a protein supplement for the growth of chicks was duplicated in this experiment. The slightly better growth was probably due to the fact that this experiment took place during autumn and early winter.

The most striking fact was the enhanced growth of chicks on fish meal, supplemented with dried brewers' yeast (Lot III). With casein as a supplement, the chicks grew very well for the first three weeks, but then showed a decline in growth and a high incidence of paralysis. The casein group showed better food utilization and greater gains per unit protein ingested. It would thus appear that the addition of casein improved growth, by supplying some factor essential for growth. The yeast supplement increased growth, but the biological value according to Osborne, Mendel and Ferry remained nearly eight per cent. lower than where casein was utilized. The biological value of fish meal is thus lower than that of fish meal supplemented by casein. At the same time, fish meal apparently lacks at least two factors supplied by dried brewers' yeast. The first is a growth promoting factor also contained in casein, and the second is a factor which prevents paralysis. Casein is also deficient in this anti-paralysis factor.

The meat and bone meal used in this experiment also proved to be inferior to fish meal supplemented with yeast or casein, i.e. lots 3 and 4 grew significantly better than lot 2. Thus meat and bone meal supplemented fish meal to some extent, but growth was significantly poorer than in group 2 where all the animal protein was supplied by meat and bone meal.

The biological values obtained for lots II and VI are, however, essentially the same. It would thus appear that the meat and bone meal used was also deficient in this growth promoting factor, as the quantity used to supplement the fish meal in lot VI did not supply enough for optimum growth. Another explanation would, of course, involve a lack in each of the same essential amino acids; this seems hardly possible.

Peanut meal supplemented fish meal to about the same extent as meat meal. As in the case of lot III, but not to so marked a degree, there was a deficiency of the anti-paralysis factor. This complicates the interpretation as far as growth is concerned, as the paralysis interferes rather seriously with feeding, and the paralysis factor itself might be growth promoting.

Summary.

1. Significant differences in the growth promoting ability of meat meals was demonstrated.

2. One sample of fish meal tested gave extremely poor growth.

3. It was shown that fish meal lacks at least two factors:—a growth promoting factor and a factor which prevents paralysis.

BIBLIOGRAPHY.

ALLERDYCE, W. J., HENDERSON, W. AND ASMUNDSON, V. S. (1933). Fish Meal supplements for chicks. *Poultry Sc.* 7. pp. 163-166.

ALMQUIST, H. J., STOKSTAD, E. L. R. AND HALBROOK, E. R. (1935). Supplementary values of animal protein concentrates in chick rations. *J. of Nutrition.* 10, pp. 193-209.

BOAS-FIXSEN, M. A. AND JACKSON, H. M. (1932). The biological value of proteins III. The biological values of proteins of wheat, maize and milk. *The Bioch. Jnl.* 26. pp. 1923-1933.

CHICK, H., BOAS-FIXSEN, M.A., HUTCHINSON, J. C. D., JACKSON, H.M. (1935). VII. The influence on the variation in the level of protein in the diet and of heating the protein on its biological value. *The Bioch. Jnl.* 29. pp. 1712-1719.

DANIEL, E. P., McCULLUM, E. V. (1931). Studies on the nutritive value of fish meals. *U.S. Dept. Com. Bur. Fisheries Invest. Rept.* 2, Vol. I, pp. 1-19.

FAIRBANKS, B. W. AND MITCHELL, H. H. (1935). The nutritive value of skim-milk powders, with special reference to the sensitivity of milk proteins to heat. *Jnl. of Agr. Res.* 51, pp. 1107--1121.

GREAVES, E. O. AND MORGAN, A. F. (1934). Nutritive value of raw and heated casein with and without added amino acids. *Proc. Soc. Exp. Biol. and Med.* 31, pp. 506-507.

HOAGLAND, R. AND SNIDER, G. G. (1926). Nutritive value of protein in beef extract, ox blood, ox palates, calf lungs, hog snouts, and cracklings. *Jnl. of Agr. Res.* 33, pp. 829-843.

INGVALDSON, T. (1929). Fish meals I. The effect of the high temperature employed for drying on the N. partition. *Con. Chem. Metall.* 13, pp. 97-99.

MAYNARD, L. A., BENDER, R. C., AND McCAY, C. M. (1932). Vitamin A and protein content of various fish meals. *Jnl. Agr. Res.* 44, pp. 591-603.

MAYNARD, L. A., TUNISON, A. V. (1932). Influence of drying temperature upon digestibility and biological value of fish protein. *Jnl. Ind. Eng. Chem.* 24, pp. 1168-1169.

MORGAN, A. F. (1931). The effect of heat on the biological value of cereal proteins and casein. *Jnl. Biol. Chem.* 90, pp. 771-792.

MORGAN, A. F. AND KERN, G. C. (1934). The effect of heat on the biological value of meat protein. *Jnl. of Nut.* 7, pp. 367-369.

OSBORNE, T. B., MENDEL, L. B. AND FERRY, E. L. (1919). A method for expressing numerically the growth promoting value of proteins. *Jnl. Biol. Chem.* 37, pp. 223-229.

PLIMMER, R. H. A., ROSEDALE, J. L., RAYMOND, W. H., LOWNDES, J. (1934). Relative values of proteins. *The Bioch. Jnl.* 28, pp. 1863-1886.

PRANGE, R. W., HAUGE, S. M. AND CARRICK, C. W. (1927). The study of the protein in a commercial meat product. *Poultry. Sci.* 6, pp. 302-307.

PRANGE, R. W., CARRICK, C. W. AND HAUGE, S. M. (1928, *a*). Growth values of proteins from commercial animal products. I. Commercial meat and bone scraps. *Poultry Sc.* 7, pp. 95-105.

PRANGE, R. W., HAUGE, S. M. AND CARRICK, C. W. (1928, *b*). Growth values of proteins from commercial animal products II. Commercial Digester Tankage. *Poultry Sc.* 7, pp. 186-193.

PRANGE, R. W., HAUGE, S. M. AND CARRICK, C. W. (1928, *c*). III. Commercial meat meal. *Poultry Sc.* 7, pp. 233-238.

RECORD, P. R., BETHKE, R. M., WILDER, O. H. M. AND KENNARD, D. C. (1934). The comparative nutritive value of different fish meals for chicks. *Poultry. Sc.* 8, pp. 259-266.

SCHNEIDER, B. H. (1932). N balance studies with various fish meals. *Jnl. of Agric. Res.* 44, pp. 723-732.

TITUS, H. W., BYERLY, T. C., ELLIS, N. R. AND NESTLER, R. B. (1936). The effect of packing house by-products in the diet of chickens, on the production and hatchability of eggs. *Jnl. of Agric. Res*, 53, pp. 453-

WILGUS, H. S., Jr., NORRIS, L. C. AND RINGROSE, R. C. (1933). Studies of the essential nutritive properties of some common proteins. *Poultry Sc.* 12, pp. 331-332.