CXXVI. EXPERIMENTS ON NUTRITION. VII. FAT-SOLUBLE VITAMIN REQUIREMENTS OF CHICKENS.

By ROBERT HENRY ADERS PLIMMER,
JOHN LEWIS ROSEDALE (*Beit Memorial Research Fellow*)
AND WILLIAM HENRY RAYMOND.

*From the Chemical Department, St Thomas's Hospital Medical School,
London.*

(Received June 14th, 1927.)

OUR original objects in the study of the rearing of chickens were to ascertain the minimum quantities of each vitamin, in terms of cod-liver oil, marmite or yeast, and orange juice, that were required [1922]. We have found [1923, 1] that vitamin C is not required, that the vitamin B requirement is 9 % of marmite [1923, 2], or 10 % of dried yeast [1927]. The quantity of fat-soluble vitamin in terms of cod-liver oil has in the meantime been determined by Dunn [1924] at 0.5 %. Emmett and Peacock [1923] have also referred to the requirement of vitamin A by chickens and contrasted their requirement with that of pigeons and rats. Pigeons need very little, if any, and rats were thought to need less than chickens.

It became necessary for us, in connection with our work on the balance of food by vitamin B, to ascertain the amount of fat-soluble vitamins required, since a possible cause for the bow legs and other deformities observed on a high protein diet was little cod-liver oil in the diet.

EXPERIMENTAL.

These trials have been made during the course of the previous experiments. The conditions of rearing were the same as then described.

All the cod-liver oil has been obtained from the same source and said to be of the same quality. It was procured in 1 or 2 gallon lots at different times and may not always have contained the same amount of fat-soluble vitamins. This may account for slightly different results with approximately the same quantity of the oil. It was not possible to test each lot for its vitamin content by special experiments.

A series of experiments, as shown in Table I, has been made.

The first three experiments were made in the same fashion as the first three series with high protein (see foregoing paper), in which one part of cod-liver oil was made up with the food. Group XXIII is the corresponding one to those in this series. The last five experiments were made with a diminishing percentage of cod-liver oil. Groups XXXIII and XXXV are controls.

Table I.

Group	White rice	Dried yeast	Fishmeal	Cod-liver oil	No. of birds	Losses
XXIV	90	20	5	0	8	8
XXXI A	90	20	5	0.5	3	2
XXXII A	90	20	5	0.7	8	4
		or				
XXIV	78	17	4	0		
XXXI A	78	17	4	0.4		
XXXII A	78	17	4	0.6		
XXXIX	75.3	16	8	0.7	8	0
XLIII	75.5	16	8	0.5	9	0
XXXI B	75.7	16	8	0.3	8	1
XXXII B	75.8	16	8	0.2	8	1
XLVIII	75.9	16	8	0.1	7	2

Group XXIV. All the birds died within 4 weeks. Autopsy showed that the bones were soft. The intestines showed no special abnormality, but the kidneys were generally pale in colour. In one bird the body cavity was full of water.

Group XXXI A. The birds were clumsy on their legs in the 3rd week; the legs were stretched outwards rather than twisted as in the abnormalities on the high protein diets. The two losses were in the 4th and 5th weeks. The yolk sacs were found not to be completely absorbed. The livers were not normal and the kidneys seemed distended. The excretion of these birds seemed difficult. The remaining bird was then placed in the group XXXII A.

Group XXXII A. The four losses occurred in the 3rd and 4th weeks. All these birds showed some congestion round the intestines; the guts were clean. The lungs of all were congested and they died of pleurisy. The other birds seemed fairly normal. The experiment was not continued further, as it already indicated that 0.6 part of oil was hardly sufficient. The early deaths of these birds in contrast with the longer life of the birds in the protein series is remarkable. The slightly larger quantity of cod-liver oil in those experiments was at any rate beneficial, though it may not have been enough. The later experiments were made to compare with the fourth series of protein experiments and the series with high fat and carbohydrate.

Groups XXXIX and XLIII. The birds in these two groups were probably the best birds that were reared in any of our experiments. Those of group XLIII with one cock were kept altogether for about 40 weeks and never showed any signs of illness, or deformity. They started laying in the 24th week. Many of the first eggs were soft, and the birds were egg eaters. On testing for fertility by incubation the eggs were mostly unfertile.

0.5 % of cod-liver oil of good quality is sufficient to rear chicks to maturity.

The other experiments in this series were made to find out how far the quantity of cod-liver oil could be reduced.

Group XXXI B with 0.3 % of oil gave a good lot of birds with only one loss. This bird was weak on its legs in the 12th week and was killed in the 19th week. There was no fat inside, but the appendices were slightly swollen; no sign of gut stoppage could be found. The gut was practically empty; the

heart was possibly a little larger than normal. Examination of the birds at the end of the experiment when they were killed showed the intestines to be practically normal; the appendices were not quite normal in all the birds; in one case there was dark food material in the appendices. The hearts seemed slightly large.

Group XXXII B. The one loss was in the 9th week. This bird was weak on its legs and was chloroformed. It had a large wound in one leg, probably from injury. No abnormality could be seen internally. Two of the birds had deformed wings, but no special error could be detected in the internal organs after death. There was a little fat round the gizzards, in one case there was fat round the heart.

Group XLVIII. The first loss was in the 5th week. The kidneys were very pale. The appendices were distended and there was blood on the food residues in them. The rest of the gut seemed normal. The other loss was in the 15th week. This bird was shaky for the previous 2 weeks and had to be killed. The intestines seemed normal, though dark food material was present in the appendices.

It was remarkable that the birds could be reared on such small quantities of cod-liver oil as 0.1 and 0.2 %. In appearance, however, the birds could not be said to be quite fit and well.

A comparison of the weekly weights (g.) of the different groups, given in Table II, shows that the rate of growth is almost the same in the several groups. The cocks grew more slowly on quantities of cod-liver oil below 0.5 %, as was made evident first at the 10th and 11th weeks.

Table II.

Group ... Cod-liver oil % Week	Cocks				
	XLVIII 0.1	XXXII B 0.2	XXXI B 0.3	XLIII 0.5	XXXIX 0.7
0	41	38	38	41	39
1	73	56	54	61	68
2	117	82	86	102	128
3	183	148	140	176	211
4	272	236	192	215	299
5	325	348	273	315	384
6	407	502	357	442	502
7	550	653	461	552	623
8	678	810	650	726	827
9	833	993	847	956	963
10	995	1085	957	1135	1181
11	1155	1290	1231	1362	1401
12	1388	1485	1363	1621	1682
13	1527	1540	1611	1817	1856
14	1755	1847	1808	2074	2105
15	2082	2010	1988	2314	2304
16	2068	2235	2185	2520	2586
17	2372	2505	2249	2794	2730
18	2618	2547	2537	2794	2910
19	2892	2805	2735	3066	3045
20	2972	2800	2974	3007	3348
21	3075	2745	—	3112	3485

Group	... Cod-liver oil %	Hens				
		XLVIII 0.1	XXXII B 0.2	XXXI B 0.3	XLIII 0.5	XXXIX 0.7
Week						
0	40	39	39	37	38	
1	71	52	55	56	70	
2	119	78	88	92	117	
3	182	124	137	154	175	
4	294	187	185	187	243	
5	298	269	275	260	305	
6	383	361	357	372	402	
7	490	476	445	477	500	
8	593	588	610	615	637	
9	732	745	790	796	768	
10	865	855	878	939	915	
11	1033	1009	1085	1079	1050	
12	1233	1178	1162	1263	1238	
13	1373	1275	1330	1404	1300	
14	1622	1501	1432	1549	1455	
15	1687	1587	1548	1684	1578	
16	1712	1765	1690	1810	1737	
17	1872	1903	1748	1950	1807	
18	2025	1914	1960	1954	1927	
19	2173	2117	2095	2161	2000	
20	2236	2177	2130	2142	2122	
21	2370	2030	—	2259	2220	

The earlier experiments showed that 0.4 and 0.6 % of cod-liver oil were too little. The later experiments showed that 0.5 % was enough. The actual quantity depends upon the actual value of the cod-liver oil. In general it may be said that 1 % will be an ample quantity.

Experiments on a maize diet.

Some work in another direction using maize as a source of carbohydrate and vitamin B has led to another test regarding the requirement of cod-liver oil in the diet. There have been three groups tried so far for this purpose.

Diet.

Group	Maize	Fishmeal	Cod-liver oil	No. of birds	Losses
M V	89	10	1	8	0
M VI	90	10	0	9	5
M VII	89.75	10	0.25	6	1

M V birds have been reared successfully.

M VI birds showed definitely in the first 4 weeks symptoms of rickets and five died, showing congested intestines and appendices with stiff pasty food. These birds are shown in Plate VI, fig. 6.

Their appearance is quite different from that of the birds on high protein diet. Their legs are stretched outwards. The high protein birds had either bow legs or were knock-kneed. Often also the birds with too little vitamin B had a twisted leg. The outstretching seems to be the sign of rickets in chicks. In the early symptoms of polyneuritis the bird tends rather to sit on its legs and one leg tends to bend underneath the bird.

M VII birds, except one, have lived for 8 weeks and up to that time have shown no signs of rickets in their legs. Signs have then appeared.

It is thus essential to add cod-liver oil to the maize diet to rear chicks, and 0.25 % is too little.

Just as in the rice-dried yeast birds the minimum quantity of cod-liver oil appears to be 0.5 %.

We have several times observed that on keeping groups of birds beyond maturity these small quantities of cod-liver oil are not enough. The eggs have been unfertile and if fertile did not hatch, or the chicks soon afterwards died. On raising the cod-liver oil to 3 % improvement in fertility and hatching was observed. It is proposed at a later date to test this point specially.

SUMMARY.

The quantity of cod-liver oil that is required for rearing chicks is 0.5 % as a minimum. Samples of cod-liver oil, presumably of the same quality, vary and it is better to take 1 % as the smallest quantity.

Part of the expense of this work has been defrayed out of a grant to one of us from the Government Grant Committee of the Royal Society, to whom we express our thanks. Dried yeast has been kindly placed at our disposal by the Marmite Food Extract Co., Ltd.

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