III. THE REARING OF CHICKENS ON THE INTENSIVE SYSTEM. PART I. THE VITAMIN REQUIREMENTS.

PRELIMINARY EXPERIMENTS.

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THE attempts of previous workers to rear chickens in confinement under laboratory conditions have not been altogether successful. Drummond [1916] considered that there were other factors than an adequate diet which must be supplied to the growing chick. Osborne and Mendel [1918] commented upon various statements by Drummond and remarked "if the conditions under which chickens continue to grow normally in confinement can be learned, it will be possible to obtain much information of practical use in poultry husbandry." Further they say "There is a widespread belief among poultry raisers that young chickens cannot be reared under the artificial conditions of housing and diet which many other experimental animals tolerate without detriment. The current ideas are expressed in the statement that the birds must be kept 'on the ground,' that they must have exercise, outdoor life, and green food."

In their previous experiment [1916] with four chicks from 3 to 4 weeks old, two died and two were observed to the age of 77 days. Two other birds 81 days old at this time were actually kept for a total of 309 days in which time they reached maturity in apparent full vigour. The birds at the ages of 77 and 81 days had very ruffled feathers; this appearance was attributed to frequent handling. Osborne and Mendel believed the success was largely due to the supply of blotting paper as roughage. Out of another group of ten birds, two only reached maturity; the others failed to grow and showed leg weakness. We may record the better success of Buckner, Nollau and Kastle [1915] and of Palmer and Kempster [1919]. Hart, Halpin and Steenbock [1920] have emphasised the frequent occurrence of leg weakness in chickens reared in confinement and, like Osborne and Mendel, attribute the cause to

the absence of roughage from the diet. Drummond's birds were fed upon ordinary commercial chicken food; Osborne and Mendel fed their birds upon the foods which they supplied to rats, containing butter fat and protein-free milk as sources of the A and B accessory food factors, a diet quite satisfactory for their growth. Buckner, Nollau and Kastle used grain mixtures and supplied some "green" food. Hart, Halpin and Steenbock used a diet similar to that of Osborne and Mendel.

It is now known that, though rats and a few other animals can be reared on a diet containing only A and B factors, most animals, including man, require the inclusion of C factor for the maintenance of health. It was thus possible that the poor success was due to the absence of this third factor, although it was added to the diets fed by Hart, Halpin and Steenbock. With reference to this third factor, the work of Chick and her colleagues [1919] insists upon the inclusion of a definite daily quantity which must be above a certain minimal amount. The necessity for a daily amount of the other vitamins has not been so clearly established, but at any rate it is indicated by the experiments of Cooper [1913] and of Chick and Hume [1917].

In these experiments the birds have been supplied with the usual protein, carbohydrate and fat; salts other than those contained in the foodstuffs were not added. Accessory food factors have been given in the form of cod liver oil for A, autolysed yeast or marmite for B, and lemon or orange juice for C. The choice of these three substances was made on account of the general experience that cod liver oil is the most concentrated in A factor, marmite in B, and lemon or orange juice in C, as well as the fact that these substances are very fairly constant in their respective vitamin content. The diet was composed essentially of oatmeal and milk and no account was taken of the presence of vitamins in these foods. Water was always freely provided.

Arbitrary amounts of the vitamin foods had to be chosen as the requirements for chickens are unknown. Later work is designed to determine the minimal daily amount of each vitamin, and subsequently these amounts will have to be translated into the terms of natural foodstuffs as supplied by the poultry keeper. It must be pointed out that the natural foods are very unequal in their vitamin content and that at present, in the absence of chemical knowledge of vitamins, only comparable data are capable of investigation. Also, it must be clearly stated that the diet now supplied is not one that would be given under ordinary conditions to poultry.

With the food supplied 21 chickens out of 24 have been reared to maturity; two were lost from illness apparently due to insufficient vitamin B in the diet and one was lost accidentally; in other terms 91 % were successfully reared. In Part II [1922] it will be seen that nine birds out of nine, or 100 % were brought to maturity.

EXPERIMENTAL.

Housing. The chicks up to the age of about four weeks were housed in an ordinary type of foster mother, heated by a paraffin lamp¹. After this age they were kept in wooden poultry houses measuring $6 \times 4\frac{3}{4} \times 6\frac{1}{2}$ feet high with an entrance door at one end and an opening into a run at the other end. Ventilation hatches were provided at each end at the top. The run of wire netting on wooden supports on a wood floor had the size of $6 \times 4\frac{3}{4} \times 3$ feet high. Altogether there were four identical houses, two on the roof of the building, two in a room measuring $30 \times 20 \times 15$ feet high on the ground floor of the Institute. The foster mother was kept in the ground floor room.

The wooden floors of the foster mother, poultry houses and runs were covered with broken peat moss litter, except that during wet weather, sand and coal ashes were used in the houses on the roof. The peat moss litter was scraped about but, as far as could be ascertained, very little was eaten. Grit was supplied in the form of coal ashes from the age of about two months. The birds were weighed separately every two days.

Diet. There is very little information about the daily quantity of food consumed by little chicks; it is stated [Board of Agriculture and Fisheries, 1907] that chicks eat about 3 lbs. of dry food during the first eight weeks of their life. Consequently definite amounts were prepared every day; portions were given at intervals of 2-3 hours to the little chicks and 2-4 times daily as they grew older. In this way a record could be kept of the amount eaten at the different ages. It was found that the total consumption corresponded to that stated.

Kilned oatmeal of pin head size was selected as the basal diet, mainly on account of its method of manufacture which would exclude the presence of vitamins, but their entire absence could not be expected. A small quantity of milk was also given to provide extra protein; the amount was at first rather variable, but later was always measured. Towards the end caseinogen was substituted for milk in the case of half the birds and at the same time B factor was excluded, since a comparison between caseinogen and marmite and at the same time an estimate of the vitamin content of the caseinogen, were wanted.

The accessory food factors were added to the daily quantity of oatmeal. According to the health of the birds the original amounts required alteration. The course of the experiment is most conveniently divided into periods from which the variations in food consumption and vitamin needs are more easily ascertained.

Twenty-four chicks were comprised in the group, 12 white and 12 black Leghorn. They were hatched in an incubator and were from Miss Fraser's strains at the North of Scotland College of Agriculture. At the time of their arrival their age was approximately three days; several were suffering from diarrhoea and were very weak and some mortality was expected.

¹ Kindly lent by Miss Fraser of the North of Scotland College of Agriculture.

Period 1 from July 13th to Aug. 10th, 1920. The birds were housed in the foster mother and supplied daily with 120 g. oatmeal, 5 cc. cod liver oil, 0.5 g. marmite, 30 cc. lemon juice.

Extra food, as required, after the above mixture had been eaten, was given in the form of dry oatmeal, or a mixture of dry oatmeal and biscuit meal; at first 30 g. was eaten daily, but it gradually increased until at the end of the period 200 g. was eaten. Including the basal mixture, the total food consumption per bird increased from 6 to 13 g. per day.

In addition the birds were given 200 to 250 cc. of milk every day; it was mostly spilt and thus no record of its consumption could be made. On two occasions the yolk of an egg was given and lemon skins were put into the run for the birds to peck at and for their amusement; as far as could be seen, none was eaten.

On July 21st, *i.e.* on the ninth day, one of the weak birds was found dead in the outer part of the foster mother.

The other chicks recovered from the chicken diarrhoea and no signs of illness were noticed in any of the other birds.

The average weight of the birds on July 27 was 78 g.; on Aug. 20 it was 150 g. The increase averaged 5.1 g. per day.

Period 2 from Aug. 11th to Sept. 3rd, 1920. The 23 birds were now divided into two groups. Group I had six black and six white; group II had five white and six black chicks. The selection was made so that the average weight of the two groups was approximately the same: group I weighed 154, group II 156 g. per bird. The two groups were housed in the poultry houses in the ground floor room.

Each group received as basal diet 120 g. of oatmeal. The vitamins were added as before, but the amounts were divided between the two groups, except in the case of C factor. Each group received 2.5 cc. of cod liver oil and 0.25 g. of marmite per day. The difference in the amount of C factor was made on account of the stress that poultry keepers lay on green food for birds, and because, presumably, C factor is the most abundant in these foods. Group I was given 15 cc., group II 20 cc. of lemon juice per day; in the case of group I it was thus the same as before.

For the first three days extra food was given as oatmeal and biscuit meal; each group consumed about 44 g. per day. On Aug. 14th, the extra food was given as a mixture of oatmeal and milk, 10 cc. of milk being mixed with 30 g. of oatmeal. The proportion of milk was raised to 20 cc. on Aug. 26th, since the protein ratio was very low on the former mixture. The protein ratio of the total thus became 1 : 6 approximately. No account of the presence of vitamins in the milk was taken as it is now proved that the vitamin content of milk is variable and the quantity so supplied was expected to make little difference to that supplied directly.

Five days after the separation into two groups, on Aug. 15th, illness was observed amongst the birds of group I. There was no particular characteristic

sign; the birds were less active and drooped. The cause was attributed to insufficiency of C factor. The quantities were therefore increased. Group I was given 35 cc. and group II 30 cc. per day, *i.e.* in the reverse order to that previously. A little improvement was noticed, but the birds still remained unwell. Consideration was then given to the amount of B factor. The quantity of 0.25 g. to each group was very small and the amount was raised to 0.5 g. per day to each group on Aug. 19th.

After this increase some birds of group II showed similar signs of illness to those of group I, and the quantity of lemon juice was again increased to 40 and 50 cc. per day respectively to groups I and II.

Group H. One bird of group I was so ill on Aug. 24th that it was removed and housed in the foster mother (not heated). The next day two other birds from group I and one bird from group II were also put into the foster mother. This so-called hospital group H was given the basal diet of oatmeal and vitamins supplied to group II, but with the cod liver oil increased to 5 cc.; so far no alteration had been made in the quantity of A factor and the illness was possibly due to its insufficiency. The increase had no effect; the birds got no better and on Aug. 27th the first bird of group I died. Its death was diagnosed by Dr W. Taylor as due to chicken cholera.

Some of the birds now showed distinct signs of leg weakness, drooping wings and ruffled feathers. These symptoms have been described in the case of birds suffering from polyneuritis gallinarum in its early stages. The cause of the illness was thus indicated to be due to insufficiency of B factor. Extra marmite was consequently given, but owing to the poor appetite of the birds it could not be given in the food; on Sept. 1st, it was therefore supplied in the form of a 2 % marmite drink. This was greatly relished and on the third day unmistakable signs of improvement in health were observed. Just as this improvement was noticed two more birds from group II had to be admitted to the hospital group (Sept. 3rd). With the marmite drink they also got better in three days. The drink was stopped on the 9th Sept. and as the birds were now quite well they were returned to their groups on Sept. 11th.

Period 3 from Sept. 4th to 10th, 1920. The birds remaining in groups I and II were supplied from Sept. 1st to 3rd with the same daily diet consisting of 300 g. oatmeal, 120 cc. milk, 2.5 cc. cod liver oil, 0.5 g. marmite, 50 cc. lemon juice. Since there was no object in continuing the same diet to both groups, a change was made on Sept. 4th in the quantity of A factor. Group II was given 10 cc. Loss of appetite was noticed in both groups and several more birds in group II were ill. A drink of lemon juice had no effect. The remarkable effect of the marmite drink had just been observed in group H and it appeared clear that too little B factor was being supplied. The quantity of marmite in the basal diet of both groups was therefore doubled on Sept. 6th. Group I relished the increase by showing an improved appetite, but group II still appeared ill. On Sept. 8th group II was given a drink of 2 % marmite; its effect was again striking. It thus appeared clear that too little B factor had

been given and that chickens are very susceptible to an insufficiency; it was very noticeable that the leg weakness disappeared with the increase. Guinea-pigs show a similar behaviour, but their susceptibility is to C factor. The daily amount of marmite in the diet was doubled for the last two days of this period.

Period 4 from Sept. 11th to 16th, 1920. On Sept. 11th the birds of the hospital group were returned to their respective groups. On account of the death each group had now eleven birds.

The effect of the cod liver oil on group II had had the noticeable effect of producing a loss of appetite and signs of ill-health; another period of a similar diet was therefore tried. Both groups were given more marmite, 2.5 g. per day and the same amount of lemon juice 30 cc. gradually reduced from 50 cc. Oatmeal remained as before. Group I had 5 cc. of cod liver oil; group II 12.5 cc. The birds of group I (except one which was given 0.5 g. marmite, dissolved in water, by hand on Sept. 14th, after which it recovered) appeared well and had a good appetite. The birds of group II showed marked loss of appetite, and the quantity of marmite was doubled on Sept. 14th; by Sept. 17th their appetite had again become normal. The extra cod liver oil was thus not itself the cause, but rather the extra fat required B factor for its assimilation. Braddon and Cooper [1914] have made similar observations in cases of beri-beri, and have suggested that the amount of B factor ran parallel to the caloric value of the diet.

During this period a bird of group I swallowed a nail and died.

Period 5 from Sept. 19th to Nov. 10th, 1920. The above observations indicating that the amount of B factor needed bore a constant ratio to the amount of carbohydrate and fat in the diet led to a general rearrangement of the diet. For every 30 g. of oatmeal a quantity of 0.5 g. of marmite was given; cod liver oil and lemon juice were given in a constant quantity per day. The only difference in the two groups was the extra cod liver oil for group II and its balancing by 2 g. of marmite. The daily food consumption for the first part of this period was the following:

	Group I				Group II				Extra for groups I and II		
	Oatmeal g.	Cod liver oil cc.	Marmite g.	Lemon juice cc.	Oatmeal g.	Cod liver oil cc.	Marmite g.	Lemon juice cc.	Oatmeal g.	Marmite g.	Milk cc.
Sept. 19-21	180	5	3	30	180	12.5	5	30	120	2	80
„ 22-Oct. 17	180	5	3	30	180	12.5	5	30	240	4	160
Oct. 18-21	180	5	3	30	180	12.5	5	30	360	6	240

The food was supplied in two portions, and in consequence of the greater size of the birds the milk portion was rapidly increasing above the original quantity. It was therefore decided to reduce the milk to 100 cc. per day and for greater convenience all the items were made into a single mixture:

	For group I					For group II				
	Oatmeal g.	Milk cc.	Cod liver oil cc.	Marmite g.	Lemon juice cc.	Oatmeal g.	Milk cc.	Cod liver oil cc.	Marmite g.	Lemon juice cc.
Oct. 22-Nov. 10	660	100	5	11	30	660	100	12.5	13	30

These quantities were eaten daily by the birds of group II, but on two occasions they were not eaten by group I, due to the fact that this group had 10 birds against 11 in group II.

There were no signs of illness throughout this period of 54 days; the birds grew steadily, increasing on the average 25 g. every two days. Group I increased from 406 to 1019 or 613 g., group II from 329 to 1011 or 682 g. It would appear that the extra cod liver oil had a stimulating action, but as two birds of group II were small at the start and two were cockerels of a large strain, it was not a real effect.

An alteration in the housing was made on Oct. 12th, both groups being moved to the roof. The move made no difference to the regular weight increase nor to the daily food consumption, so that housing is of minor importance provided diet and cleanliness are satisfactory. During this period the cocks began to crow, the first one crowing on Oct. 13th.

Period 6 from Nov. 11th to Jan. 13th, 1921. The quantities of the several accessory factors supplied in the previous period were evidently sufficient to keep both groups in perfect health. Group III (see Part II) was receiving a diet containing caseinogen, secwa and 0.25 g. marmite per 30 g. oatmeal per day, *i.e.* half the amount of marmite. The caseinogen and secwa would thus together contain 0.25 g. of B factor reckoned as marmite. It was possible that the caseinogen alone contained B factor equivalent to that in the marmite. Caseinogen was therefore substituted for marmite in group I. It was also of interest to compare the protein of caseinogen with that contained in marmite. The diets thus became:

	For group I					For group II				
	Oatmeal g.	Milk cc.	Caseinogen g.	Cod liver oil cc.	Lemon juice cc.	Oatmeal g.	Milk cc.	Marmite g.	Cod liver oil cc.	Lemon juice cc.
Nov. 11-Dec. 6	660	100	13	5	30	660	100	13	5	30
Dec. 7-24	990	150	19	7.5	45	990	150	19	7.5	45

The increase at the later date was an extra half ration on account of the greater daily consumption; as before, group I with ten birds did not require food on two occasions.

Both groups increased in weight: group I from 1018 to 1489 or 471 g., group II from 1045 to 1515 or 470 g. per bird. No signs of ill-health were noticed. It was necessary to separate the cocks and hens at the last date. Two main groups were made: group I a white cock and four white hens, group II a black cock and six black hens. The extra cock birds were kept in separate houses. The same diet was continued to the end of the period. The hens then began to lay and another rearrangement of groups was necessary. The white birds (group IV) were compared with group III (see Part II) and the blacks were divided into two groups (I and II) consisting of three hens and a cock, the extra cock being taken from the extra set.

Period 7 from Jan 14th to Feb. 28th, 1921. Numerous experiments on the effect of vitamins on egg laying are conceivable. Since it had been found that

birds are most susceptible to insufficiency of B factor, the effect of extra marmite on egg laying was first tried.

The birds (groups I and II) were given an identical diet except that group II was given double the amount of B factor. To compensate for any extra protein in the marmite the two groups were supplied with the same total quantity, but in the case of group I half was heated in the autoclave at 120° C. for one hour to diminish the B factor. The daily diets were:

Group I						Group II				
Oatmeal g.	Milk cc.	Marmite g.	Heated Marmite g.	Cod liver oil cc.	Lemon juice cc.	Oatmeal g.	Milk cc.	Marmite g.	Cod liver oil cc.	Lemon juice cc.
360	40	6	6	3.5	15	360	40	12	3.5	15

No signs of ill-health were noticed in either group and the average weights remained constant at about 1609 g. for group I and 1638 g. for group II. There was a slight difference in the number of eggs:

Group I			Group II		
Jan. 14-31	10 weighing	45.5 g. on average	4 weighing	47 g. on average	
Feb. 1-28	27	51.5 g. „	36	51.5 g. „	

There were two double eggs weighing 84 and 73 g.

The egg laying period was too short to yield a definite result, but if any recognition can be given to the actual birds in the groups, those in group I were better and started laying earlier than those in group II, and yet more eggs were laid by group II.

The experiment had to be discontinued at this period.

CONCLUSIONS.

Chickens can be reared in confinement on a diet of oatmeal and milk if the three vitamins are all contained in the diet.

Chickens are very susceptible to an insufficiency of B factor in the diet. The amount of B factor required in the diet seems to run parallel to the amount of carbohydrate and fat. It may be represented by 0.5 g. of marmite per 30 g. of oatmeal and per 5 cc. of cod liver oil for 11 birds.

A daily amount of A factor as contained in cod liver oil of 5 cc. and a daily amount of C factor as present in lemon juice of 30 cc. suffice for 11 birds.

The above figures are not to be regarded as minimal figures.

It is probable that the necessary "green" food for fowls supplies extra B factor rather than the expected A and C factors.

It would appear that the leg weakness of chicks is due to insufficiency of B factor in the diet.

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