RESISTANCE OF ANIMALS TO PARASITISM AS AFFECTED BY A PROTEIN SUPPLEMENT OF SOYBEAN OIL MEAL

by

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INTRODUCTION

Natural resistance to helminthic parasites may result from one or all of such factors as age, genetic constitution and diet. It is impossible to raise chickens without their passing through the period when they are highly susceptible to helminthic infections, and it is not feasible to raise only the heavy breeds and strains of chickens with resistant genetic constitutions; therefore, diet is the best means of approach to the problem of developing natural resistance of growing chickens to helminths.

One of the most common intestinal helminths of chickens is the large roundworm Ascaridia galli (A. lineata). In a survey of helminths taken from 1000 chickens in the vicinity of Manhattan, Kansas, it was found that 49 percent of the chickens were infected with an average of 10 worms per chicken (Ackert, 1930). Ackert and Herrick (1928) studied chickens heavily infected with these worms and found the chickens to be sluggish; their feathers ruffled; wings drooped; losses of appetite, blood and weight; retarded muscle and bone development; and an increased rate of mortality particularly the first three weeks after parasitism.

In studies made of chickens parasitized with Ascaridia galli, it was found that chickens may tolerate an average infection of 17.9 worms without any significant effects provided that the chickens received the proper diet (Wisseman, 1944).

Experimental evidence stressing the importance of vitamins A and B in the diet to create natural resistance in the fowl has been presented by Zimmerman, Vincent and Ackert (1926); and Ackert, Fisher and Zimmerman (1927). Ackert and Spindler (1929) stated

that vitamin D is beneficial in protecting the host against the effects of parasitism rather than inhibiting the development of the worms. Recently Branson (1944) began to study the effects of animal and plant protein supplements upon the resistance of chickens to A. galli.

The increase of soybean production as a cheap protein source and the accelerated wartime demand for milk and meat products by our allies suggested further investigation to see if a protein supplement of soybean oil meal could replace a protein supplement of skim milk or meat scrap in the diet without lowering the resistance of chickens to the roundworm Ascaridia galli.

REVIEW OF LITERATURE

The first study of soybean oil meal as a growth factor in chickens was made by Tomhave and Mumford (1933), who found that ground soybeans supplemented with bone meal cannot replace all the animal proteins in a ration without affecting the growth and mortality of chickens. They stated that if the cost of soybean is less than 65 percent of the cost of meat scrap having 55 percent protein, then one-third of the meat scrap in the ration may be economically substituted by ground soybeans.

Many papers are now available concerning the effects of proteins supplemented by soybean oil meal in rations on the growth of animals. Christiansen, Deobald, Halpin and Hart (1939) found that soybean oil meal needs additional protein supplement for maximum growth efficiency. Winter (1943) stated that mashes having soybean oil meal as the sole protein supplement promotes

satisfactory chick growth but that this ration is inferior to one having a combination of soybean oil meal, dried whey and meat scrap. Robertson, Rhian and Palofox (1943) found that soybean oil meal is superior to meat scrap but inferior to dried skim milk in gross value in promoting weight gains in pullets and cockerels.

Polk and Barnett (1943) found that soybean oil meal supplemented with minerals compared favorably to animal protein sources in maintenance of chick weight; and that meat scrap may cause slip tendon without the addition of proper minerals. The minerals and vitamins lacking in soybean oil meal supplement may easily be supplied by pasture and artificial means (Carrick, 1942). Titus (1942) stated that properly toasted soybean oil meal is comparable to meat scrap in biological value of proteins and may partially replace animal proteins when one takes care to include extra sources of riboflavin, calcium, potassium and salt all of which are insufficiently present in soybean oil meal. Winter (1943), Tepper and Durgin (1941), Polk and Barnett (1943), Bird (1943) and Wilgus and Gassner (1941) found that combinations of two or more protein sources included in a basal ration result in promoting either better growth or higher hatchability than a ration containing protein from only one source.

That the resistance of animals to parasites is affected by nutrition was shown by Ackert and his associates (1927, 1929, 1931) in a series of studies on vitamins A, B (complex), and D. Chickens on diets lacking any of these food accessories had their resistance lowered either to the growth of the worms or to the effects of them.

Evidence that concentrates are of importance in resistance was furnished by Taylor (1943), who fed three groups of lambs and then gave them equal numbers of trichostrongylid larvae. He found at autopsy that the lambs which had a full ration of hay and concentrates had 3,000 worms, the group receiving hay only had 9,000 worms and the group receiving straw only had 14,000 worms. He also fed equally heavy infections of the same parasite to two groups of lambs. After seven months he found the fecal egg count of the group receiving the full ration to be only one-fourth the original fecal egg count; the other group which received the hay diet had risen to five times the original level.

Further evidence of nutrition as a factor in resistance was given by Shorb (1933), who found that rats infected with the tapeworm Hymenolepis fraterna had very little resistance when receiving a diet of water and white bread which was deficient in vitamins, minerals and proteins.

Luttermoser and Rex (1942) parasitized two groups of Rhode Island Red chickens with the tapeworm Raillietina cesticillus. The chickens receiving 13 percent protein showed growth retardation while the fowls receiving 26 percent protein did not. No correlation was found between number of worms present and growth rate retardation of the host.

A study of effects of different protein sources on resistance of chickens to the nematode Ascaridia galli was made by Ackert and Beach (1933). They used worm numbers and worm lengths as the criteria for measuring the degree of resistance and found that chickens receiving meat meal and skim milk in addition to a

basal cereal ration had both fewer and shorter worms than chickens receiving the basal ration plus meat scrap or peanut meal. They stated that the worms from chickens receiving peanut meal protein supplement were longer but less numerous than those from the chickens receiving the ration in which protein was supplemented by meat scrap.

In recent investigations by Branson (1944) continued studies on proteins as a possible factor in resistance to parasitism were made. Chickens parasitized with the nematode Ascaridia galli were placed on basal rations supplemented with different sources of proteins. She found that soybean oil meal used as a 20 percent supplement to an otherwise adequate ration is as effective as meat scrap or meat scrap and powdered skim milk in maintaining the resistance of chickens to the growth of the roundworm A. galli.

MATERIALS AND METHODS

The chickens used in these experiments were single comb, white leghorns purchased from commercially approved hatcheries. At intervals the chickens were ordered in five lots, 75 chickens per lot, thus continuing the experiments through a period of at least a year. Upon arrival the day old chickens were placed in an automatic brooder, and were given a standard diet for periods varying slightly with the rate of mortality. These periods varying from seven to 10 days allowed sufficient time for the weaker chickens to be eliminated before each experiment was begun.

The chickens of each lot were then weighed, banded and divided into three equal groups. This separation into groups was

based upon the individual weights. Every chicken of one group was weighed for a comparison with another chicken of approximately the same weight from each of the other two groups. The three groups had about 20 chickens each and were designated as Group I, Group II, and Group III.

The standard diet consisted of yellow corn meal 39.3 percent, ground wheat 14.2 percent, ground oats 14.2 percent, bran 7.1 percent, alfalfa leaf meal 7.1 percent, calcium carbonate 1.4 percent, salt (iodized) 1.4 percent, vitamin D supplement 1.1 percent, and manganese sulphate a trace. Group I received the standard diet plus 14.2 percent soybean oil meal and skim milk (every other day). Group II received a diet similar to Group I except that the skim milk was omitted. Group III received the same diet as Group II except that 14.2 percent of meat meal replaced the soybean oil meal.

From the time that the chickens were banded until the experiment was terminated weekly records of their weights were made. From these weights the weekly gain of each chicken, the average weekly gain of each group of chickens, and the average weekly weight of each group of chickens were carefully determined.

The parasite used was the nematode Ascaridia galli. Fertile eggs were removed from the uteri of mature worms taken from an infected bird. These eggs were cultured in a Petri dish containing some water and a few drops of one to two percent formalin. With frequent changing of the solution in the Petri dish, incubation was continued for a period not exceeding 37 days at a temperature of 32° C. The eggs were infective when they appeared clear and the coiled embryo could be seen microscopically.

Thirty days after the chickens were weighed and banded each was given 100 ± 10 infective Ascaridia galli eggs on a small piece of fine tissue paper. Twenty-one days after being parasitized, the experiment was terminated.

The small intestine from the gizzard to the yolk sac diverticulum was removed and its contents flushed out with warm water into small jars by the hydraulic method of Ackert and Nolf (1929). A few hours later the contents of each jar were emptied into a moist dish resting on a black background which made it easy to find the worms. In some cases the binocular microscope was used to find the smaller worms. The worms from each chicken were placed into a small vial along with the wing band and enough 10 percent formalin to preserve the worms.

The worms were magnified six times by a projector on a ground glass plate. A piece of onion tissue paper was placed over the ground glass plate, and the shadow of the worm traced with a pencil. By this magnification errors in measuring were reduced. The length of the drawing of the worm was measured with a wheel so calibrated as to give the length of the worm in millimeters.

Experiment 1

The single comb, white leghorn chickens used in this experiment were received as day old birds. Twelve days later they were banded, weighed, separated into three groups according to weight, and were placed on their respective diets. After 30 days the chickens were parasitized; and on the 21st day after parasitism they were killed, and the worms of each chicken were count-

ed and measured.

That the conditions under which these chickens were raised were about normal is indicated by the growth curves of Fig. 1, which represent the average weekly weights of the groups of chickens; they follow closely the normal curve for chickens of this breed as found by Card and Kirkpatrick (1918). Group I (soybean oil meal and skim milk supplement) made the best gains during the experiment, Group II (soybean oil meal) the slowest gains, while Group III (meat scrap) made slightly lower gains than Group I.

Concerning the numbers of worms, Group I had 61 worms taken from 12 of the 17 chickens; Group II had 107 worms from 13 of the 22 chickens; and Group III had 133 worms from 13 of the 20 chickens in the group. The infections ranged from one to 14 per bird in Group I, as compared to the ranges of one to 25 for Group II and one to 24 for Group III. The average number of worms per bird for Group I was 3.6 worms, Group II 4.9 worms, and Group III 6.65 worms.

The heaviest infection of 14 worms in Group I was in a chicken two grams below the average group weight; while the smallest infections were in five birds, each having but one worm, and only two of these chickens had weights below the average weight for the group. In Group II the heaviest infections of 25 and 24 worms were in two chickens one slightly below and the other well above average group weight, respectively. Only one bird of Group II had one worm and its weight was well above the average weight for the group. In Group III the infections ranged

from one worm taken from a chicken of below average weight to 24 worms taken from a bird well above average weight. The heaviest bird of Group I had two worms, while the lightest had only one. In Group II the heaviest chicken had three worms, while the lightest had none. The heaviest chicken of Group III had no worms, and the lightest chicken had four worms.

The average length of worms for Group I was 23.3 mm with a range of 20.7 mm, taken from a bird of below average weight, to 30.1 mm taken from a bird far above average group weight. In Group II the average worm length was 21.7 mm. The worms of this group ranged in length from 14.4 mm taken from a bird above average weight to 24.7 mm taken from a fowl weighing slightly below average. For Group III the average worm length was 21.6 mm. The longest worms (29.62 mm) were taken from a bird having a final weight of about 20 percent above average for the group. The shortest worms of 12.9 mm came from the lightest chicken of the group, which weighed only 450 g as compared with 640 g, the average weight of the group.

Using numbers and lengths of worms as criteria for the degree of resistance of the chickens, it appears that Group I with an average of three worms per chicken was more resistant than was Group II with an average of 4.9, or Group III with an average of 6.55 worms per bird. The data from lengths of worms, however, indicate that Group I was more susceptible (worms averaging 23.3 mm) than Group II and Group III whose average worm lengths were 21.7 mm and 21.6 mm, respectively.

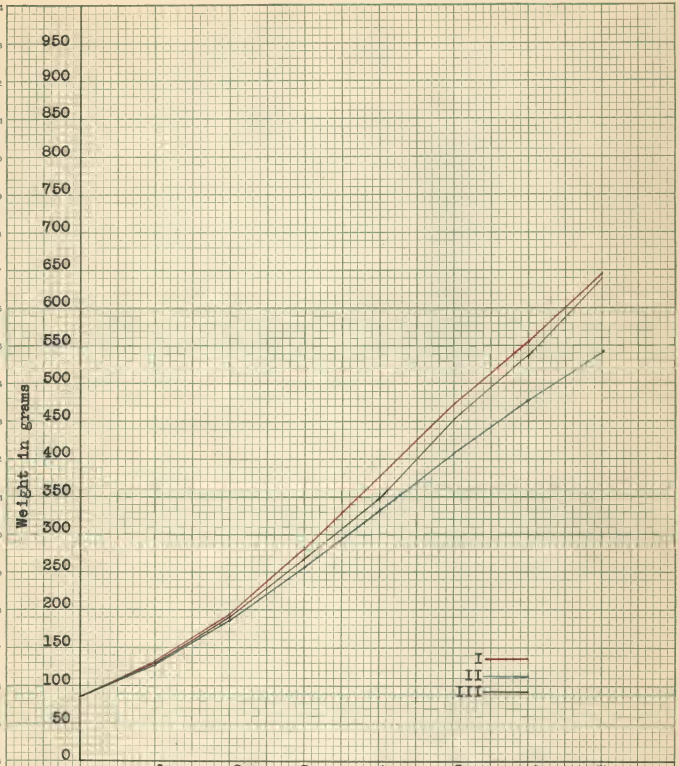

Fig. 1. Showing comparative growth rates of chickens of Groups I, II and III in Experiment 1.

Table 1. Comparison of chicken weights, and number and lengths of worms in the chickens of Groups I, II and III in Experiment 1 (initial age of chickens, 13 days; final age, 63 days).

Group I. Soybean oil meal and milk					Group II. Soybean oil meal					Group III. Meat scraps				
Chick number	Chicken's weight in grams		Worms		Chick number	Chicken's weight in grams		Worms		Chick number	Chicken's weight in grams		Worms	
	Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)
2252	99	777	0	0.0	2261	98	609	0	0.0	2280	98	825	0	0.0
2259	96	780	1	26.7	2317	96	755	0	0.0	2295	97	818	7	25.5
2310	94	674	1	28.2	2298	95	758	3	20.5	2255	93	744	21	21.2
2254	92	802	11	20.9	2282	93	684	1	18.1	2265	93	710	24	24.0
2263	92	668	1	28.0	2318	92	483	9	19.9	2251	91	680	0	0.0
					2275	90	564	24	22.0	2294	90	710	6	29.6
2268	90	768	0	0.0	2281	90	505	3	23.3	2315	90	576	4	21.7
2271	89	480	1	24.4	2278	89	533	25	24.7	2290	89	835	0	0.0
2291	88	620	6	22.1	2301	88	620	0	0.0	2302	88	680	13	22.7
2262	87	642	14	24.8	2287	87	564	3	14.4	2283	86	603	15	23.1
2257	85	518	13	22.8	2300	86	468	4	15.8	2293	85	560	4	21.3
2258	84	655	0	0.0	2284	84	524	2	20.6	2309	84	564	2	19.9
2270	84	610	6	21.7	2304	84	582	0	0.0	2320	84	609	0	0.0
2277	84	527	0	0.0	2274	83	370	2	17.4	2260	82	576	1	20.1
					2324	81	560	5	20.2	2285	81	570	0	0.0
					2307	80	475	4	15.5					
2288	79	587	0	0.0	2279	78	276	0	0.0	2308	78	650	0	0.0
2272	76	518	3	20.7	2296	78	535	13	23.0	2311	78	506	0	0.0
2292	76	778	3	30.1	2305	76	589	0	0.0					
					2314	76	489	4	15.3	2322	76	624	18	21.8
					2276	72	497	0	0.0	2306	72	450	4	12.9
2312	64	452	1	23.0	2269	64	474	5	20.3	2267	62	520	14	22.9
Average	84.54	645.06	3.6	23.3	Average	84.54	541.55	4.9	21.7	Average	84.23	640.4	6.65	21.6

Experiment 2

The chickens for Experiment 2 were weighed, banded, separated into groups according to weight, and given their respective diets eight days after they were hatched. They were parasitized on the 31st day, and 21 days later the chickens were killed and the worms were removed, counted, and measured.

The growth curves of Fig. 2 show that the three groups of chickens used in this experiment developed more slowly than the chickens used to establish the normal growth curve for single comb, white leghorns. The best weekly gains of weight were made by Group I which received soybean oil meal and skim milk. The slowest weekly gains were made by Group II (soybean oil meal). The average weekly gains of weight of Group III (meat scrap) were much lower than Group I but slightly higher than Group II.

Although the chicks received many more embryonated eggs than they retained as infections at the end of the experiment, Table 2 shows that in Group I only six of the 16 chickens carried the total of 19 worms for the group. Group II had a total of 61 worms in seven of the 17 chickens, and Group III had 60 worms in 11 of the 18 chickens for that group. The smallest infection for Group I was one worm, while the highest infection was eight worms. In Groups II and III the range of infections (smallest and greatest) were one to 34 and one to 16 worms, respectively. Group I had an average of 1.2 worms as compared to 3.6 for Group II and 3.3 for Group III.

The heaviest infection for Group I was in a chicken almost 5.0 percent above average weight; the smallest infections of one

worm came from two chickens, one slightly below and the other much below average weight. Neither the heaviest nor the lightest bird of the group had any worms. In Group II the largest number of worms were taken from a chicken 126 g below average weight; the smallest number of worms came from a fowl 94 g above average weight. Neither the heaviest nor the lightest bird of the group had any worms. In Group III the largest number of worms came from a fowl about 21 percent above average weight. Only one worm was found in each of five chickens for the smallest infection, and the weight of these birds ranged from much below to well above average weight for the group. No worms were taken from the heaviest or the lightest bird of the group.

The longest worms of 28.3 mm in Group I were taken from a chicken much above average weight; the shortest worms had a length of 17.8 mm and were taken from a fowl much below average weight. For Group II the range in length of the worms was from 14.3 mm to 22.2 mm. The shortest worms were in a chicken 68 g above average weight; the longest worms were in a fowl 25 g above average weight. In Group III the longest worms of 28.0 mm were in a bird 111 g above average weight; the shortest worms with a length of 12.6 mm were taken from a bird 44 g above average weight. The average worm length for Group II was 21.8 mm, Group III 23.3 mm, and Group I 26.4 mm.

In regard to number of worms, Group I with an average of 1.2 worms per chicken was much more resistant than Group II with an average of 3.6 worms or Group III with an average of 3.3 worms per fowl. In respect to worm lengths, Group I with an average

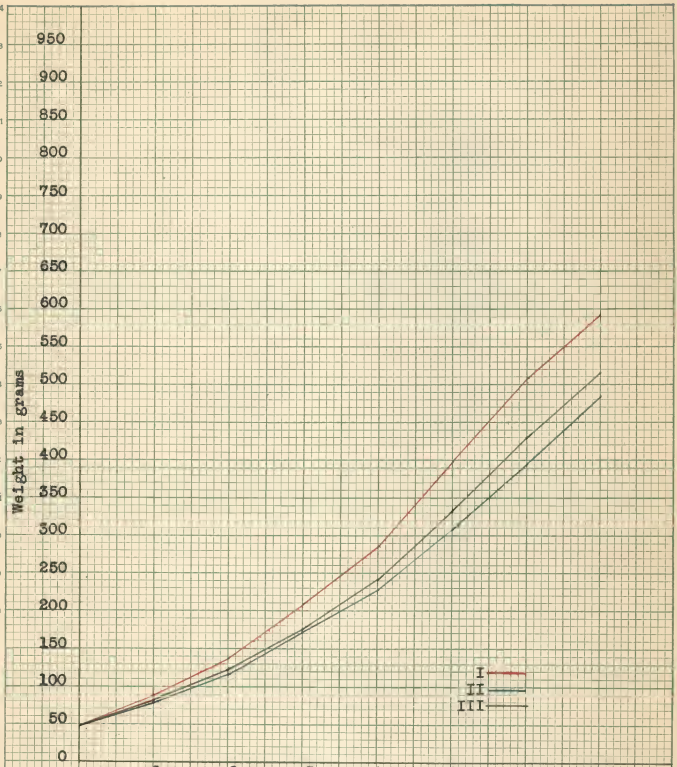

Fig. 2. Showing comparative growth rates of chickens in Groups I, II and III in Experiment 2.

Table 2. Comparison of chicken weights, and number and lengths of worms from the chickens in Groups I, II and III, Experiment 2 (initial age of chickens, 8 days; final age, 59 days).

Group I. Soybean oil meal and milk					Group II. Soybean oil meal					Group III. Meat scrape				
Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms	
	Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)
2348	62	600	3	26.6	2376	64	642	0	0.0	2353	62	560	2	12.6
2337	60	674	0	0.0	2345	59	358	34	20.8	2377	58	473	1	22.8
2327	56	618	8	28.3	2380	58	380	4	15.9	2371	58	627	16	28.0
2335	54	582	1	21.0	2334	54	582	0	0.0	2350	53	665	0	0.0
2333	52	571	0	0.0	2349	52	548	1	14.3	2336	53	270	0	0.0
					2351	51	665	0	0.0	2354	52	646	9	23.4
2372	51	584	0	0.0						2368	51	503	0	0.0
2331	50	662	3	22.2	2374	51	421	0	0.0	2356	51	519	1	12.9
2346	50	651	0	0.0	2359	50	533	3	21.8	2360	50	608	7	23.7
2355	49	654	3	23.7	2325	49	507	14	22.2	2338	50	566	0	0.0
2344	48	589	0	0.0	2352	48	560	0	0.0	2361	48	439	6	16.0
2326	46	660	0	0.0	2367	48	302	3	18.2	2330	48	562	0	0.0
2340	46	478	1	17.8	2332	46	520	0	0.0	2347	46	408	2	13.0
2358	45	628	0	0.0	2328	44	485	2	22.0	2381	45	450	1	14.0
2341	44	507	0	0.0	2343	44	214	0	0.0	2365	44	543	0	0.0
2373	44	425	0	0.0	2378	44	460	0	0.0	2379	44	448	0	0.0
					2370	42	578	0	0.0	2366	40	421	14	22.5
2375	37	569	0	0.0	2357	40	476	0	0.0	2339	38	583	1	17.3
Average	49.3	590.8	1.2	23.3	Average	49.7	484.4	3.6	21.8	Average	49.5	516.2	3.3	23.3

length of 23.3 mm had about the same resistance as Groups II and III, whose worm lengths were 21.8 mm and 23.3 mm.

Experiment 3

The chickens used in this experiment were separated into three equal groups by weight and placed on their respective diets at 11 days of age. They were parasitized at 42 days of age, and at 63 days of age they were killed and the worms removed for examination.

That the chickens used in this experiment developed almost normally is shown by the growth curves of Fig. 3. Group I (soybean oil meal and skim milk) surpassed the established normal growth curve; the other two groups developed slightly below the established normal curve. Group II (soybean oil meal) made the slowest gains, while Group III (meat scrap) made the second best gains.

Pertaining to the numbers of worms, Group I had 20 worms in seven of the 21 chickens, Group II 25 worms from nine of the 19 chickens and Group III 34 worms in eight of the 19 chickens. The range of infections per bird for Group I chickens were from one to four worms. Group II had an infection range of one to 12 worms per chicken; Group III had an infection range of one to 10 worms. The average number of worms per bird for Group I was 0.95 worms, Group II 1.95 worms, and Group III 6.65 worms.

The heaviest infection of Group I (four worms) was in a fowl 78 g below average weight. The smallest infections were in two birds with one worm each. One of these chickens was 106 g

below average weight; the other was 140 g below average weight. The heaviest chicken of the group had no worms; the lightest chicken of the group had one worm. In Group II the heaviest infection of 12 worms was in a chicken much below average weight, whereas, the smallest infections were in two below average weight chickens having one nematode each. The heaviest chicken of the group had no worms; the lightest chicken of the group had two worms. In Group III neither the heaviest nor the lightest chicken had any worms. The two chickens of Group III having the heaviest and lightest infections, respectively, for the group differed only 27 g in weight. Both fowls had weights slightly lower than average. The bird with the most worms weighed the most.

In Group I the shortest worms of 10.9 mm were in a chicken only slightly below average weight; the longest worms of 22.4 mm were in a chicken with a weight much above the average group weight. The shortest worms of Group II from a bird 111 g below average weight had a length of 13.5 mm. The longest worms of this group had a length of 20.7 mm, and they were taken from a chicken with a weight 10 g below the group average. The shortest and longest worms of Group III measured 13.0 mm and 20.6 mm. They were in two birds each weighing a little less than the average. The difference in weight of the two chickens was about 14 g. The heaviest chicken had the shortest worms. The average lengths of worms were as follows: Group I 17.6 mm, Group II 16.5 mm, and Group III 16.3 mm.

From the data of Table 3 Group I with an average of 0.95 worms per chick was more resistant than Group II with an average

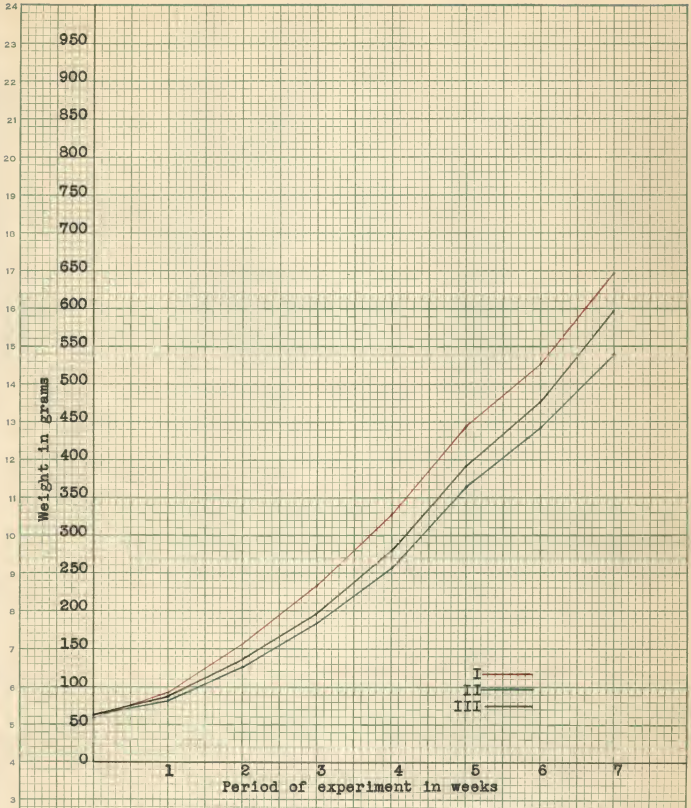

Fig. 3. Showing comparative growth rates of chickens in Groups I, II and III in Experiment 3.

Table 3. Comparison of chicken weights, and number and lengths of worms of chickens in Groups I, II and III, Experiment 3 (initial age of chickens, 11 days; final age, 62 days).

Group I. Soybean oil meal and milk					Group II. Soybean oil meal					Group III. Meat scraps				
Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms	
	Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)
2425	75	644	0	0.0	2415	78	676	0	0.0	2411	80	695	0	0.0
2428	72	742	0	0.0	2414	73	603	0	0.0	2440	73	635	0	0.0
2409	71	922	0	0.0	2413	72	600	0	0.0	2419	72	646	5	17.1
2422	70	625	2	10.9	2396	70	510	1	17.8	2420	70	845	0	0.0
2383	68	703	0	0.0	2442	70	641	0	0.0	2450	70	658	7	17.1
2424	64	587	0	0.0	2398	64	480	0	0.0	2421	65	622	0	0.0
2418	63	598	3	15.4	2432	64	568	4	18.5	2399	64	446	0	0.0
2391	62	730	2	22.4	2410	62	560	0	0.0	2386	63	657	0	0.0
2416	61	782	0	0.0	2387	61	429	8	13.5	2390	62	587	10	14.0
2395	60	558	0	0.0	2427	61	568	0	0.0	2382	60	405	0	0.0
2441	60	665	0	0.0	2401	60	510	2	16.8	2438	60	720	0	0.0
2393	59	750	0	0.0	2431	59	530	1	20.7	2443	58	509	0	0.0
2397	58	570	4	18.2	2407	58	582	3	20.2	2385	58	559	0	0.0
2417	57	640	0	0.0	2430	57	538	4	14.8	2392	56	427	3	16.9
2429	55	542	1	14.7	2389	56	538	0	0.0	2406	55	560	1	13.0
2446	52	690	0	0.0	2388	52	576	2	14.4	2405	52	598	2	16.9
2412	52	592	0	0.0	2439	52	428	0	0.0	2445	52	546	4	20.6
2433	51	655	0	0.0	2434	46	677	0	0.0	2444	49	489	2	14.3
2447	49	540	7	19.1	2404	46	461	12	17.2	2437	48	745	0	0.0
2403	49	508	1	16.9										
2436	42	565	0	0.0										
Average	59.5	648	0.95	17.6	Average	61.1	540.8	1.95	16.5	Average	61.4	597.3	1.79	16.3

of 1.95 worms, and Group III with an average of 1.79 worms. From the viewpoint of worm lengths Group I with an average worm length of 17.6 mm was more susceptible than either Group II or III, whose average worm lengths were 16.5 mm and 16.3 mm, respectively.

Experiment 4

For this experiment the chickens were weighed, banded, divided into three equal groups, and given their rations 11 days after hatching. They were parasitized at 31 days of age, and 21 days later they were killed and the nematodes collected.

The three groups of chickens had growth curves (Fig. 4) below the normal curve for single comb, white leghorns. Group II (soybean oil meal) gained weight more quickly than the other two groups until the chickens were parasitized. Group I (soybean oil meal and skim milk) and Group III (meat scrap) made approximately the same gains until parasitism. After parasitism Group I led the groups until the last week, and Group II showed a tendency to drop below the other two groups.

Group I (Table 4) had a total of 16 chickens. Sixteen worms were taken from six chickens of this group. Group II had 13 worms in seven of the 16 chickens, and Group III had 14 worms taken from four of the 19 chickens. The lowest to highest infections of Group I ranged from one to five, Group II one to three, and Group III two to eight. The average worm number for Group I was 1.0 worms, Group II 0.82 worms, and Group III 0.74 worms.

The highest number of five worms in Group I was in a chicken with a weight more than average. The lowest infection of one worm for the same group was in each of two chickens. Their weights also were above the average weight for the group. Two chickens of Group II whose weights were slightly above average had the highest infection of three worms each. Three chickens tied for the smallest infections of two worms each. One of these chickens had the smallest weight for the group; another had the highest weight; whereas, the third had about average weight. In Group III the heaviest infection of eight worms was in the heaviest chicken of the group. The smallest number of infections of two worms each were in three chickens all of whose weights were from slightly below to well above average.

The average length of worms for Group I was 22.94 mm, Group II 22.05 mm, and Group III 21.6 mm. In Group I was a chicken whose weight was well above average, and it had the longest worms of 26.7 mm. One of the lightest chickens in the group had the shortest worms of 11.9 mm. In Group II the longest worms of 25.2 mm were in the lightest chicken of the group; the shortest worms (16.5 mm) were in a chicken slightly above average weight. In Group III the longest worms with a length of 23.3 mm were in the smallest chicken of the group. The shortest worms were 17.4 mm; they were in the second heaviest chicken of the group.

From the information of Table 4 one may readily see that Group III (meat scrap) was slightly more resistant than each of the other two groups when taking worm length and worm number as the test for resistance. Group I (soybean oil meal and skim

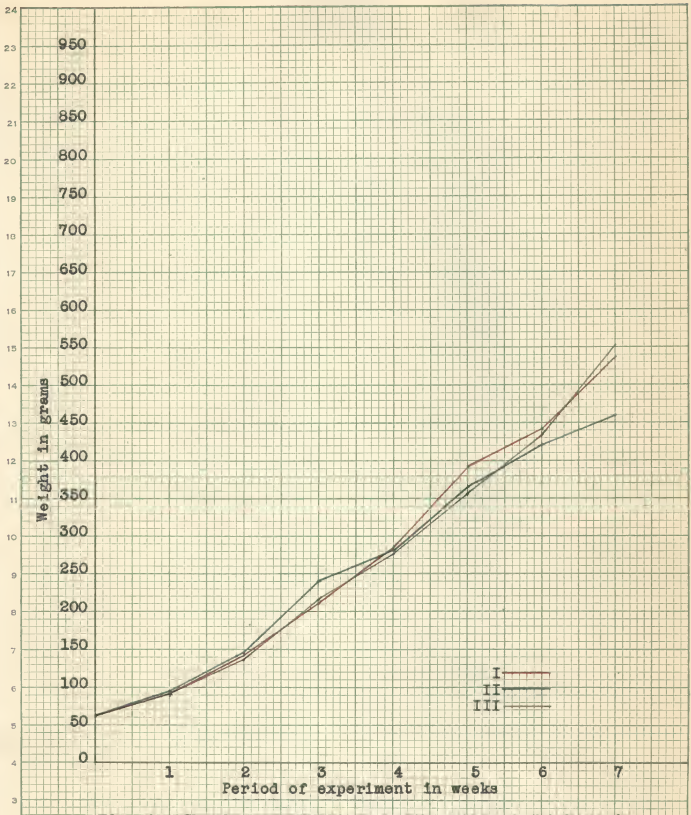

Fig. 4. Showing comparative growth rates of chickens in Groups I, II and III in Experiment 4.

Table 4. Comparison of chicken weights, and number and lengths of worms in the chickens of Groups I, II and III, Experiment 4 (initial age of chickens, 11 days; final age, 63 days).

Group I. Soybean oil meal and milk					Group II. Soybean oil meal					Group III. Meat scraps				
	Chick weight in grams		Worms			Chick weight in grams		Worms			Chick weight in grams		Worms	
Chick number	Initial	Final	Number	Average length (mm)	Chick number	Initial	Final	Number	Average length (mm)	Chick number	Initial	Final	Number	Average length (mm)
2503	50	521	0	0.0	2486	49	363	0	0.0	2466	49	401	0	0.0
2510	51	420	0	0.0	2460	50	500	2	20.2	2455	51	454	0	0.0
2477	53	457	0	0.0	2454	52	528	0	0.0	2468	52	407	0	0.0
2478	54	460	0	0.0	2467	53	496	0	0.0	2506	54	603	0	0.0
2461	55	690	0	0.0	2481	54	424	1	25.2	2500	54	582	0	0.0
2490	57	555	5	23.1	2458	55	465	0	0.0	2459	55	320	5	23.3
2484	60	500	0	0.0	2465	58	562	0	0.0	2499	60	595	2	17.5
					2464	60	532	3	21.66					
2485	62	634	2	24.3	2476	60	490	2	23.3	2505	61	652	0	0.0
2494	62	495	0	0.0	2453	62	530	3	16.5	2502	62	590	0	0.0
2491	63	610	1	22.3						2497	63	585	0	0.0
2462	64	556	6	23.6						2479	64	509	2	22.9
2508	65	449	1	11.9	2457	64	580	0	0.0	2507	64	679	0	0.0
										2472	64	410	0	0.0
2488	68	595	0	0.0	2483	67	518	1	18.0	2473	65	548	0	0.0
2492	69	653	1	26.7	2495	68	441	0	0.0	2470	67	579	0	0.0
					2474	71	537	0	0.0	2496	68	604	0	0.0
										2471	72	597	0	0.0
2452	73	570	0	0.0	2482	76	555	0	0.0	2456	73	715	0	0.0
2504	77	739	0	0.0	2480	84	744	1	22.1	2469	76	682	2	17.4
Average	62.16	539.1	1.0	22.94	Average	62.35	510.3	0.82	22.05	Average	61.8	553.2	0.74	21.6

milk) was the most susceptible of the three groups since it had the longest as well as the most worms per bird.

Experiment 5

For the last experiment the chicks were banded and grouped according to weight when 11 days old. When they had been banded and fed their rations for 32 days, they were parasitized. Twenty-one days later, they were killed and the worms removed.

That the conditions under which these chickens developed were about normal may be seen from the growth curves of Fig. 5. Groups I and III gained weight quite normally since their growth curves follow closely the established normal growth curve. Group II (soybean oil meal) made the slowest gains after the experiment had been in progress for two weeks. The group, however, lagged behind the normal curve. Group I (soybean oil meal and skim milk) was slower than Group III (meat scrap) during most of the experiment.

Groups I and III of Table 5 had 19 chickens each, Group II had only 18. Group I had 21 worms in five chickens, Group II 21 worms in seven chickens, and Group III two worms in only one of the chickens. The average number of infections of Group I was 1.10 worms, Group II 1.11 worms, and Group III 0.10 worms. The range of infections from the highest to lowest of Group I was two to seven, Group II one to six, and in Group III only one one chicken had two worms.

The heaviest infection of seven worms in Group I were in each of two chickens; one of these had below average weight; whereas, the other was slightly above average. The lowest in-

fections of two worms each were in two chickens, one with a weight above average and the other a weight below average. In Group II a chicken with a weight above average had the heaviest infection of six worms. The smallest infections of one worm were in each of two chickens whose weights were from far below average for one to far above average for the other. In Group III the two worms for the group were in a chicken of exactly average weight.

The shortest worms of Group I had a length of 10.53 mm, and they were taken from a chick whose weight was considerably below average. The longest worms of 22.5 mm were taken from a chick far above average. In Group II the shortest worms whose length was 10.7 mm were taken from a chicken of below average weight. The longest worms for the group (24.42 mm) were also from a chicken of below average weight. In Group III the only worms had a length of 13.5 mm. They were taken from a chicken whose weight was exactly average. The average worm length for Group I was 13.14 mm, Group II 18.31 mm, and Group III 13.5 mm.

The data of Table 5 indicate that Group II was much more resistant than Groups I and III when considering only worm lengths as a measure of resistance. Group III was almost as resistant as Group I. Basing resistance on the numbers of worms per group, Group II with an average of 1.11 worms was as resistant as Group I with an average infection of 1.10 worms. Group III, however, was more resistant than either Groups I and II, since it had only 0.10 worms per chicken.

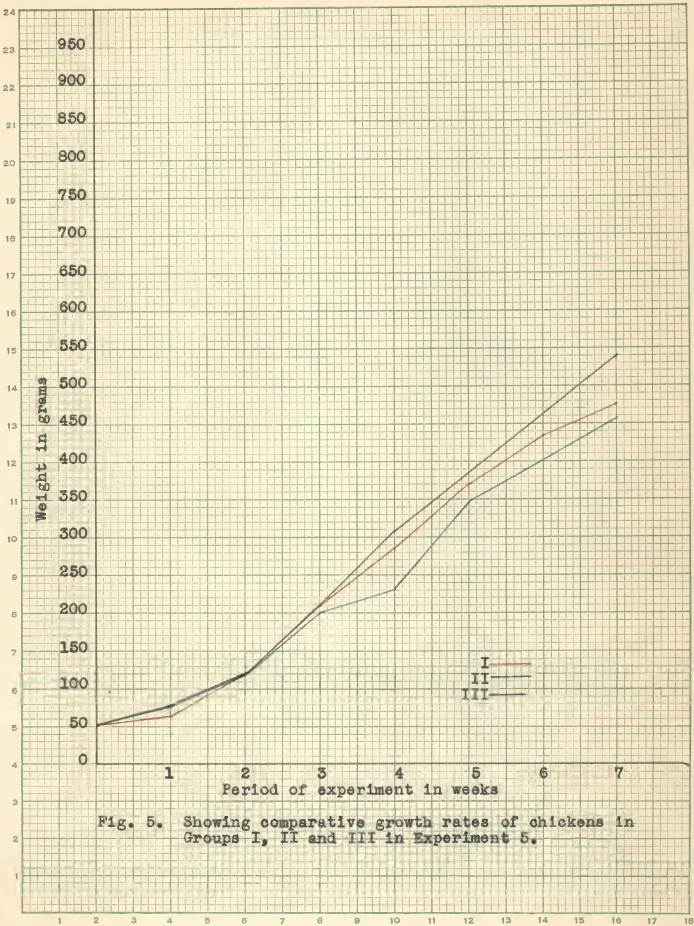

Fig. 5. Showing comparative growth rates of chickens in Groups I, II and III in Experiment 5.

Table 5. Comparison of chicken weights, and number and lengths of worms from chickens in Groups I, II and III, Experiment 5 (initial age of chickens, 10 days; final age, 63 days).

Group I. Soybean oil meal and milk					Group II. Soybean oil meal					Group III. Meat scraps				
Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms		Chick number	Chick weight in grams		Worms	
	Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)		Initial	Final	Number	Average length (mm)
2545	61	520	3	22.5	2555	60	545	1	16.4	2511	61	520	0	0.0
2554	57	470	0	0.0	2561	60	590	0	0.0	2529	58	470	0	0.0
2526	56	512	2	12.6	2521	58	430	0	0.0	2547	57	530	0	0.0
2575	55	400	2	15.5	2514	56	576	0	0.0	2518	56	770	0	0.0
										2513	55	540	2	13.5
2516	54	686	0	0.0	2527	55	520	3	17.8	2568	55	458	0	0.0
2550	54	610	0	0.0	2530	54	405	0	0.0	2570	54	500	0	0.0
2562	54	490	0	0.0	2552	54	590	0	0.0	2557	54	600	0	0.0
2571	54	530	0	0.0						2548	54	520	0	0.0
2522	53	492	7	11.2	2573	54	484	0	0.0	2520	53	450	0	0.0
2574	51	390	0	0.0	2533	53	394	0	0.0	2577	53	598	0	0.0
2528	51	406	0	0.0	2532	52	390	2	10.7	2569	51	583	0	0.0
2556	50	452	0	0.0	2549	51	520	6	17.3					
2543	49	400	0	0.0	2539	50	320	5	24.4	2540	50	370	0	0.0
2512	48	565	0	0.0	2566	50	490	0	0.0	2542	48	582	0	0.0
2544	48	412	7	10.5	2531	48	292	0	0.0					
2558	44	480	0	0.0	2564	48	540	0	0.0	2551	47	425	0	0.0
2539	44	460	0	0.0						2572	45	474	0	0.0
					2517	45	362	1	13.6	2534	44	420	0	0.0
2538	41	500	0	0.0						2567	42	520	0	0.0
2560	38	485	0	0.0	2519	42	432	2	17.8	2536	40	474	0	0.0
					2524	40	380	0	0.0					
Average	50.5	476.8	1.1	13.14	Average	51.36	483.52	1.11	18.31	Average	51.24	540.7	0.10	13.5

Table 6. Summary of average worm numbers and average worm lengths.

Experiment	Group I		Group II		Group III	
	Number per chicken (worms)	Length per chicken (mm)	Number per chicken (worms)	Length per chicken (mm)	Number per chicken (worms)	Length per chicken (mm)
1	3.6	23.3	4.9	21.7	6.7	21.9
2	1.2	26.4	3.6	21.8	3.3	23.3
3	1.0	17.6	2.0	16.5	1.8	16.3
4	1.0	22.9	0.8	22.1	0.7	21.6
5	1.1	13.1	1.1	18.3	0.1	13.5
Average	1.5	21.0	2.6	20.5	2.6	21.7

COMBINED RESULTS

In respect to the combined results of the five experiments Group I (soybean oil meal and skim milk supplement) had 90 chickens, Group II (soybean oil meal supplement) 92 chickens, and Group III (meat scrap supplement) 95 chickens. The data of Table 6 show that Group I had an average of 1.5 worms per chicken, whereas, Groups II and III each had averages of 2.6 worms. The average lengths of the worms were 21.0 mm, 20.5 mm, and 21.7 mm for Groups I, II and III, respectively.

In four of the five experiments the nematodes of Group I were shorter than those of either Group II or III. Two of the five experiments gave results showing that the worms in Group III were longer than those of Group II. The worm lengths of individual chickens in the groups had a wide range, while the combined group averages showed small differences. Group I worms had an average length of 0.5 mm longer than Group II and 0.7 mm

shorter than Group III. Group II average worm length was 0.2 mm shorter than Group III. Since the worms of Group III are shorter than those in Groups I and II in most of the five experiments, a greater trend toward establishing resistance toward nematodes is indicated in Group III by the worms taken from that group. The wide range of worm lengths of various birds within the same groups indicate that the small differences between the average worm lengths of the three combined groups are within the range of experimental error.

The five individual experiments of Table 6 indicate that in respect to worm numbers there is a trend toward establishing resistance in Group I, because in four of the five experiments the worms of Group I are as few or less than those of Group II. There is a similar trend shown by three of the five experiments between Groups I and III. The trend toward developing resistance between Groups II and III is in favor of Group III, since in all of the experiments except the first the worms are fewer.

Groups II and III each had 1.1 worms per chicken more than chickens of Group I. The wide range of infections within the groups causes the differences in the average results between Groups I, and Groups II and III to fall within the range of experimental error.

When determining resistance on the basis of worm numbers and worm growth the results are contradictory. Group I shows a greater trend toward establishing higher resistance than either of the other groups when considering resistance from the viewpoint of worm number; it is less resistant in respect to worm growth than Group III, because the worms in that group are

slightly longer than those of Group II. The combined group averages show small differences between Groups II and III both in worm number and worm length. The combined group averages in respect to worm number and worm length were subjected to biometrical treatment but the results were not significant.

When determining resistance development on the basis of worm numbers and worm lengths the data indicate that a soybean oil meal supplement to a basal ration is as effective as soybean oil meal and skim milk supplement and as meat scraps supplement in developing resistance in the fowl to the nematode Ascaridia galli.

DISCUSSION

Since the chickens of each experiment were equally divided into groups by weight, it was easy to establish their growth patterns and compare them to the established growth curves of single comb, white leghorns. In practically all of the experiments the growth curves were similar to those of Card and Kirkpatrick (1918) until the chickens had been parasitized. The lag of the growth curves of the experimental chickens after parasitism was undoubtedly partly caused by the parasitism in addition to one or more other factors. Branson (1944) stated that the cause of the decline of growth rates after parasitism is perhaps partly caused from crowding. Great care was taken throughout the experiments to make certain that the chickens had the proper required feeding space suggested by Winter and Funk (1941) They found that other factors such as temperature, ventilation and moisture are very essential and must be carefully controlled to

promote normal growth.

That Group I (soybean oil meal and skim milk) made the best gains of weight while Group II (soybean oil meal) made slightly lower gains than Group III (meat scrap) might partially be explained on the basis that in early development chickens can utilize only 41.9 percent of the protein in meat scrap, 76 percent of the protein in soybean oil meal and 88 percent of the protein in casein (Van Landingham, Clark and Schneider, 1942). This, however, does not explain the greater gains of weight of Group III chickens over those of Group II. The protein of Group I ration of both animal and vegetable source may account for the rapid gain of weight of that group (Polk and Barnett, 1943).

There is no correlation between weight of chicken and worm number or weight of chicken and worm length in the individual experiments. The combined results, however, show that the worms of Group I are both fewer and shorter than those of each of the other two groups. As indicated by weight gains, Group I received the best ration; therefore, one would expect the worms of that group to be both most numerous and longest of the three groups; since investigations of Ackert, Todd, and Tanner (1938) and Ackert, Whitlock and Freeman (1940) show that nematodes thrive better in richer media and in the host receiving the most concentrated diet. The worms of Groups II and III might have been longer than those of Group I, because the worms of the two former groups were more numerous. Ackert and Herrick (1928) found that with a greater number of infections the toxins secreted as waste by the worms are absorbed by the host with the result that the resistance of the host may be reduced.

Malaquin (1901) studied the effects of crowding on sex in some parasitic species. He stated that in species of Monstrillidae where there is a difference in size of male and female, excessive crowding results in the production of more males. Since the male ascarids are shorter than females, that might be an explanation for the worms being slightly shorter and fewer in Group I than in Groups II and III where the worms were more numerous.

From another viewpoint one might expect the worms of Group I to be both shortest and fewest of the groups. The more rapid increase of weight in Group I might indicate an earlier maturity with an earlier increase in development of goblet cell immunity, which may cause worm development to be retarded at an earlier date (Ackert, Edgar and Frick, 1939; Ackert, Porter and Beach, 1935; and Porter and Ackert, 1933).

There were no differences in worm number and only slight differences in worm length between the chickens of Groups I and II.

In the paper by Branson (1944) it may be noted that she had both shorter and fewer worms per group of chickens than the chickens in these experiments. That may easily be accounted for. The first few hours after parasitism many of the infective eggs may pass out with the feces. The chickens may pick the dropping wires and again ingest many of the eggs as accidental infections. Such small worms in the present study would be eliminated by dipping the wires in an aseptic dip on the second and third days after parasitism.

The lack of significant differences in the present results might have been due to the optimum protein level. Taylor (1943) in his experiments on lambs showed that the richer foods promoted greater resistance toward the Trichostrongylid larvae; and Wisseman (1944) found that with the proper diet chickens may carry as many as 17.9 worms without the host showing any effects. The average worm numbers per group of chickens in these experimental results were far below those of Wisseman. The results might have been more striking if the chickens had been parasitized at an earlier age, since older chickens have a larger number of goblet cells which secrete mucin containing an inhibitory worm growth factor (Ackert, Edgar and Frick, 1939). The goblet cell mucus of seven-day old chicks has but little of the inhibitory growth factor.

SUMMARY

1. A series of five experiments was performed on 275 chickens to ascertain if a basal ration supplemented by soybean oil meal could replace that supplemented by meat scrap or by soybean oil meal and skim milk every other day in maintaining resistance of chickens to the roundworm Ascaridia galli.

2. The chickens of each experiment were divided into three equal groups by weight and given a basal cereal ration including adequate minerals and vitamins. In addition Group I received 14.4 percent soybean oil meal and skim milk every other day; Group II 14.4 percent soybean oil meal; and Group III received 14.4 percent meat scrap.

5. Weekly records of the chick weights were made after the chickens were divided into groups.

4. About five weeks after hatching the chickens were fed 100 ± 10 embryonated Ascaridia galli eggs. Three weeks later the chickens were killed and the worms removed for examination.

5. The criteria for judging the degree of resistance of each group of chickens were worm numbers and their average lengths.

6. Group I made the best weekly gains of weight. Group II made weekly gains of weight slightly lower than those of Group III.

7. Group I had an average of 1.5 worms per chicken while each of the other groups had 2.6 worms.

8. The average worm length for Group I was 21.0 mm, Group II 20.5 mm, and Group III 21.7 mm.

9. Since the data indicate no significant differences between the groups of chickens, a basal cereal diet containing 14 percent soybean oil meal may replace that of either an equal amount of soybean oil meal and skim milk every other day or that of meat scrap for a period of two months without lowering the resistance of the fowl to the nematode Ascaridia galli.

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