XCVI. THE REARING OF CHICKENS ON THE INTENSIVE SYSTEM. PART IV. C-VITAMIN REQUIREMENTS OF CHICKENS AND OTHER BIRDS.

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THE growth of the chick in the shell to the day of hatching is one of the best indications that C-vitamin is not needed by the growing bird, since there is no evidence to show that the contents of eggs have any anti-scorbutic value. Further, in those species of animals which suffer from scurvy, the young are most quickly affected. These considerations suggested to us that birds would not require C-vitamin at any time during their lives. The earlier workers upon beri-beri maintained chickens for many weeks upon a diet free from C-vitamin. More recently, Shorten and Ray [1921] kept fowls for 13 weeks on a diet of dried vegetables, proved by experiments on guinea-pigs to be free from C-vitamin, but their birds died from some unknown causes.

Sugiura and Benedict [1923] have kept pigeons on a diet without C-vitamin for 147 days. They consider also that A-vitamin is not required by pigeons (or at most only a very small amount). The birds produced eggs and raised their young on the same diet. Chickens have been kept by Mitchell, Kendall and Card [1923] for about 20 weeks on a diet not containing C-vitamin; the addition of food with C-vitamin to a control set of birds made no appreciable difference to the rate of growth. These observers, and also Emmett and Peacock [1923], find that A-vitamin is needed in considerable amount by chickens.

In view of the fact that scurvy, which is due to the absence of C-vitamin, does not appear in man for a period of four to six months, though guinea-pigs succumb in three to four weeks, a period of 20 weeks can hardly be considered sufficiently long to prove that chickens do not need C-vitamin. At any rate birds should be maintained on such a diet for twice as long as the fatal period in man, *i.e.* for 8 to 12 months. This long period was designed for our experiments and in that time it was expected to raise another generation. The

experiments have been extended to pigeons and other birds. Though success in raising a new generation has been very limited, which appears to be connected with some other deficiency in the diet, it may still be concluded that chickens, pigeons and other birds never seem to require the addition of C-vitamin to their food. The addition of green food to the food of birds so constantly advised by poultry keepers is not for the C-vitamin which it contains.

EXPERIMENTAL.

Chickens.

The birds used in these experiments were those of Group VI and also Group VII. The pigeons were those also described in Part III [1923]. The other birds were ducks, geese, guinea-fowl, turkeys and pheasants. With these latter birds the main experiment was in connection with their comparative B-vitamin requirements (see Part V, p. 794).

Group VI. The chickens of this group were formed into a breeding group on Dec. 19th, 1922, and kept until Aug. 10th, 1923, at which date the experiment was concluded. Throughout the whole period lasting for nearly 14 months these birds were given the same diet of white rice and dried skim milk supplemented with marmite and cod-liver oil.

Eggs were laid regularly from Dec. 1922 to Aug. 1923. The egg record is not of any value, since many eggs were laid in the house, or run, and were eaten by the birds. In order to stop the egg eating, the amount of marmite in the diet was raised on Jan. 15th to 4.5 g., on Feb. 1st to 5.25 g., on Feb. 16th to 6 g., on Mar. 13th to 6.75 g. per 90 g. of rice or 120 g. of food. This did not altogether stop the egg eating.

The hatchability of the eggs was not tested till Feb. 5th. Those laid between this date and Mar. 7th were not fertile. Most of the eggs laid between Mar. 7th and Apr. 9th were unfertile, but five had germs; these were not strong enough to hatch.

The A-vitamin content of the eggs was now investigated by Miss Coward and Mr Channon, whose results will be published shortly. The A-vitamin content was found to be below normal. In consequence of this deficiency the amount of cod-liver oil in the diet of the birds was raised from 0.5 to 2 cc. per bird per day on Apr. 18th.

Eggs tested at the end of April and beginning of May showed greater fertility, but still did not hatch. Many of them had well developed chicks. This ill success in hatching may have been due in part to the incubator, which was of the laboratory pattern not adapted for hatching eggs.

It became possible to test the hatchability of eggs laid in June under a broody hen. Out of three eggs tested one hatched out and has been reared successfully to the middle of August. The other two eggs were not fertile and were laid by a hen whose eggs had throughout been unfertile.

At the same time as these eggs were put under a broody hen, two eggs from a hen of Group VII were also tried; both were fertile and chicks hatched. A second generation has thus been procured from birds whose diet has not contained C-vitamin. As Group VII had given eggs from which birds could be hatched it became unnecessary to keep the birds of Group VI after they had been on a diet free from C-vitamin for about 14 months. The group was therefore got rid of.

During the course of the experiment one of the hens was found dead on inspection in the morning. No actual cause could be found on post mortem examination. An egg was found fully formed in the oviduct and death was probably due to its being egg bound.

Two hens died in July. One of them, an excellent egg layer, had its legs broken probably by the cock and evidently died of the shock. The other never laid an egg; like the hen which died at the end of the ninth week it was found to have a fibrous ovary.

Two other hens were bad egg layers. One laid a few eggs in January. The other, as far as we were able to notice, never laid an egg, though she may have laid in the run and eaten it. Post mortem examination of these hens showed in each case a well developed ovary with eggs in the several stages of development. Both the bodies were covered with fat and in the abdomen there were masses of fat weighing in each case over 500 g. The fat was quite white, owing to the colourless diet of rice and dried skim milk. This fat will have been formed from the carbohydrate and protein of the food which contained only 0.5 % of fat.

As was to be expected from the work of Palmer and Kempster [1919] the yolk of the eggs was colourless. Such white yolks were not observed by them nor by us in the eggs of the birds of Groups I to III. The whiteness of the yolks was best seen after hard boiling; it was then difficult to distinguish between white and yolk. Colour of yolk and reproduction have thus no relationship. The yolk of one of the eggs was analysed and found to correspond with the normal:

	Water %	Ash %	Protein %	Fat %
White yolk	44.4	1.8	15.8	36.7
Normal yolk	47.1	2.0	15.5	33.3

The palatability of the eggs was not different from that of the ordinary egg with yellow yolk.

The chicks hatched from these white yolk eggs were almost pure white, instead of the usual yellowish colour.

The size of the eggs on the average was normal; they seldom exceeded 2 oz., in general they averaged about $1\frac{3}{4}$ oz., or 50 g.

It might appear from these experiments that hatchability was largely connected with the A-vitamin content of the food. This is probably only one factor of that problem; it is much more likely that protein, B-vitamin and proper salts are also concerned.

Group VII. The birds of this group were made into a breeding pen on Apr. 14th, 1923 (see Part III). After one week on the former diet of white rice, dried skim milk, dried yeast and cod-liver oil, the diet was changed to the simplest possible. It was composed of 100 g. rice, 20 g. dried yeast, 0.25 g. of salt and 1 g. of quick lime, slaked with water before being added to the food. The quantity of dried yeast was chosen as 20 g. as it had previously been found that 8.6 % of marmite = 17.2 % of dried yeast was a sufficient addition for 90 g. of rice and 5 g. of fish meal. This diet had the composition:

Water	Salt	Ash	Fibre	Protein	Fat	Carbohydrate
9.8 %	0.2 %	2.7 %	0.2 %	12.5 %	0.5 %	74.0 %

The lime was added as it was found, on analysis, that dried yeast contained only traces of calcium.

Cod-liver oil to supply A-vitamin was omitted from the food up to the end of June, but the birds were given cod-liver oil by hand at the rate of 1 cc. per day for periods of five to seven days. The cod-liver oil was not given to any of the birds until May 15th, *i.e.* until they had been on the new diet for three weeks, at which period several of the birds were unwell. It was then given to the cock and two hens. The effect was striking. The cock who had lost his voice, again began to crow and became very active. The hens which had ceased to lay once more began laying. The dosing of these birds with cod-liver oil was then stopped and two other hens were given the cod-liver oil. They also began to lay after the doses of oil. These remarkable observations require repetition on another set of birds. They were not continued at the time, as birds from another group were mature and were added to this group as a breeding group, and as it was desired to ascertain the egg production and hatchability on this simple diet. Cod-liver oil was added to the food at the rate of 2.5 cc. per 100 g. of rice. The composition was not materially changed except as regards the fat as seen from the following figures:

Water	Salt	Ash	Fibre	Protein	Fat	Carbohydrate
9.6 %	0.2 %	2.7 %	0.2 %	12.3 %	2.5 %	72.4 %

with a protein to fat and carbohydrate ratio of 1 : 6.1.

The results of this diet as regards fertility and hatchability of the eggs will not be known for some time.

At the time of change to this diet on July 1st the birds had been kept without C-vitamin for six months. The eggs laid between Apr. 29th and June 30th were tested for fertility and hatchability. The first eggs up to May 8th were all unfertile. Two eggs laid in June were put under a broody hen and both hatched out and both chicks were thriving well in August. The other eggs were incubated. They were mostly fertile and had well developed chicks; the ill success in hatching was probably due to the incubator being

not specially adapted for hatching eggs. C-vitamin thus appears to be not needed by the chicken at any period of its life.

Pigeons.

The two pairs of pigeons (see Part III) previously kept on a rice and fish meal diet for the comparison of marmite and cerema were placed, on Apr. 25th, 1922, on a diet consisting of 90 g. oatmeal, and 15 g. fish meal (1). This diet had the composition:

Water	Salt	Ash	Fibre	Protein	Fat	Carbohydrate
8.6 %	0.5 %	4.3 %	0.9 %	18.9 %	7.7 %	59.5 %

B-vitamin was added to the extent of 0.75 g. of marmite for the red pair, and 1.5 g. of cerema for the blue pair. Cod-liver oil was not added, as it was probable that sufficient A-vitamin was present in the fish meal. The quantity of cerema was reduced to 0.75 g. 17 days after the start so that both pairs had then the same diet. C-vitamin was omitted.

The daily food consumption was on the average 45 g. oatmeal and 7.5 g. fish meal for each pair. It was greater during the periods of rearing young birds.

Both pairs of birds laid eggs every month during the breeding season, but except once in 1922 and once up to June 1923 no young lived longer than 10 to 14 days. The data of the eggs and rearing is given in the table. On account of the failure to rear the young birds, the diet was slightly altered:

(1) The marmite was omitted from the food of the red pair on June 18th, 1922; the cerema from that of the blue pair on July 13th, 1922.

(2) The fish meal was reduced from 15 to 10 g. on June 28th and to 5 g. on Aug. 1st for both pairs.

This diet consisting only of 90 g. oatmeal and 5 g. fish meal (1) was continued without alteration until June 10th, 1923. Its composition was

Water	Salt	Ash	Fibre	Protein	Fat	Carbohydrate
7.9 %	0.2 %	2.7 %	0.9 %	14.5 %	8.2 %	65.8 %

with a protein to fat and carbohydrate ratio of 1 : 5.1.

The alterations were made with the idea of diminishing the frequency of the egg laying. The failure to rear was possibly due to the desire of the hen bird to lay, as eggs appeared a few days after the young were apparently deserted. The alterations made no difference; one young bird was raised by the red pair from the last eggs of the 1922 season. The red pair again raised one young bird early in the 1923 season; this bird had crooked feet and was chloroformed. At the same time the observation was made that the parent birds did not actually desert their young. The cause of the failure was probably in connection with the diet; it is being sought for by alteration in B- and A-vitamin content. This has consisted in the addition of 1.5 g. of marmite to the food of the red pair and of the addition of 1 cc. of cod-liver oil to that of the blue pair per 90 g. of oatmeal. The effect has been the rearing of another

pair of young by the red pair, but the continued failure of the blue pair. Further experiments on this finding must await the next breeding season.

The maintenance of the two pairs in health for one year and two months, with the production of fertile eggs and at any rate three perfect young birds, is sufficient evidence that pigeons never need the inclusion of C-vitamin in their diet.

An unfortunate accident happened on Nov. 15th, 1922. The two blue birds escaped during the cleaning of their cage. The hen returned the same evening but the cock was lost. Luckily the single red pigeon which had been reared was a cock and he was now paired with the blue hen. All the data of the blue pair since Nov. 20th, 1922 refer to this red cock and blue hen. The red cock had been reared entirely without C-vitamin and the eggs produced were fertile (see table).

Table of egg production by pigeons.

Red pair				Blue pair			
Eggs laid on	Weights g.	Hatched	Result	Eggs laid on	Weights g.	Hatched	Result
15. v. 22	20.4	—	Unfertile	25. v. 22	19.0	11. vi. 22	Both squabs
16. v. 22	22.3	3. vi. 22	Squab died	26. v. 22	19.0	12. vi. 22	died
15. vi. 22	23.1	4. vii. 22	Squab died	24. vi. 22	19.0	12. vii. 22	Both squabs
	—	—	—	26. vi. 22	19.5	13. vii. 22	died
18. vii. 22	23.2	5. viii. 22	Squab died	25. vii. 22	19.0	11. viii. 22	Both squabs
19. vii. 22	24.7	5. viii. 22	„	26. vii. 22	20.0	12. viii. 22	died
23. viii. 22	22.2	9. ix. 22	Reared	25. viii. 22	19.2	11. ix. 22	Both squabs
24. viii. 22	24.0	9. ix. 22	Died	26. viii. 22	21.0	12. ix. 22	died
				27. ix. 22	18.0	14. x. 22	Both squabs
				29. ix. 22	19.4	15. x. 22	died
9. iii. 23	22.0	Eggs deserted, addled		6. ii. 23	19.5	Unfertile	—
11. iii. 23	23.0	27. iv. 23	—	8. ii. 23	18.0	„	—
8. iv. 23	22.5	Reared, crooked feet		24. iii. 23	20.5	7. iv. 23	Both squabs
10. iv. 23	23.5	—	Squab died	26. iii. 23	20.5	7. iv. 23	died
				18. iv. 23	18.5	6. v. 23	Both squabs
				20. iv. 23	19.5	7. v. 23	died
12. v. 23	23.0	29. v. 23	Both squabs	15. v. 23	19.0	3. vi. 23	Squab died
13. v. 23	?	30. v. 23	died	16. v. 23	Broken	—	—
13. vi. 23	23.0	2. vii. 23	Reared	11. vi. 23	20.0	29. vi. 23	Deserted
15. vi. 23	23.0	2. vii. 23	„	12. vi. 23	20.0	29. vi. 23	„

The last two eggs were laid after changing the diets, by adding marmite to that of the red pair, cod-liver oil to that of the blue pair.

The weights of the birds remained almost constant. Those of the blue pair rose at first after the recovery from the rice diet. The reduction after Jan. 1923 may be connected with the breeding season. The record was:

	Red cock	Red hen	Blue cock	Blue hen
	g.	g.	g.	g.
25. iv. 22	434	455	370	247
3. viii. 22	463	475	482	406
8. xi. 22	525	560	560	450
			Young red cock on	
			8. xi. 22:—430 g.	
8. i. 23	545	620	470	445
23. iii. 23	487	542	435	420
20. iv. 23	475	505	405	405

• *Other birds.*

Day-old ducks, geese, turkeys, guinea-fowl, and pheasants have been used for ascertaining their B-vitamin requirements (see Part V, p. 794). They were all given a diet consisting of oatmeal and fish meal to which marmite and cod-liver oil were added. C-vitamin was not included.

Several losses amongst all the groups occurred, due to insufficient B-vitamin, but except in the case of turkeys, several birds were raised to maturity. One turkey was kept for 10 weeks. The other birds were kept for 12 to 16 weeks.

C-vitamin thus appears to be unnecessary for these birds.

SUMMARY.

1. Pigeons have been kept for 15 months and have laid eggs and reared young on a diet without C-vitamin.
2. Chickens have been kept from the day old stage to maturity without C-vitamin. They have laid eggs and a few young chicks have been hatched from the eggs.
3. Ducks, geese, turkeys, guinea-fowl and pheasants have been reared from the day old stage for periods varying from 12 to 16 weeks without C-vitamin.
4. C-vitamin does not appear necessary in the food of domestic and farm birds.

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