5-1-1939

Protein requirements of chickens at various stages of growth and development, Bulletin, no. 312

Tepper, A. E.

Durgin, R. C.

New Hampshire Agricultural Experiment Station

Station Bulletin 312 May, 1939

Protein Requirements of Chickens

at Various Stages of Growth and Development

A. E. Tepper, R. C. Durgin and T. B. Charles

New Hampshire Agricultural Experiment Station
University of New Hampshire
Durham

Protein Requirements of Chickens at Various Stages of Growth and Development

A. E. Tepper, R. C. Durgin and T. B. Charles

THE protein requirements of growing chicks have been studied by numerous investigators both from the standpoint of determining the optimum percentage levels as well as the most efficient sources or combination of sources. Carver et al[6]; Morris, Thompson and Heller[21]; Norris and Heuser[22]; St. John et al[31]; Swift et al[32] and Tepper, Charles and Reed[33] have all reported rather similarly that during early life the growing chick has a greater demand for protein than during later life. Norris and Heuser[22] report that greatest growth during the first eight weeks was attained when the ration contained approximately 20 per cent protein. Following this initial starting period, however, the protein requirement dropped to about a 15 per cent level. Tepper et al[33] have reported that a 20 per cent protein level is most desirable and efficient for battery brooding of chicks up to thirteen weeks of age.

Curtis et al[8] state. "Feeding experiments with chicks at this experiment station have demonstrated that considerable variation exists in the nutrition value of animal protein concentrates." They also report previous work by investigators of the same station[25, 26, 27], wherein it was found that meat meals and digester tankage were inferior to meat scraps when fed at the same protein levels. As reported by Prange et al[27] a deficiency of the amino acid tryptophane was noted in the meat meal. Prange et al[24] further state: "Variations exist in the nutritive value of proteins from meat and bone scraps made by different manufacturers. The cause of this variation is not definitely known, but we surmise it may be due to differences in both amounts and kinds of tissues included in the product. The variation exists not only in similar products made by different manufacturers but it is possible that it may exist in different samples of the same brand." Mitchell, Beadles, and Kruger[19] agree with Prange et al[24], that probably the variation in the nutritive value of the various samples is due to various percentage contents of connective tissue.

Record et al[28] in comparative feeding trials on chicks of various types of fish meals state that "all the rations which contained fish meal, with the exception of the ration containing flame-dried menhaden, showed a greater efficiency than the meat scraps alone or meat scraps and five per cent milk rations". The investigators refer, however, to the work of Asmundson and Bicly[4] wherein no significant difference was observed in the nutritive value of salmon and pilchard meals or dried skimmilk when fed at levels to supply ten per cent of protein.

Johnson and Brazie[14] in a test of the comparative value of Argentine meat scrap, Vico meat scrap, Alaska herring meal, fish shreds, skimmilk

powder and various blends of these protein concentrates in rations for growing chicks report: "Chicks fed Alaska herring meal made the best growth, those fed Argentine meat scrap made the poorest, while those fed the concentrates and blends of concentrates showed a growth about midway between the two."

Although there appears to be some agreement among investigators as to the desirable percentage of protein needed in rations for the various purposes of starting, growing, fattening and egg production, there seems to be much less agreement as to the best sources of this protein. Apparently the general term "protein" is too inclusive for a satisfactory decision, and the analyst must go further into a study of methods of manufacture, vitamin content, digestibility coefficients, cost, amino acid content, blends of products used in manufacture of protein concentrates as well as other factors. The reader is referred to a recent article by Fairbanks[10] in which he discusses this "all inclusive" term in a very able manner.

Object

The threefold object of the experimental procedure herein reported was to determine (1) optimum levels of protein intake for chickens during their various stages of growth and production, (2) efficient sources of protein and (3) the most efficient combinations of sources for the various growth periods studied. It was also thought desirable to determine the influence of (1), (2), and (3) on growth rate, sexual maturity, feather growth, feed consumption, mortality, egg production and egg weight.

Experimental

In Test I, twelve groups of 30* New Hampshire chicks were started April 4, 1935, and raised in growing batteries up to 12 weeks of age. At this time representative groups of ten pullets from each lot were selected and held for placement in individual laying cages to continue growth and production up to 70 weeks of age. The groups were fed various protein-carrying rations as outlined below:

Table I. Percentage content of protein, calcium, phosphorus and ash in protein concentrates and basal ration

	Protein		Calcium	Phosphorus	Ash
Ingredients	Test 1	Test 2	Test 2	Test 2	Test 2
Fish meal	57.23	62.00	7.89	4.08	23.05
Meat scraps	55.62	55.34	8.88	4.34	26.56
Dried skimmilk	33.58	38.09	1.58	1.03	7.93
Basal ration	13.09	12.56	1.54	.54	6.78

* In Test II, twelve groups of 60 New Hampshire chicks were started April 7, 1937. Representative lots of 20 pullets from each group were selected and held for placement in laying cages.

Groups 1, 2, and 3: basal ration plus meat scraps to make 15, 17, and 19 per cent protein content, respectively. Groups 4, 5, and 6: basal ration plus white fish meal, vacuum processed, to make 15, 17, and 19 per cent protein content, respectively. Groups 7, 8, and 9: basal ration plus dried skimmilk to make 15, 17, and 19 per cent protein content respectively. Groups 10, 11, and 12: basal ration plus a combination of the three animal protein sources in equal protein-carrying amounts to make 15, 17, and 19 per cent protein content respectively.

The basal ration was composed of 200 pounds yellow corn meal, 100 pounds wheat bran, 100 pounds white flour middlings, 100 pounds ground heavy oats, 25 pounds alfalfa leaf meal, 15 pounds oyster shell flour, 5 pounds salt and 3 pounds biologically tested sardine oil. All groups in both Test I and II were fed this ration plus specified animal protein in an all-mash form throughout the experimental procedure.

In Test I all chicks used were individually wing-banded and weighed weekly throughout the experimental period of 70 weeks. In Test II average group weights were recorded up to time of placement in laying cages. Individual bi-monthly weights were recorded from this period to the end of the test. Feed consumption records in Test I were determined weekly by groups throughout the first 12 weeks of the experimental period. After females were placed in laying cages the feed consumption was maintained weekly on an individual bird basis. In Test II feed consumption records were maintained throughout the experimental period on a group basis weekly.

Protein Concentrates Used

Meat Scraps used in the two tests were made from butcher shop and packers' trimmings. The product at the time of purchase was not over ten days old, but complete history of its manufacture together with percentage amounts of its component parts could not be secured.

Dried Skimmilk was made by the roller process and was received within one week of the date of manufacture.

The Fish Meal used in the tests is commonly termed vacuum-processed white fish meal. It was made from fish that were caught one day and processed the following day. The product produced contained several

Table II. Calcium-phosphorus content of mixed rations as determined by computation; Test II

Ration	Ca/P	% Calcium	% Phosphorus
15% Meat scrap	2.58:1	1.96	.76
17% Meat scrap	2.46:1	2.30	.93
19% Meat scrap	2.37:1	2.61	1.11
15% Fish meal	2.59:1	1.85	.71
17% Fish meal	2.45:1	2.11	.86
19% Fish meal	2.36:1	2.37	1.03
15% Dried skimmilk	2.63:1	1.51	.59
17% Dried skimmilk	2.47:1	1.55	.63
19% Dried skimmilk	2.09:1	1.55	.74
15% Mixture	2.60:1	1.80	.69
17% Mixture	2.47:1	1.98	.80
19% Mixture	2.39:1	2.15	.90

varieties of fish but consisted largely of cod and haddock. The raw product was ground, cooked and pressed previous to being placed into the dehydrator. The product was dehydrated at a 26″-27″ vacuum at an inside temperature of approximately 120° Fahrenheit.

During the course of the 140 weeks of actual test time, it was necessary to secure more than one lot of protein concentrate. The successive lots used, however, were of the same brand and were made under as identical conditions as possible. The variation in protein content is shown in Table I.

Test I—Discussion

Starting Period (0-12 Weeks)

In this study experiments have been limited to three animal protein sources; namely, meat scrap, fish meal, and dried skimmilk. In Table III, showing a summary of weight records for the respective groups, it is interesting to note that in all protein groups as the percentage content increased, so did the weight. The group receiving 15 per cent dried skimmilk was the lowest in weight at 2.293 pounds per chick. Group 12 receiving 19 per cent protein from all three animal sources averaged the greatest weight at 2.961 pounds per chick. These results are in harmony with previous work at this station indicating that protein levels of from 18-20 per cent during the first 12-week period produce the greatest gains in weight.

Summarizing results by groups according to type of animal protein concentrate received, we find the mixture groups (10, 11, and 12) leading with an average weight per chick of 2.855 pounds. The fish meal, meat scrap and dried skimmilk groups follow in the order named. Only very slight differences of little significance are apparent. No significant differences occur among groups insofar as feed consumption per bird is con-

Table III-a. Summary of weight records in pounds per bird by stated weekly periods for meat scrap groups

Age	Group 1		Group 2		Group 3	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1 Day	.0916	.0885	.0946	.0923	.0940	.0923
4 Weeks	.4617	.3911	.5324	.4538	.5770	.4788
8 ″	1.392	1.161	1.437	1.270	1.546	1.354
12 ″	2.448	2.200	2.600	2.416	2.758	2.348
16 ″	2.903	3.510	3.097	3.260	3.330	3.286
19 ″	3.593	3.706	3.790	3.775	3.928	3.868
23 ″	4.272	4.239	4.408	4.179	4.434	4.295
27 ″	4.805	4.926	4.989	4.697	4.992	4.767
31 ″	4.853	4.498	5.183	4.428	5.229	4.519
35 ″	4.995	5.132	5.214	4.982	5.224	5.202
39 ″	5.005	5.142	5.258	5.027	5.305	5.246
43 ″	5.035	5.004	5.338	5.169	5.238	5.396
47 ″	5.047	5.137	5.081	5.060	4.926	5.253
51 ″	5.153	5.192	5.173	5.251	4.898	5.432
55 ″	5.217	5.035	5.361	5.182	4.876	5.443
59 ″	5.155	5.217	5.466	5.218	4.902	5.548
63 ″	5.176	5.205	5.450	5.205	4.765	5.393
67 ″	5.210	5.191	5.434	5.361	4.691	5.441
70 ″	5.256	5.240	5.225	4.971	4.820	5.281

cerned (Table IV). All groups ranged between a high consumption of 11.544 pounds and a low consumption of 9.335 pounds of feed per bird for the 12-week period. In feather development there was apparently no difference among the groups. Table VI shows that relatively little mortality occurred in any of the groups during the starting period. The loss of five chicks in Group 9 could not be explained as being due to the ration. Autopsies of the chicks which died showed the cause of death in all cases to be pneumonia.

In a comparison of the 12 groups on a basis of efficiency of feed utilization (Table V), using as a guide the number of pounds of feed consumed per pound gain in weight, we find the mixed animal protein groups (10, 11, and 12) the most efficient. These groups were closely followed by the fish meal lots which in turn were followed by the dried skimmilk and meat scrap groups. The most efficient was Group 3 with a feed consumption of 3.38 pounds per pound of gain and the least efficient was Group 1 with a feed consumption of 4.37 pounds. These two groups were fed 19 and 15 per cent meat scrap, respectively.

Growing Period (13-23 Weeks)

As previously mentioned, from all groups at the age of 12 weeks, there was selected a representative group of ten pullets for the experimental unit. In the case of Groups 8 and 9 only nine and eight pullets respectively were available for use. These, however, received treatment similar to all the other groups which had the full complement of ten pullets. The same feed in all-mash form was continued as during the first growth period. Table III shows that the final weights per chick at 23 weeks of age in each group have maintained a somewhat similar relationship to that which existed at 12 weeks of age. In all cases the groups receiving

Table III-b. Summary of weight records in pounds per bird by stated weekly periods for fish meal groups

Age	Group 4		Group 5		Group 6	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1 Day	.0936	.0923	.0920	.0923	.0946	.0884
4 Weeks	.1934	.1745	.5320	.4961	.5900	.5287
8 "	1.364	1.180	1.560	1.484	1.617	1.592
12 "	2.429	2.721	2.797	2.750	2.780	2.798
16 "	2.942	3.500	3.310	3.555	3.423	3.538
19 "	3.531	4.106	3.798	3.987	3.981	4.215
23 "	4.084	4.454	4.296	4.300	4.531	4.513
27 "	4.631	4.749	4.795	4.831	4.983	4.909
31 "	5.174	4.423	5.106	4.321	5.132	4.428
35 "	5.235	5.034	5.515	4.938	5.375	5.113
39 "	5.158	5.106	5.460	5.015	5.214	5.166
43 "	5.383	5.114	5.349	5.012	5.450	5.216
47 "	5.391	5.183	5.251	5.011	5.399	5.293
51 "	5.304	5.313	5.649	5.110	5.278	5.585
55 "	5.305	5.183	5.864	5.092	5.331	5.457
59 "	5.446	5.389	5.646	5.181	5.429	5.360
63 "	5.317	5.280	5.682	5.168	5.832	5.591
67 "	5.323	5.401	5.772	5.134	5.721	5.824
70 "	5.329	5.376	5.468	5.212	5.766	5.610

the higher protein content feeds were the heaviest in weight. At the end of the period the group receiving 19 per cent fish meal was leading in average weight per pullet by a very slight advantage over the 19 per cent mixed protein group.

If we again summarize by groups according to animal protein source, we find the groups receiving the mixture of animal protein to be leading with an average weight of 4.383 pounds per bird. The meat, fish and milk groups follow closely with 4.371, 4.304, and 4.063 pounds per bird. During the second growth period feed consumption was materially increased over that of the first period. There was a difference of less than three pounds per bird between high and low groups. According to Table IV the average weekly feed consumption per bird varied from 1.297 pounds in the 15 per cent milk group to 1.539 pounds in the 19 per cent mixture group.

The efficiency of feed utilization, based upon pounds of feed required to produce one pound of gain, during the second growth period illustrates to good effect the changing protein requirements as age increases. In all cases the groups receiving the 15 per cent protein content rations were most efficient in producing gains in weight. Of all the experimental groups, Group 1 was the most efficient with 8.28 pounds of feed per pound of gain. Group 11 was the least efficient with 12.06 pounds of feed to produce one pound of body gain.

The only bird which died during the second growth period was from Group 11, receiving 17 per cent animal protein mixture. According to autopsy examination the intestines were small in size, and the kidneys covered with urates. Indications were that the bird was an individual case showing indigestion and lack of assimilation of feed. Death occurred in the 23rd week.

The production of eggs previous to the 24th week varied to some

Table III-c. Summary of weight records in pounds per bird by stated weekly periods for dried skimmilk groups

Age	Group 7		Group 8		Group 9	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1 Day	.0933	.0884	.0923	.0923	.0910	.0923
4 Weeks	.4748	.4325	.4966	.4570	.5392	.4637
8 "	1.308	1.125	1.403	1.000	1.511	1.153
12 "	2.293	2.167	2.645	2.222	2.805	1.913
16 "	2.869	2.741	3.042	2.710	3.315	2.600
19 "	3.502	3.430	3.453	3.306	3.676	3.156
23 "	4.010	3.815	3.977	3.621	4.202	3.480
27 "	4.495	4.176	4.394	4.017	4.715	3.847
31 "	4.984	3.911	4.551	3.709	4.895	3.657
35 "	5.238	4.402	4.830	4.135	5.028	4.138
39 "	5.201	4.398	4.627	4.225	5.273	4.200
43 "	4.961	4.431	4.653	4.214	5.230	4.278
47 "	5.113	4.280	4.550	4.221	5.332	4.228
51 "	5.128	4.333	4.510	4.363	5.333	4.357
55 "	5.171	4.455	4.713	4.217	5.325	4.323
59 "	5.544	4.463	4.860	4.270	5.295	4.317
63 "	5.628	4.475	4.721	4.273	5.297	4.256
67 "	5.374	4.533	4.535	4.386	5.153	4.280
70 "	5.666	4.478	4.513	4.303	5.212	4.159

extent between groups, all of which showed some production except for the dried skimmilk groups. The latter were somewhat slower in sexual maturity than were the other groups. Other than this, protein percentage of ration or kind of protein did not significantly influence date of sexual maturity.

Production Period (24-70 Weeks)

The same groups of pullets previously mentioned were continued in the laying cages up to 70 weeks of age. Egg production, egg weight, feed consumption, weight and mortality records were maintained for comparative studies. No change in management or feed occurred during this period.

The increase in weight by group averages was quite irregular during the production period. Not one group showed a steady increase in weight by weeks, all being subject to occasional losses. Group 6 maintained its lead over all others as in the growth period, averaging at the end of the 70-week period 5.766 pounds. The lowest in weight at the end of this period was Group 8 with an average weight of but 4.513 pounds.

The total feed consumed per bird during the production period varied from a high of 90.734 pounds in Group 6 to 69.347 pounds in Group 3. The average weekly feed consumption per bird varied between the same groups with a high of 1.924 pounds in Group 6 and 1.478 pounds in Group 3, the lowest. The groups having the greater feed consumption also produced the greater number of eggs.

As noted in Table IV, there is no relationship between percentage protein content and total feed consumed. There appears to be considerable variation among groups. Those receiving the variable amounts of fish

Table III-d. Summary of weight records in pounds per bird by stated weekly periods for protein mixture groups

Age	Group 10		Group 11		Group 12	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1 Day	.0923	.0923	.0933	.0846	.0916	.0884
4 Weeks	.4739	.4041	.5741	.4827	.6067	.5040
8 "	1.413	1.241	1.543	1.525	1.657	1.508
12 "	2.714	2.339	2.890	2.777	2.961	2.846
16 "	3.292	3.196	3.352	3.472	3.383	3.519
19 "	3.878	3.795	3.836	3.795	3.957	4.093
23 "	4.151	4.221	4.192	4.217	4.507	4.335
27 "	4.987	4.716	4.828	4.714	4.961	4.733
31 "	5.089	4.457	4.948	4.280	4.941	4.485
35 "	5.221	5.108	5.063	4.755	5.251	5.012
39 "	5.171	5.138	5.205	4.825	5.367	4.995
43 "	5.380	5.098	5.140	4.875	5.409	4.992
47 "	5.240	5.006	5.292	4.922	5.533	4.928
51 "	5.412	5.139	5.292	4.910	5.700	4.975
55 "	5.403	4.969	5.350	4.995	5.487	4.974
59 "	5.454	5.141	5.494	5.136	5.334	5.287
63 "	5.448	5.417	5.600	4.908	5.300	5.261
67 "	5.108	5.375	5.265	5.039	5.560	5.254
70 "	5.714	5.266	5.756	4.976	5.611	5.501

meal as the only animal protein source consumed the greatest total amount of feed, 263.27 pounds. The meat scrap groups had the lowest feed consumption with a total of 222.93 pounds.

In Table VII is presented the relationship between average feed consumed per bird and the production of eggs. Feed consumption figures are calculated from the start of the 24th week. Comparing the efficiency of the various groups on the basis of number of pounds of feed consumed to produce one dozen of eggs, we find a distinct relationship between production and type of animal protein supplement. The fish meal groups show most efficient consumption of feed with a range of 6.51 to 8.41 pounds of feed to produce one dozen eggs. The groups receiving dried skimmilk as the animal protein supplement were least efficient with a range of 24.52 to 39.50 pounds of feed required to produce a dozen eggs.

Mortality during the production period amounted to 34.4 per cent. Of this amount 32.5 per cent was due to ruptured egg yolk, 20 per cent to indigestion, and 17.5 per cent to cage injury causing a paralysis of legs. The remainder was spread between ovarian tumor, pneumonia, ruptured liver, favus, and uremia. In explanation of the paralysis of legs, it should be stated that birds would occasionally get their legs through the wire cage floor. Many times they were held there until released by the attendant. The struggle to free themselves probably resulted in a rupture of the nerve controlling leg action and caused paralysis.

Many investigators believe the cause of ruptured egg yolk to be excessive handling or mechanical injury. If this is true, the explanation of the large mortality from this cause is apparent since all birds on the test were individually handled each week for weight records. It is interesting to note that the lowest total mortality was experienced in the milk groups, whereas the groups receiving the meat scraps as animal protein supplement had the greatest total mortality.

The egg production summary as shown in Table VII indicates a considerable variation among groups according to type of animal protein supplement consumed. As noted under the column headed "average production per bird," the groups receiving the fish meal protein supplement averaged a greater laying rate than the other groups. The 15 per

Table IV-a. Summary of feed consumption records in pounds per chick for meat scrap and fish meal groups

Feed consumed		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Test I							
0-12 weeks	Total	10.713	11.124	9.335	10.379	11.201	10.474
13-23 weeks	Total	15.115	16.054	16.032	15.704	15.464	16.806
	Per week	1.374	1.459	1.457	1.432	1.405	1.527
24-70 weeks	Total	77.691	75.895	69.317	85.514	87.022	90.734
	Per week	1.653	1.614	1.478	1.816	1.846	1.924
Test II							
0-12 weeks	Total	8.355	9.001	9.574	9.822	8.969	9.694
13-23 weeks	Total	16.253	15.592	16.441	16.740	15.585	16.751
	Per week	1.477	1.417	1.494	1.521	1.416	1.522
24-70 weeks	Total	80.501	80.813	82.515	81.196	82.697	85.278
	Per week	1.712	1.719	1.755	1.727	1.759	1.814

cent group (fish meal) had an average production per bird of 121.92 eggs as compared with the 15 per cent mixture, 15 per cent meat scrap and 15 per cent dried skimmilk groups of 101.07 eggs, 91.88 eggs, and 38.70 eggs, respectively.

A similar relationship is observed when comparing the 17 per cent protein groups with but one exception. In this instance the 17 per cent mixture group outlayed all others with an average production of 174.13 eggs. The 17 per cent fish meal, meat scrap, and dried skimmilk groups followed in the order named with 152.54 eggs, 61.38 eggs, and 35.90 eggs.

In a comparison of average production per bird for the 19 per cent protein groups we note the fish meal group as leader with 167.11 eggs per bird as compared with the 151.51 eggs for the mixture group, 42.40 eggs for the meat scrap group, and 24.70 eggs per bird in the group receiving dried skimmilk. Based on an average production figure the fish meal groups produced at the highest rate with the mixture, meat scrap and dried skimmilk groups following in the order named.

Table VII also presents a definite cost comparison of the different rations used as well as the computed feed cost per dozen eggs produced by each group. It will be noted that as the protein content of ration is increased, the cost per pound of this feed is increased. If the feed cost per dozen eggs produced is increased with each increase in protein content, it then appears doubtful if such an increase is worthwhile or advantageous. By referring to Table VII and considering figures applicable only to Test I, one can see that each advance in protein from the meat and milk sources caused an increase in the feed cost per dozen eggs produced. In the case of the mixed protein groups there was a decided drop in feed cost per dozen eggs as protein content was increased from 15 per cent to 17 per cent. An approximate saving of seven cents per dozen is noted. With an additional two per cent increase in protein content, feed cost per dozen jumps approximately two cents over that for the 17 per cent protein group. A similar comparison of the groups fed fish meal as the animal protein source indicates a definite reduction in cost as the protein content increases. All three groups, however, are relatively close and show little spread in feed cost between lowest and

Table IV-b. Summary of feed consumption records in pounds per chick for dried skimmilk and protein mixture groups

Feed consumed		Group 7	Group 8	Group 9	Group 10	Group 11	Group 12
Test I							
0-12 weeks	Total	9.917	10.238	11.544	10.481	10.856	11.481
13-23 weeks	Total	14.269	14.392	15.880	16.579	15.714	16.935
	Per week	1.297	1.308	1.443	1.507	1.428	1.536
24-70 weeks	Total	81.937	73.318	80.989	84.264	90.132	83.823
	Per week	1.736	1.556	1.720	1.789	1.913	1.782
Test II							
0-12 weeks	Total	7.755	8.401	7.345	8.952	10.019	10.061
13-23 weeks	Total	13.901	12.996	12.905	15.498	15.596	15.908
	Per week	1.263	1.181	1.173	1.408	1.417	1.446
24-70 weeks	Total	75.649	71.807	71.612	80.000	79.196	82.366
	Per week	1.609	1.527	1.523	1.702	1.685	1.752

highest protein-fed groups. In the case of the other protein source groups a considerable spread is noted between high and low protein-fed groups.

From these comparisons, it appears that fish meal was the most complete and efficient animal protein source used in the tests. Meat scrap and milk protein sources are either deficient in some very necessary food essential and increasing their supply will not offset this deficiency, or else some "abnormal" effect on the digestive process is occasioned by their increased use. On the basis of the actual products used in this test, the maximum level in a ration at which one may use either meat scraps or dried skimmilk is quite definitely lower than the level at which fish meal may be used in the compounding of rations. In Test I the following percentage levels of the three animal protein sources were used in Groups 1 to 9, respectively: 4.48, 9.19, 13.87, 4.32, 8.85, 13.39, 9.32, 19.08 and 28.84.

Starting with the 35th week of age periodic records of egg weight according to groups were made. All eggs laid over a four- or five-day period every two months were weighed and recorded. In this manner 656 eggs were recorded for the 12 groups. The average egg weight by protein groups was 1.95 ounces for the fish meal groups; 1.89 ounces in the mixture groups; 1.84 ounces for meat scrap groups; and 1.82 ounces per egg for the groups receiving dried skimmilk.

As noted in Table VIII there appears to be no significant relationship between the percentage of protein fed and the size of egg laid.

Test II—Discussion

Starting Period (0-12 Weeks)

As reported in the previous year's work the groups receiving higher protein-carrying rations showed, generally, more rapid weight gains than

Table V. Pounds of feed required to produce one pound of gain—all groups

	Periods	15% Meat scrap	17% Meat scrap	19% Meat scrap	15% Fish meal	17% Fish meal	19% Fish meal	15% Dried milk	17% Dried milk	19% Dried milk	15% Mix-ture	17% Mix-ture	19% Mix-ture
Test 1	1-12 wks.	4.37	4.27	3.38	4.27	4.00	3.76	4.32	3.87	4.11	3.86	3.75	3.87
	13-23 wks.	8.28	8.87	9.56	9.48	10.31	9.59	8.31	10.80	11.36	9.54	12.06	10.95
Test 2	1-12 wks.	3.79	3.73	4.08	3.61	3.26	3.46	3.58	3.78	3.84	3.83	3.61	3.54
	13-23 wks.	7.78	8.84	8.44	9.66	10.05	9.77	8.44	9.29	8.24	8.24	10.83	10.68

Table VI. Mortality summary—all groups

	Group	1	2	3	4	5	6	7	8	9	10	11	12
	Test No.	%	%	%	%	%	%	%	%	%	%	%	%
0-23 wks. Inclusive	1	6.6	3.3	3.3	10.0	3.3	3.3	3.3	0.0	16.6	10.0	10.0	10.0
	2	10.7	0.0	9.2	9.2	0.0	9.2	6.2	1.5	4.6	10.7	12.3	4.6
24-70 weeks Inclusive	1	50.0	60.0	30.0	20.0	50.0	10.0	33.3	33.3	0.0	50.0	33.3	40.0
	2	20.0	5.0	20.0	10.0	10.0	20.0	10.0	25.0	21.0	16.6	16.6	25.0

those receiving low protein rations. In Test II at the end of the first 12-week period the group receiving a 19 per cent protein ration from dried skimmilk as animal protein source was lowest in weight, averaging per pullet chick 1.913 pounds (Table III). The group receiving the 19 per cent mixed protein was highest in average weight with 2.846 pounds per chick.

The use of a 19 per cent protein ration using dried skimmilk did not cause more rapid weight gains. This tends to support our previous statement that there is a limit beyond which we should not go in the feeding of this product to insure rapid weight gains. The 17 per cent protein group carried 17.3 per cent of dried skimmilk and the 19 per cent group carried 25.2 per cent. Kempster and Funk[15] have concluded that growth in White Rock chicks was in proportion to the amount of dried skimmilk used in the ration until the amount was over 30 per cent.

In summary, according to type of animal protein concentrate received, the fish meal groups averaged highest with 2.756 pounds per chick, followed in order by mixture, meat scrap and dried skimmilk, showing 2.654 pounds, 2.321 pounds, and 2.101 pounds, respectively. One point of interest in the weight records is evidenced by the lack of variance in average weight per chick for the fish meal groups. Only slight differences in weight were occasioned by the increase in percentage of fish meal used in the ration.

The groups receiving dried skimmilk were definitely inferior in weight,

Table VII. A cost comparison of feed consumption and egg production per bird for all groups

Group	Test	Ave. prod. per bird (eggs)	Prod. per bird (doz.)	Ave. feed consumed per bird (pounds)	Lbs. feed per doz. eggs	Cost per lb. of feed (¢)	Feed cost per doz. eggs (¢)
15% Meat	I	91.88	7.65	77.691	10.15	2.02	20.50
	II	116.00	9.66	80.501	8.33	2.11	17.57
17% Meat	I	61.38	5.11	75.895	14.85	2.05	30.44
	II	133.20	11.10	80.813	7.28	2.18	15.87
19% Meat	I	42.10	3.53	69.347	19.64	2.09	41.04
	II	107.10	8.92	82.515	9.25	2.25	20.81
15% Fish	I	121.92	10.16	85.511	8.41	2.01	16.90
	II	134.00	11.16	81.196	7.27	2.07	15.04
17% Fish	I	152.54	12.71	87.022	6.81	2.05	14.02
	II	152.30	12.69	82.697	6.51	2.12	13.80
19% Fish	I	167.11	13.92	90 731	6.51	2.08	13.54
	II	131.10	11.17	85.278	7.63	2.16	16.48
15% Milk	I	38.70	3.22	81.937	25.44	2.37	60.29
	II	118.70	9.89	75.619	7.61	2.52	19.25
17% Milk	I	35.90	2.99	73.318	24.52	2.78	68.16
	II	95.50	7.95	71.807	9.03	2.91	26.28
19% Milk	I	24.70	2.06	80.989	39.50	3.18	125.61
	II	98.00	8.16	71.612	8.77	3.31	29.03
15% Mixture	I	101.07	8.42	84.261	10.00	2.11	21.10
	II	111.50	9.29	80.000	8.61	2.22	19.11
17% Mixture	I	174.13	14.51	90.132	6.21	2.26	14.03
	II	120.80	10.06	79.196	7.87	2.36	18.57
19% Mixture	I	151.51	12.62	83.823	6.64	2.40	15.94
	II	118.50	9.87	82.366	8.34	2.48	20.68

condition and appearance when compared with the other protein source groups.

No very significant difference occurred between groups in rate of feed consumption. There was a lower total consumption for this year's test than for the previous test. This, however, was also associated with a slightly reduced growth rate. All rations for both tests were made as identical as possible. Average consumption per chick varied from 7.345 pounds in Group 9 to 10.06 pounds in Group 12—the lowest and highest average weight groups.

So far as could be determined there was apparently no difference between groups in feather growth. At about ten weeks of age the group receiving the 15 per cent mixed protein ration developed the vice of feather picking. Those groups receiving the single protein sources did not exhibit this condition.

Higher mortality was experienced this year in the test than last year. Considerable variation between groups occurred as noted in Table VI. The average mortality according to protein source ranged from 3.1 per cent in dried skimmilk groups to 8.2 per cent in the mixed protein lots. Autopsy reports showed the major cause to be pneumonia. A few cases of ulcerated gizzards were noted.

For a comparison of efficiency of feed utilization based on the number of pounds of feed required to produce a pound of gain, we find in Table V

Table VIII. Average egg weights in ounces according to groups

Group	Test	Number eggs weighed	Range in weight	Average weight
15% Meat	1	47	1.2 — 2.3	1.88
	2	328	1.4 — 2.3	1.92
17% Meat	1	24	1.5 — 2.2	1.85
	2	359	1.3 — 2.6	1.96
19% Meat	1	13	1.6 — 2.1	1.78
	2	278	1.3 — 2.6	1.93
15% Fish	1	104	1.6 — 2.5	2.01
	2	353	1.4 — 2.4	1.89
17% Fish	1	91	1.6 — 2.4	1.84
	2	412	1.3 — 2.4	1.92
19% Fish	1	112	1.7 — 2.5	2.01
	2	384	1.1 — 2.3	1.90
15% Milk	1	11	1.3 — 2.2	1.81
	2	262	1.1 — 2.3	1.87
17% Milk	1	17	1.2 — 2.0	1.76
	2	265	1.0 — 2.6	1.93
19% Milk	1	11	1.7 — 2.1	1.88
	2	255	1.3 — 2.4	1.86
15% Mixture	1	47	1.5 — 2.2	1.83
	2	262	1.4 — 2.5	1.99
17% Mixture	1	89	1.7 — 2.3	1.93
	2	295	1.3 — 2.4	1.87
19% Mixture	1	90	1.4 — 2.4	1.90
	2	355	1.4 — 2.5	1.95
Total eggs weighed	1	656	1.2 — 2.5	
	2	3808	1.0 — 2.6	

computations covering all groups. The most efficient was Group 5 and the least efficient was Group 3.

Averages according to animal protein source show that the fish meal groups consumed 3.44 pounds of feed per pound of gain. The mixture groups followed with an average of 3.66 pounds, dried skimmilk with 3.73 pounds and meat scraps with 3.83 pounds of feed. Even though the difference between groups is small it is worth noting that in the previous test the group receiving 19 per cent meat scrap ration was the most efficient. The work of this year indicates it to be the least efficient. Certainly no definite recommendations may be stated in the face of such contradictory evidence.

Growing Period (12-23 Weeks)

At the age of 12 weeks, representative groups of 20 pullets from each of the 12 groups were selected for placement in laying cages. These groups were held in growing batteries up to 16 weeks of age and then transferred to cages. Group 11 was lacking in number of pullets and consequently only 18 birds were available for use. Rations for all birds were similar to those used during the previous period.

As will be noted in Table III, the final weights per chick at 23 weeks of age for each group were maintained at a somewhat similar relationship as they existed at 12 weeks of age. It is interesting to note that the weight differences between high and low protein groups that existed at the end of the 12-week period have been narrowed considerably. The groups receiving the lower protein sources show evidence of gradually overcoming the lead established by the higher protein groups at 12 weeks of age. It is of further interest to note that the greater the percentage of dried skimmilk fed the lower was the average weight per bird. The group receiving 19 per cent fish meal was leading in average weight per pullet over all other groups with an average weight of 4.513 pounds.

In a summarization of groups according to type of animal protein source, we find the groups receiving fish meal averaged heaviest at 4.422 pounds per bird. The mixture, meat and dried skimmilk groups followed with 4.258, 4.238 and 3.639 pounds per bird, respectively.

Average feed consumption per bird over the second growth period

Table IX. Relative production periods and age at first egg for all groups

	No. days		No. days to first egg		Ave. no. days to first egg	
Group	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
1	333	351	158	145	180	175
2	332	351	159	145	187	171
3	351	348	140	142	186	181
4	334	346	157	141	199	165
5	320	352	172	138	190	162
6	348	350	143	140	175	169
7	295	337	196	153	229	170
8	325	343	167	147	191	183
9	329	337	162	153	187	193
10	345	343	146	147	174	178
11	365	338	126	152	158	173
12	359	353	133	137	167	175

varied between groups from a low of 12.905 pounds to a high of 16.751 pounds. This difference of less than four pounds compares quite favorably with the previous year's work.

The number of pounds of feed required to produce one pound of gain during this growth period varied from 7.78 pounds in the 15 per cent meat scrap group to 10.83 pounds in the 17 per cent mixture group. Generally, the groups receiving the lower protein percentages were the most efficient in feed utilization.

During the 17th week two pullets from Group 7 and two pullets from Group 10 died. Autopsy of these four birds by the poultry pathology laboratory revealed that all birds had very small, undeveloped abdominal organs. Lack of development of these organs apparently lessened the birds' ability to utilize available food, resulting in emaciation and eventual death. No definite disease conditions were in evidence.

From the standpoint of age at first egg, Table X shows that the earliest production started at 137 days of age by one individual in Group 12. At the age of 144 days individuals from all three fish meal groups and from the 19 per cent meat scrap group had started production. At the age of 161 days all groups showed production to some extent with the fish meal groups leading all others with a total production of 142 eggs. The milk, meat and mixture groups followed with 63, 51, and 48 eggs, respectively. Percentage protein in ration did not significantly influence age at first egg. This is in agreement with Winter, Dakan and Bayes[34] who state, "There is no correlation between the level of protein intake and the age at which the first egg is produced."

Production Period (24-70 Weeks)

The conditions of management of birds during the production period were similar to those of Test I except that individual bird feed consumption records were not maintained. The figures presented are group averages. At the start of this period the groups receiving fish meal had

Table X. Iron, manganese, copper and lactose content in terms of dry skimmilk as determined by analysis of ingredients;* Test II

Ingredient or mixed ration	Group No.	% Fe.	% Mn.	% D. S. M.	P. P. M. Cu.
15% Meat scrap	1	.086	.044	.38	18.4
17% Meat scrap	2	.091	.038	1.52	7.4
19% Meat scrap	3	.113	.036	.32	12.0
15% Fish meal	4	.09	.047	1.61	37.0
17% Fish meal	5	.077	.036	.36	26.5
19% Fish meal	6	.089	.036	.14	9.8
15% Dried skimmilk	7	.084	.043	8.16	9.4
17% Dried skimmilk	8	.064	.031	15.30	7.6
19% Dried skimmilk	9	.046	.024	20.84	9.7
15% Mixture	10	.078	.042	3.06	3.6
17% Mixture	11	.074	.036	4.29	3.6
19% Mixture	12	.076	.032	5.84	9.0
Dried skimmilk		.033	.000	——	11.0
Meat scraps		.265	.0054	——	13.2
Fish meal		.159	.014	——	9.4
Basal ration		.108	.035	1.65	10.0

* Analysis by American Dry Milk Institute, Inc.

the heaviest average weight and were followed in order by the mixture, meat scrap and dried skimmilk groups. The 19 per cent fish meal group averaged the heaviest of all groups and the 19 per cent dried skimmilk fed group averaged the lightest in weight. The very same order of weight classifications was held by these several groups at the end of the experimental period. Those groups receiving the fish meal protein supplement weighed on the average 5.399 pounds per bird. They were followed in order by the protein mixture, meat scraps and dried skimmilk groups weighing 5.247, 5.164 and 4.313 pounds per bird, respectively. Generally, those groups fed the higher percentage protein maintained greater weight than the lower protein groups. The dried skimmilk fed groups were just the reverse, however. The less milk fed the greater was the weight.

In a consideration of feed consumption during the production period considerable weekly variation occurred among groups. The range in total feed consumed per bird by groups was from 71.612 pounds in the 19 per cent dried skimmilk group to 85.278 pounds for the 19 per cent fish meal group. There appeared to be a very close relationship between body weight and feed consumed.

Table VII presents a cost comparison of the different protein rations as used in the two tests. The last column, showing the feed cost to produce one dozen eggs, gives some very pertinent information concerning the relative values of these animal protein concentrates as used in this experimental procedure. The reader will quickly notice that the most efficient protein source from this analysis was fish meal with a feed cost per dozen eggs produced of 13.5 to 16.9 cents. The mixture, meat scrap and dried skimmilk protein sources followed in order.

The mortality which occurred during the production period is shown in Table VI. A total of 39 birds died during the period, constituting a loss of 16.3 per cent. Of this total mortality 23.1 per cent of the cases were ruptured egg yolk, 15.4 per cent indigestion, and 10.2 per cent nephritis. Other deaths were the results of cage injury, coccidiosis, peritonitis, anemia, gout, ruptured liver, ruptured spleen, ulcerated gizzard and leukemia. By referring to the mortality discussion in Test I the reader will notice that the greatest loss on both tests was occasioned by ruptured egg yolk and indigestion. Mortality attributable to the single animal protein fed groups varied between tests. For this reason no definite statements concerning the mortality preventative or causative action of these protein sources can be given.

The egg production summary as shown in Table VII demonstrates that those groups fed the fish meal protein supplement had a greater average production per bird than any of the other groups. They were followed in order by the meat scrap, mixture and dried skimmilk fed groups. There was some variation among groups as to the average number of days to first egg, but there was no definite relationship between percentage protein fed and date of first egg. The average number of days elapsing previous to the production of the first egg was 165.3, 175.3, 175.6, and 182.0 for the fish meal, mixture, meat scrap and dried skimmilk fed birds.

Egg weights were recorded for all eggs laid by each bird during the first four days of each month, beginning in October. At this initial period birds were 25 weeks of age. Eleven groups of egg weights were recorded, the total number of eggs weighed being 3,808. Table VIII presents a summary of egg weights according to groups. As reported in the discussion of Test I there is no significant relationship between percentage protein fed and size of eggs laid.

Henderson[13] states, "It has been found that the annual mean egg weight of eggs from pullets is slightly (1.5 grams) but significantly, less when pullets are fed the higher concentrations of protein supplements (15%) either in the form of milk, meat and bone meal or combinations of the two. . . . 10% of meat and bone meal supplement in an all mash ration is detrimental to egg size."

In order that we might have some information relative to the iron, manganese, copper and lactose content of the various rations, representative samples of the rations were analyzed and results are presented in Table IX. It was thought that the information might throw some light on the reason for the poor results given by the dried skimmilk fed birds. The lactose content was computed in terms of dried skimmilk. Groups 1, 3, 5 and 6, while showing some evidence of lactose content, in reality contained none; the amounts calculated in terms of dry skimmilk appear within the limits of experimental error of the method. A somewhat larger content of lactose was found in rations fed Groups 2 and 4, but no explanation of this condition is able to be made inasmuch as none of these groups mentioned above had any dried skimmilk added to the ration. The results determined for Groups 7, 8, and 9 as well as those for Groups 10, 11, and 12 appear to be within reason since increasing amounts of dried skimmilk were actually included within the rations for these groups.

Flavor and Odor Tests

From the standpoint of the consumer of poultry meat and eggs the problem of determining the causes for possible variance in flavor and odor of these products is of utmost importance. Any research problem concerned with the formulation of rations or of separate ingredients intended for incorporation in rations should be vitally concerned with the possible effects on consumer acceptance of products produced through the feeding of these rations or ingredients.

Accordingly six birds, each 78 weeks of age, were submitted to the Home Economics department for comparative flavor and odor tests. Three of these birds had been fed since hatching a liberal quantity (13%) of vacuum processed fish meal as the sole source of animal protein and three had been fed the regular meat scrap ration used in Group 3. The birds were dressed and drawn one day previous to the test and numbered by means of a metal wing band.

Sample lots of six eggs produced by similarly fed groups were also submitted for test. Eggs numbered 1 to 6 were produced by the fish meal fed birds while those numbered from 7 to 12 were used as normals.

Each chicken was roasted separately without dressing or seasoning in a 350° F. oven. The eggs were cooked by pouring boiling water over the two lots—six in each sauce pan. They were kept in this water six minutes; then each was removed from its shell to individual saucers for test.

Ten judges were used in testing the chicken and seven in testing the eggs. In Table XI where a total of only nine votes appear for either distasteful flavor or strong odor in chicken the tenth vote was stated as "undecided". The final conclusions of the judging committee were that bird number one seemed to have an off-flavor but the ten judges agreed that there was no outstanding flavor or odor which would be objectionable if they had purchased and were using any of these birds. They agreed also that all the eggs so tested had a good flavor and odor. They were unable to determine by such tests which eggs were laid by the hens fed fish meal, and which eggs were laid by those hens fed the meat scrap ration.

Asmundson et al[3] state, "Feeding rations containing 25 per cent of high grade fish meals did not produce off flavors when slaughtered birds were held at low temperatures until drawn and cooked. When birds were not starved prior to killing and were held in a warm room from 12-24 hours after killing, the flavor was generally adversely affected." Marsden[18] reports, "It was found that high grade sardine (pilchard) or tuna meal could be fed at levels commonly used, without ill effects upon the flavor of cooked turkey meat . . . however, when high grade white fish meal (East coast) was fed, fishy flavor was imparted to the flesh of the turkeys and was very noticeable." Davies and Gill[9] conclude, " . . . the occurrence of fishiness in fats is associated with the presence of traces of peroxides, formaldehyde and tertiary N, as either trimethylamine or trimethylamine oxide or both." Schroeder[29] states that there appeared to be a positive correlation between the iodine number of the abdominal fat and the intensity of fishy flavor. Knandel[16] states that they have conducted tests to determine whether excess amounts of fish meal or fish oil or both cause a fishy flavor in eggs. The determination of fresh opened out quality and hard boiled eggs was made on the basis of odor and taste. In none of the groups was there any indication that the excessive use of fish products caused fishy flavored eggs. Knandel, Hunter and Marble[17] write, "The carcasses of turkeys 28 weeks of age which had been fed either one per cent of poultry grade cod liver oil or ten per cent vacuum dried fish meal, or both, had a fishy flavor and odor."

Table XI. Summary of flavor and odor tests

	Test No.	1	2	3	4	5	6	7	8	9	10	11	12
Chicken	Distasteful flavor Yes	8*	3	1	0	4	3	—	—	—	—	—	—
	Distasteful flavor No	1	7	5	10	6	6	—	—	—	—	—	—
	Strong odor Yes	1	1	5	1	3	1	—	—	—	—	—	—
	Strong odor No	6	5	1	9	6	5	—	—	—	—	—	—
Eggs	Distasteful flavor Yes	0	0	0	2	0	0	0	0	0	0	0	0
	Distasteful flavor No	7	7	7	5	7	7	7	7	7	7	7	7
	Strong odor Yes	0	0	0	1	0	0	0	0	0	0	0	0
	Strong odor No	7	7	7	6	7	7	7	7	7	7	7	7

* Tenth vote "undecided"

Summary

As the percentage protein content of ration increased from 15 to 19 per cent, a definite increase in body weight of chicks fed these rations also occurred. These results are in harmony with previous work at this station indicating that protein levels of from 18 to 20 per cent during the first 12-week period produce the greatest gains in weight.

There is no apparent relationship between per cent protein fed and total feed consumption, but a very definite relationship occurs between total feed consumed and body weight attained throughout the experimental period.

Those groups receiving the protein mixture and fish meal supplements were significantly heavier in weight at 12 weeks of age than were the meat scrap or dried skimmilk fed groups.

Generally, the groups receiving the lower protein percentages were the most efficient in feed utilization during the growing period; i.e., 12-23 weeks of age.

Those groups receiving fish meal as the sole source of animal protein concentrate averaged (1) a heavier rate of production and produced a greater number of eggs per bird than did the other groups (2) were lowest in feed cost per dozen eggs produced, and (3) earliest in sexual maturity as measured by average days to first egg.

There appears to be no significant relationship between per cent protein fed and size of egg laid.

Percentage protein in ration did not significantly influence age at first egg.

No significant relationship was observed between mortality and source of animal protein fed.

Under the conditions of this experiment the maximum amount of protein which can be supplied from either meat scraps or dried skimmilk is quite definitely lower than that which is furnished by vacuum processed fish meal.

Odor and flavor tests on eggs produced by and carcasses of birds fed the fish meal ration containing 19 per cent protein content (13 per cent of fish meal) showed quite definitely that no outstanding distasteful odor or flavor could be detected in either the meat or eggs.

Bibliography and Selected References

1 Ackerson, C. W.; Blish, M. J. and Mussehl, F. E. "The Utilization of Food Elements by Growing Chicks" Nebraska Exp. St. Res. Bull. 94, 1937.

2 Almquist, H. L.; Stokstad, E. L. and Holbrook, E. R. "Supplementary Values of Animal Protein Concentrates in Chick Rations" Jour. of Nutrition, Vol. 10, No. 2, 1935.

3 Asmundson, V. S.; Jukes, T. H.; Fyler, H. M. and Maxwell, M. L. "The Effect of Certain Fish Meals and Fish Oils in the Ration on the Flavor of the Turkey" Poul. Sci., Vol. 17, No. 2, 1938.

4 —— and Biely, J. "Fish Meal Supplements for Chicks" I. Sci. Agr. 13: 236-248.

5 Bauernfeind, J. C. "Calcium and Phosphorus Requirements of Poultry" Abst. from Cornell Nutr. School, Oct., 1937.

6 Carver, J. S.; St. John, J. L.; Aspinwall, T. E. and Flor, I. H. "The Protein Requirements of Chickens" Poul. Sci., Vol. 11, No. 45, 1932.

7 Carver, J. S.; St. John, J. L.; Miller, M. W. and Bearse, G. E. "The Comparative Efficiency of Various Proteins for Growing Chicks" Wash. Bull. 321, 1935.

8 Curtis, P. B.; Hauge, S. M.; Kraybill, H. M. "Nutritive Value of Certain Animal Protein Concentrates" Jour. of Nutr. Vol. 5, No. 5, 1932.
9 Davies, W. L. and Gill, E. "Investigations on Fishy Flavors" J. Soc. Chem. Indust. 1936, 55, 141 T-146T. (Nat. Inst. Res. Dairying. Univ. Reading).
10 Fairbanks, B. W. "What Do You Mean Proteins?" The North Amer. Vet., Vol. 19, No. 10, 1938.
11 Fraps, G. S. and Reid, D. H. "Use of Protein from Different Sources in Feeding Baby Chicks" Poul. Sci., Vol. 8, No. 6, 1929.
12 Hamilton, T. S. "Influence of the Percentage of Protein upon the Thermogenic (specific dynamic) Effect and the Net Energy of the Diet" Abst. Jour. of Nutr. Vol. 13, No. 6, 1937.
13 Henderson, E. W. "Biological Value of Different Levels of Meat Scrap and Milk Combinations for Egg Production and the Influence of Rations and Management on Egg Quality and Egg Size" Iowa Agr. Exp. Sta. Annual Report, Part 1, 1937.
14 Johnson, O. and Brazie, D. "Comparative Value of Some Commercial Protein Supplements in the Rations of Growing Chicks" Jour. Agr. Res., Vol. 48, No. 2, 1934.
15 Kempster, H. L. and Funk, E. M. "Dry Skimmilk in Rations for Baby Chicks" Mo. Agr. Exp. Sta. Bul. 310, 1932.
16 Knandel, H. C.—Poultry Tribune, Jan., 1938.
17 ——, Hunter, J. E. and Marble, D. R. "Nutrition of Turkeys" Penna. Ann. Report, Bull. 352, Oct., 1937.
18 Marsden, S. J. "Research Reviews" Turkey World, Oct., 1938.
19 Mitchell, H. H.; Beadles, J. R.; Kruger, J. H. "The Relation of the Connective Tissue Content of Meat to its Protein Value in Nutrition" Jour. Biol. Chem. Vol. 73, 1927.
20 Morris, L. "High and Low Protein Rations Tested" Okla. Sta. Rpt., 1927-30.
21 ——; Thompson, R. B. and Heller, V. G. "The Effect of Varying the Amounts of Protein in the Poultry Ration on Chick Growth and Subsequent Egg Production" Poul. Sci. Vol. 11, No. 6, 1932.
22 Norris, L. C. and Heuser, G. F. "The Relation of the Protein Requirements of Chicks to the Rate of Growth" Poul. Sci. Vol. 9, No. 6, 1930.
23 Parks, T. B. and Rose, E. R. "The Cu, Fe, and Mn Content of Fish" Jour. Nutr. Vol. 6, No. 1, 1933.
24 Prange, R. W., Carrick, C. W. and Hauge, S. M. "Growth Value of Proteins from Commercial Animal Products" Poul. Sci. Vol. 7, No. 3, 1928.
25 ——, —— and —— "Growth Value of Proteins from Commercial Animal Products" Poul. Sci. Vol. 7, No. 1, 1928.
26 ——, —— and —— "Growth Value of Proteins from Commercial Animal Products" Poul. Sci. Vol. 7, No. 5, 1928.
27 ——, —— and —— "The Study of the Protein in a Commercial Meat Product" Poul. Sci. Vol. 6, No. 6, 1927.
28 Record, P. R.; Bethke, R. M.; Wilder, O. H. M. and Kennard, D. C. "The Comparative Nutritive Value of Different Fish Meals for Chicks" Poul. Sci. Vol. 13, No. 5, 1934.
29 Schroeder, C. H., Unpublished data.
30 Skinner, J. T., and Peterson, W. H. "The Determination of Manganese in Animal Materials" Jour. Biol. Chem. Vol. 88, p. 347, 1930.
31 St. John, J. L.; Carver, J. S.; Johnson, O.; Moore, S. A. and Gerritz, H. "The Biological Value of Rations Containing Fish Meal" Jour. Nutr. Vol. 7, No. 1, 1934.
32 Swift, R. W.; Black, Alex.; Voris, L. and Funk, E. M. "The Optimum Protein Content of Rations for Growing Chicks" Poul. Sci., Vol. 10, No. 6, 1931.
33 Tepper, A. E.; Charles, T. B. and Reed, F. D. "Protein Levels in Battery Brooding of Chicks" N. H. Exp. Sta. Cir. 40, 1933.
34 Winter, A. B.; Dakan, E. L. and Bayes, A. "Protein Levels for Finishing Pullets" Poul. Sci. Vol. 11, No. 1, 1932.