9-1935

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SUMMARY

1. The nitrogen, calcium, and phosphorus content of 127 newly hatched chicks was determined.

2. Thirty newly hatched chicks were fed accurately known amounts of a good chick mash for 60 days. At the end of the period nitrogen, calcium, phosphorus, and fat were determined for each chick.

3. By means of the comparative slaughter test the retention of nitrogen was found to be 37.8 per cent, calcium 43.4 per cent, and phosphorus 27.3 per cent of the respective elements fed.

4. The average gain in live weight per gram of nitrogen fed was 12.0 grams.

5. The rate of gain was 41.5 per cent of the dry matter fed.

6. The coefficient of variability was approximately 5 per cent, except for the calcium figures, which had a coefficient of 8 per cent.

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Efficient poultry production demands a knowledge of the constituents of the ration from the standpoint of proteins, energy, minerals, and vitamins. Studies on the digestibility of protein, fat, and carbohydrate have contributed much information of value, and the fund of knowledge with respect to vitamin requirements is being constantly increased. Data are also accumulating on several phases of calcium and phosphorus metabolism, chiefly in connection with rickets, osteoporosis, and osteomalacia.

The determination of accurate digestion coefficients is beset with difficulties in the case of all animals, but in trials with poultry the additional inconvenience involved in the separation of urinary and fecal matter makes desirable another means of approach to the problem.

The formulation of feeding standards for poultry has been based upon several methods of investigation. Briefly stated, these methods include:

1. The determination of the coefficients of digestibility for single feeds and mixtures of feeds (1-5).
2. Growth studies, wherein the growth secured on definite rations is related to the kind and quantity of feed consumed (6, 7).
3. Nitrogen-retention studies, involving the endogenous nitrogen excretion (8, 9).
4. The determination of the net energy requirements of fowls (10, 11).
5. The comparative slaughter test (12, 13).

Discussions of the advantages and shortcomings of these methods are readily available in the literature.

Work at this station (14), wherein balance studies were carried out in order to determine the biological value of the proteins of cereals, revealed a variation among individuals which was discouragingly high. This variation arose in part from the necessity for using an indirect means of measuring the nitrogen retained by the body. In other words, the biological value of a protein was arrived at by measuring the amount of ingested protein not utilized in its passage through the digestive tract, and after applying a correction for the endogenous nitrogen excretion, it was assumed that the remainder was utilized. The method is theoretically sound, yet it is incapable of proof other than that afforded by a low coefficient of variation in the results secured.

In view of the above facts, it seemed desirable to secure information on the value of poultry feeds by means of an approach to the problem involving the chemical analysis of the birds for the purpose of determining the actual gain of nutrients secured during a feeding trial in which the amount of food ingested was accurately known.

METHOD OF INVESTIGATION

The comparative slaughter test (17) has as its basis for estimating the initial composition of the test animals, data secured on animals chosen because of their close resemblance to them at the time of starting the trial. Applying this principle to poultry, it is possible to determine the composition of the newly hatched chick with a small probable error, which may be reduced still further by increasing the number of determinations. The data thus obtained form the basis for estimating the initial amounts of nitrogen, calcium, and phosphorus contained in the chicks. At the conclusion of the trial the test birds are killed, and the amounts of nitrogen, calcium, and phosphorus in the empty birds determined. The composition of the gain made by the experimental chick can be determined with an error, the magnitude of which is that of the estimate of the initial composition plus the error of the final analysis.

This is merely the principle of the well-known slaughter test (17) adapted to chicks. To secure information in addition to that derived from the comparative slaughter test, it is necessary to have quantitative food-consumption records.

The ease with which birds can be fed forcibly is a matter of common knowledge, but when various finely ground ingredients comprise the mash to be fed, forced feeding is not readily made a quantitative procedure. When some years ago commercial feeds of various kinds appeared on the market in pellet form, the most difficult part of the quantitative feeding of young chicks was eliminated. The experimental ration can be made into pellets of a convenient size and weighed amounts fed to individual chicks without loss. To compute the total amount of the various nutrients fed, it is only required that the ration be analyzed.

Thus two factors are determinable, namely, the amounts of the nutrients consumed and the composition of the bird at the end of the trial. A third factor, that of the initial composition of the individual, is estimated as previously stated. From these data the gain in each of the nutrients from hatching time to any given weight can be ascertained. The amount fed is known, and the percentage of the total retained by the body over the period in question is readily calculated.

This method, with a record of accurate feed consumption by each individual, constitutes a refinement of the comparative slaughter test in that the retention of the nutrients can be expressed as a percentage of the total ingested. This represents the average utilization over the period, just as the gain in weight or change in composition represents an average in the slaughter test. It does not take into account the loss of nitrogen, calcium, and phosphorus in dropped feathers, etc. What is obtained is the gain of any element secured from the amount of the element fed. The gain resulting from this feeding is a measure of the bird's requirements for growth over that period of time. If it could be determined that this growth is the optimum growth that could be secured in any event, then the requirements could be definitely stated as being the requirements for optimum growth, but such a statement is incapable of ready demonstration.

Chickens lend themselves very well to studies of this sort for the following reasons: (1) it is possible to hand-feed chicks from hatching time to any desired age without loss of feed; (2) chicks increase rapidly in weight, so that marked gains in the various nutrients in the body will be reflected in short periods of time; (3) they are inexpensive as laboratory subjects, both as regards initial cost and outlay for rations; and (4) their small size, in comparison with other domestic animals, makes an analysis of the entire carcass comparatively easy to carry out. The laboratory technique involved includes the usual planning of the ration and the selection and housing of the chicks, together with their subsequent feeding and care. The ration is mixed as a mash, but to facilitate feeding, and to prevent loss in the procedure, it is pelleted in a 5/32-inch die, which produces pellets of suitable size for hand-feeding baby chicks. These are screened to remove fine material, leaving only particles which can be readily handled.

At the beginning of the experiment, diet bottles containing 150 grams of pelleted feed are assigned to each chick. Feeding tubes are made from glass tubing with a 7 mm. outside and a 5 mm. inside diameter, and 10-20 cm. long, depending on the size of the chick. One end is flared slightly and both ends are fire-polished. The pellets for the feeding of the individual are transferred to the tube by means of a V-shaped trough of tin sheeting, 1.5 cm. deep and 25 cm. long, one end of which is closed and the other rounded sufficiently to fit the flared end of the feeding tube. By this means the tubes are readily filled without loss. The filled tube is then carefully pushed down the chick's esophagus, and the pellets expelled into the crop by means of a glass rod.

The initial feedings are the most difficult but dexterity in manipulation is acquired with practice. The number of chicks which may be started on experiment at one time is limited by the amount of time available for feeding during the first month of their life, as this operation is time-consuming. Feeding progresses more rapidly as the chicks grow, but naturally the amount of ration required at each feeding also increases. With careful technique, loss of feed is avoided, but a certain number of casualties among the chicks must be expected during the first week.

The chicks are hand-fed two or more times daily during the first three weeks. At three weeks of age it is possible to put them in tall cans where they soon learn to consume the pelleted ration from feeding cups with no possibility of loss. The chicks quickly consume their feed and are replaced in the brooder without delay. By the use of this technique, accurate individual feed-consumption records are obtained. Fresh tap water is before the birds at all times. Cod-liver oil to provide an adequate vitamin D level is fed daily by pipette.

At the conclusion of the feeding trial each chick is starved overnight, weighed, and killed by placing in a desiccator and evacuating the air therefrom, which entails no loss of blood. Chilling the carcass prevents the loss of blood on opening, after which the digestive tract from the proventriculus down (the crop being already empty) is removed and emptied. The net body weight of the bird is obtained following this operation. Nitrogen is determined on the contents of the proventriculus and gizzard, and this amount is deducted from the amount of nitrogen fed. The amount of nitrogen in the remainder of the tract is also determined.

The next step consists of the disintegration of each bird with hydrochloric acid (sp. gr. 1.18) first in the cold and later on the hot plate. Beakers, their size depending on whether one chick or a group is to be the unit of analysis, are used in the digestion, and acid sufficient to cover the carcass is added. As hydrolysis and disintegration continue, the liberated fat rises to the surface, while the rest of the liquid becomes practically homogenous. Chilling the sample solidifies the fat so that it may be removed mechanically to another beaker, where it is separated from adherent material by dissolving in successive portions of ether and by removing the ether additions and dissolved fat to a weighed flask by means of a pipette. The ether is then driven off and the fat brought to constant weight.

The portion remaining after extraction of the fat is also freed from ether and returned to the original container. If necessary the solution is concentrated before being made to volume. Suitable aliquots, ranging from one to 25 per cent of the total, are digested via Kjeldahl. When the digest contains too much nitrogen for the usual distillation, it may be diluted the desired amount and nitrogen determined on convenient aliquots. From this the total amount of nitrogen in the sample is calculated. To check the possibility of loss of nitrogen and phosphorus by removal in the fat, 25 grams of fat obtained by the above method were found to contain 0.02 per cent nitrogen and 0.03 per cent phosphorus. For a newly hatched chick, the error thus incurred in the estimation of total nitrogen and phosphorus is less than a milligram, and for larger birds correspondingly small.

A portion of the initial sample (after removal of fat) is oxidized by means of a mixture of nitric and hydrochloric acids to permit the determination of calcium and phosphorus. In addition phosphorus may be run on aliquots of the Kjeldahl digest, mentioned above, to check the preparation of the sample by digestion with nitric acid.

Nitrogen, calcium, phosphorus, and ether extract are determined for each chick and also for the ration fed. With the completion of this work the following information is available for each bird: initial weight, final live weight and net body weight, weight of feed ingested, and the weights of nitrogen, calcium, phosphorus, and fat contained at the slaughter weight.

In addition to this phase of the feeding trial it is necessary to secure data on the composition of baby chicks in order that the gain of each experimental chick may be estimated. For this purpose analyses are made by means of the technique used in the analysis of the chicks at the slaughter weight. As a result it is possible to calculate the total weight of the gain, the weights of nitrogen, phosphorus, and calcium in the gain, the gain as a percentage of the dry matter fed, the gain per unit of nitrogen fed, and the percentage of retention of nitrogen, calcium, and phosphorus.

Mitchell, Card, and Hamilton (12, 13) carried out comparative slaughter tests involving 95 White Rock and 150 White Leghorn chickens in groups varying in weight from one-half pound to seven pounds. From their data they calculated the daily increments in body weight, dry substance, crude protein, ether extract, ash, calcium, and gross energy of chickens at different body weights. With regard to the application of their data they state (13, page 127), "Their practical use in the formulation of scientific feeding standards must wait upon the satisfactory evaluation of maintenance requirements and requirements for muscular activity, and the satisfactory measurement of the wastage of food in digestion and metabolism."

It is with the wastage of food in digestion and metabolism during growth of young chicks that this paper is concerned. The net requirement of matter by chicks of varying ages can be learned from analyses of carcasses of different weights, but knowing them it is still impossible to calculate the exact quantity required because of the unmeasured metabolic losses. It is the purpose of this paper to present the data and conclusions secured in a growth study of chicks in which the net retention of nitrogen, calcium, and phosphorus was determined.

RESULTS OF ANALYSIS OF NEWLY HATCHED CHICKS

In the preliminary experimental work (15) several groups of newly hatched chicks were killed, individually weighed, and disintegrated with hydrochloric acid so that determinations could be made on aliquots of the resulting solution. With the exception of the first and second groups, each chick slaughtered weighed 37±2 grams. All had been hatched about 24 hours and had received no food. Selections were made on the basis of the weight range of 35 to 39 grams. This range was arbitrarily chosen in an attempt to reduce the individual variability. Sex determinations were not made, nor were the intestinal contents removed.

The chicks were killed after weighing, and nitrogen was determined by the modified Kjeldahl method. Calcium and phosphorus were run according to the methods of analysis of the A. O. A. C., following digestion with nitric acid. They are reported as elements, not as oxides. Individual determinations were made on 46 chicks, which showed a mean nitrogen content of 0.94±0.006 gram per chick, with a coefficient of variability of 6.8 per cent. Since these figures showed a low variability, 81 chicks were analyzed in four groups. The results of all the analyses are summarized in Table 1.

TABLE 1.—*The average composition of 127 newly hatched chicks.*

Breed	Date of hatch	No. in group	Weight	Nitrogen		Phos-phorus	Calcium	Ratio Ca:P	Ether extract
			Grams	*Gram*	*P. ct.*	*Gram*	*Gram*		*P. ct.*
Barred Rock	June 4	7	34	0 92	2.66	0.12	...	...	..
White Leghorn	Jan. 15	10	37	0.90	2.39	0.11	...	...	6.6
White Leghorn	Feb. 25	14	37	0.94	2.55	0.11	...	...	7.0
White Leghorn	Mar. 25	15	38	0.98	2.62	0.08	0.13	1.7	8.0
White Rock	May 18	15 [1]	36	0.94	2.60	0.12	0.15	1.3	7.2
White Rock	May 18	16 [1]	36	0.94	2.58	0.11	0.15	1.3	6.2
White Leghorn	May 25	25 [1]	37	1.00	2.71	0.13	0.15	1.2	5.8
White Rock	May 25	25 [1]	37	0.95	2.60	0.11	0.15	1.3	8.1
Weighted average			37	0.95	2.59	0.11	0.15	1.3	7.0

[1] These chicks analyzed in groups.

While space does not permit showing the individual analyses of the chicks in Table 1, the fact that variation was not great, coupled with the fact that the figures represent 127 chicks, should make the weighted averages reliable. Furthermore, should the error incurred in estimating the initial composition be as great as 10 per cent, even then it would be reflected as less than a one per cent error in the calculation of the gains of a 350-gram chick, as illustrated in Table 2.

TABLE 2.—*The relative error in the estimation of the gains of chicks.*

	Composition of 350-gram chick		Estimated at 37 grams	Composition of gain	10% initial error	Initial error as % of gain
	Grams	*P. ct.*	*Gram*	*Grams*	*Gram*	*P. ct.*
Nitrogen	10.92	3.12	0.95	9.97	0.095	0.95
Phosphorus	1.93	0.55	0.11	1.82	0.011	0.60
Calcium	2.66	0.76	0.15	2.51	0.015	0.60

It can be readily seen that as the final slaughter weight is increased, the relative error in the calculation of the gains decreases. This error is also reduced by increasing the number of chicks used at the slaughter weight. The data of Table 1 form the basis for calculating the gain of the chicks by assuming that their initial composition agrees closely with the values found in the table.

RESULTS FROM THE EXPERIMENTAL FEEDING

To test out this plan of measuring the percentage retention of nitrogen, calcium, and phosphorus, 40 White and Barred Rock chicks hatched from pullet eggs were started on a ration which was mixed as follows:

	Per cent		*Per cent*
Yellow cornmeal	36	Meat meal	10
Shorts	20	Alfalfa meal	8
Bran	10	Dried buttermilk	5
Pulverized oats	10	Common salt	1

Analysis of this mash gave the following results:

	Per cent		*Per cent*
Nitrogen	3.21	Crude fat	4.20
Calcium	0.70	Crude fiber	5.70
Phosphorus	0.81	Ash	6.40
Protein	20.00	Nitrogen-free extract	56.50
Moisture	7.20		

The chicks had not been fed prior to being placed on experiment. They were kept on half-inch-mesh wire under electric hovers at first, but were later placed in two sections of an electrically heated battery brooder for convenience in handling. The wire mesh used permitted the bulk of the droppings to pass through but to reduce coprophagy further the cages were cleaned several times a week. The chicks were housed in a basement room of the Chemistry building. Brooding conditions were good, but 10 chicks did not survive the forced feeding at the outset of the work. Thus 30 chicks were carried through the two months of the feeding trial. The mash was pelleted, using a 5/32-inch die, and fed to the chicks in the manner previously described.

During the first three or four weeks each chick was forcibly fed the pelleted ration in approximately the same amount daily. As soon as possible the chicks were trained to take the pellets from a feeding cup in an individual container, usually a tin can of convenient size. After a short period most of the chicks took readily to this procedure, eating their fill in a few moments, so that they could be replaced in the brooder without delay. In this trial the chicks determined their daily consumption, which resulted in varying rates of growth. Each chick was assigned individual diet bottles from which feed was apportioned twice daily, so that an accurate record of the feed eaten by each chick was maintained with little difficulty. Semi-weekly weighings were made, but the critical weights are the initial and final weights, since their difference constitutes the experimental gain. Thus during the trial live-weight and food-consumption records were kept. At the end of the trial the total nitrogen, calcium, phosphorus, and ether extract of the birds were determined after the removal of the intestinal contents. With the completion of this work the following information had been collected for each bird: initial weight, final live and net body weights, weight of feed ingested, and the weights of nitrogen, calcium, phosphorus, and fat contained at the slaughter weight.

The initial composition of each chick was calculated from its initial weight and the data found in Table 1. The gain in weight is obviously the difference between the final net body weight and the initial weight. The composition of the gain is the difference between the total nitrogen, calcium, phosphorus, and fat as determined at the slaughter weight and the estimated initial content of these nutrients. The amounts of nitrogen, calcium, and phosphorus fed each chick were calculated from the amounts of feed ingested and the percentage of each in the feed. The amount of nitrogen fed was corrected for the amount which was unused in the proventriculus and gizzard at death, but the calcium and phosphorus figures were not so treated because of the small amount of each involved—only about five milligrams.

From these figures the percentage retention of nitrogen, calcium, and phosphorus was calculated by dividing the weight of each nutrient in the gain by the weight of it fed. This resulted in figures expressing for each chick the net retention of each element studied. It is not deemed practical to include all the data collected, but a summary of the results is given in Tables 3 to 7. These allow comparisons between the males and females of Lot 1. With the ration fed to the birds of this lot the mean percentage composition of the chicks and the retention of the elements by the chicks did not vary between the sexes. The figures secured possessed low coefficients of variability, indicating that the performance of the individual did not vary greatly from that of the mean.

TABLE 3.—*Individual data on chicks.*

Chick	Composition of Chick			Ratio Ca:P	Composition of Gain			Ratio Ca:P	Ether extract
	N	Ca	P		N	Ca	P		
No.	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct*	*P. ct.*		*P. ct.*
					MALES				
1	3.04	0.66	0.51	1.29	3.11	0.68	0.52	1.31	6.0
2	2.96	0.76	0.56	1.38	3.01	0.78	0.57	1.37	7.7
3	3.26	0.80	0.58	1.38	3.36	0.86	0.62	1.39	5.4
5	3.20	0.82	0.57	1.44	3.27	0.86	0.60	1.43	6.5
7	3.01	0.74	0.54	1.37	3.06	0.78	0.56	1.39	6.7
8	3.13	0.72	0.55	1.31	3.18	0.74	0.56	1.32	8.1
9	2.97	0.72	0.56	1.27	3.01	0.75	0.58	1.30	4.3
12	2.89	0.82	0.57	1.44	2.92	0.84	0.59	1.43	9.5
13	3.02	0.78	0.55	1.42	3.06	0.80	0.57	1.40	6.8
16	3.01	0.69	0.52	1.33	3.04	0.71	0.54	1.31	8.8
18	2.85	0.73	0.55	1.33	2.87	0.74	0.56	1.32	8.5
22	3.05	0.86	0.60	1.43	3.09	0.91	0.64	1.42	7.4
27	3.48	0.88	0.59	1.49	3.56	0.93	0.62	1.50	7.2
					FEMALES				
4	2.96	0.76	0.55	1.38	3.00	0.79	0.57	1.38	10.8
6	3.04	0.76	0.55	1.38	3.09	0.78	0.56	1.37	8.2
10	3.06	0.67	0.51	1.31	3.12	0.70	0.53	1.32	7.9
11	3.11	0.75	0.55	1.36	3.17	0.78	0.57	1.37	7.8
14	2.99	0.74	0.54	1.37	3.04	0.76	0.56	1.36	12.5
15	3.22	0.71	0.53	1.34	3.29	0.73	0.55	1.33	8.1
17	2.96	0.66	0.53	1.25	3.00	0.68	0.54	1.26	8.4
19	3.31	0.79	0.55	1.44	3.37	0.81	0.56	1.43	3.9
20	3.35	0.85	0.61	1.39	3.40	0.91	0.64	1.42	4.1
21	3.21	0.87	0.64	1.45	3.27	0.91	0.64	1.42	6.8
23	3.13	0.71	0.54	1.31	3.17	0.73	0.56	1.30	4.8
24	3.24	0.72	0.53	1.36	3.29	0.74	0.55	1.35	10.5
25	3.16	0.84	0.59	1.42	3.20	0.87	0.62	1.40	10.7
26	3.23	0.77	0.56	1.37	3.27	0.80	0.58	1.38	7.0
28	3.10	0.78	0.53	1.47	3.14	0.80	0.55	1.45	8.7
29	2.99	0.78	0.57	1.37	3.01	0.80	0.58	1.38	6.8
30	3.07	0.71	0.52	1.36	3.09	0.72	0.53	1.36	10.8
Mean	3.10	0.76	0.55	1.37	3.15	0.79	0.57	1.37	7.7

TABLE 3.—(*Continued*)

Chick	Final weight	Net body weight	Initial weight	Gain in weight	Dry matter fed	Rate of gain	Gain per gm. nitrogen fed
No.	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*P. ct.*	*Grams*
			MALES				
1	224	213	27	186	456	40.8	11.8
2	248	239	26	213	496	42.8	12.4
3	254	243	33	210	509	41.3	11.9
5	295	285	31	254	626	40.6	11.7
7	296	286	33	253	595	42.5	12.3
8	296	289	26	263	624	42.1	12.2
9	321	302	30	272	614	44.3	12.8
12	346	321	27	294	666	44.1	12.8
13	346	331	26	305	726	42.0	12.2
16	361	347	28	319	758	42.1	12.2
18	365	349	26	323	746	43.3	12.5
22	448	432	41	391	978	40.0	11.6
27	580	558	42	516	1267	40.7	11.8
			FEMALES				
4	287	279	29	250	584	42.8	12.4
6	295	285	26	259	622	41.6	12.1
10	314	304	37	267	616	43.3	12.5
11	337	316	34	282	695	40.6	11.7
14	353	343	32	311	755	41.2	11.9
15	354	344	33	311	740	42.0	12.1
17	361	348	31	317	738	42.7	12.4
19	360	350	25	325	808	40.2	11.6
20	370	352	40	312	772	40.4	11.7
21	440	424	40	384	970	39.6	11.5
23	510	489	38	451	1114	40.5	11.7
24	515	504	36	468	1159	40.4	11.7
25	525	507	36	471	1190	39.6	11.5
26	553	539	38	501	1218	41.1	11.9
28	596	579	36	543	1408	38.6	11.1
29	687	657	37	620	1498	41.4	12.0
30	795	758	34	724	1732	41.8	12.1
					Mean	41.5	12.0

TABLE 4.—*Nitrogen-retention data.*

Chick	Nitrogen fed	Nitrogen in gizzard contents	Net nitrogen fed	Nitrogen in chick			Nitrogen retained
				Final	Initial	Gain	
No.	*Grams*	*Gram*	*Grams*	*Grams*	*Grams*	*Grams*	*P. ct.*
				MALES			
1	15.79	0.02	15.77	6.48	0.70	5.78	36.63
2	17.14	0.02	17.12	7.08	0.68	6.40	37.40
3	17.62	0.03	17.59	7.92	0.86	7.06	40.15
5	21.67	0.01	21.66	9.12	0.81	8.31	38.39
7	20.57	0.01	20.56	8.60	0.86	7.74	37.65
8	21.57	0.02	21.55	9.04	0.68	8.36	38.80
9	21.22	0.04	21.18	8.96	0.78	8.18	38.63
12	23.05	0.04	23.01	9.28	0.70	8.58	37.28
13	25.10	0.02	25.08	10.00	0.68	9.32	37.17
16	26.22	0.02	26.20	10.44	0.73	9.71	37.06
18	25.81	0.02	25.79	9.96	0.68	9.28	36.01
22	33.83	0.02	33.81	13.16	1.07	12.09	35.77
27	43.82	0.03	43.79	19.44	1.09	18.35	41.90

TABLE 4.—(*Continued*)

Chick	Nitrogen fed	Nitrogen in gizzard contents	Net nitrogen fed	Nitrogen in chick			Nitrogen retained
				Final	Initial	Gain	
No.	*Grams*	*Gram*	*Grams*	*Grams*	*Grams*	*Grams*	*P. ct.*
			FEMALES				
4	20.19	0.02	20.17	8.25	0.75	7.50	37.15
6	21.51	0.02	21.49	8.68	0.67	8.01	37.24
10	21.31	0.02	21.29	9.31	0.96	8.35	39.19
11	24.04	0.03	24.01	9.84	0.88	8.96	37.29
14	26.13	0.02	26.11	10.28	0.83	9.45	36.19
15	25.61	0.01	25.60	11.08	0.86	10.22	39.92
17	25.52	0.01	25.51	10.32	0.81	9.51	37.30
19	27.96	0.01	27.95	11.60	0.65	10.95	39.18
20	26.70	0.02	26.68	11.80	1.04	10.76	40.33
21	33.55	0.02	33.53	13.60	1.04	12.56	37.46
23	38.52	0.03	38.49	15.30	0.99	14.31	37.18
24	40.09	0.02	40.07	16.32	0.94	15.38	38.39
25	41.15	0.03	41.12	16.00	0.94	15.06	36.63
26	42.15	0.02	42.13	17.40	0.99	16.41	38.95
28	48.73	0.02	48.71	17.96	0.94	17.02	34.95
29	51.84	0.05	51.79	19.64	0.97	18.67	36.04
30	59.90	0.06	59.84	23.24	0.88	22.36	37.36
						Mean	37.78

TABLE 5.—*Calcium-retention data.*

Chick	Calcium fed	Calcium in chick			Calcium retained
		Final	Initial	Gain	
No.	*Grams*	*Grams*	*Gram*	*Grams*	*P. ct.*
		MALES			
1	3.44	1.41	0.15	1.26	36.50
2	3.74	1.82	0.15	1.67	44.62
3	3.84	1.95	0.15	1.80	46.73
5	4.73	2.33	0.15	2.18	46.18
7	4.49	2.11	0.15	1.96	43.77
8	4.70	2.09	0.15	1.94	41.24
9	4.63	2.18	0.15	2.03	43.91
12	5.03	2.62	0.15	2.47	49.14
13	5.47	2.59	0.15	2.44	44.52
16	5.72	2.40	0.15	2.25	39.39
18	5.63	2.55	0.15	2.40	42.59
22	7.38	3.72	0.15	3.57	48.37
27	9.56	4.93	0.15	4.78	50.08
		FEMALES			
4	4.40	2.12	0.15	1.97	44.70
6	4.69	2.16	0.15	2.01	42.81
10	4.65	2.02	0.15	1.87	40.30
11	5.24	2.36	0.15	2.21	42.06
14	5.70	2.53	0.15	2.38	41.82
15	5.59	2.44	0.15	2.29	40.98
17	5.57	2.31	0.15	2.16	38.85
19	6.10	2.77	0.15	2.62	43.04
20	5.82	2.98	0.15	2.83	48.59
21	7.32	3.67	0.15	3.52	48.15
23	8.40	3.45	0.15	3.30	39.29
24	8.74	3.63	0.15	3.48	39.80
25	8.97	4.23	0.15	4.08	45.51
26	9.19	4.15	0.15	4.00	43.52
28	10.63	4.50	0.15	4.35	40.95
29	11.31	5.11	0.15	4.96	43.84
30	13.06	5.38	0.15	5.23	40.00
				Mean	43.38

TABLE 6.—*Phosphorus-retention data.*

Chick	Phosphorus fed	Phosphorus in chick			Phosphorus retained
		Final	Initial	Gain	
No.	*Grams*	*Grams*	*Gram*	*Grams*	*P. ct.*
MALES					
1	3.96	1.08	0.11	0.97	24.37
2	4.33	1.33	0.11	1.22	28.23
3	4.45	1.41	0.11	1.30	29.21
5	5.47	1.63	0.11	1.52	27.87
7	5.19	1.54	0.11	1.43	27.54
8	5.44	1.58	0.11	1.47	27.03
9	5.35	1.68	0.11	1.57	29.29
12	5.82	1.83	0.11	1.72	29.56
13	6.33	1.83	0.11	1.72	27.19
16	6.62	1.81	0.11	1.70	25.73
18	6.51	1.91	0.11	1.80	27.70
22	8.54	2.60	0.11	2.49	29.19
27	11.06	3.31	0.11	3.20	28.92
FEMALES					
4	5.10	1.53	0.11	1.42	27.79
6	5.43	1.55	0.11	1.44	26.61
10	5.38	1.54	0.11	1.43	26.57
11	6.07	1.73	0.11	1.62	26.67
14	6.59	1.86	0.11	1.75	26.46
15	6.46	1.81	0.11	1.70	26.27
17	6.44	1.83	0.11	1.72	26.69
19	7.06	1.91	0.11	1.80	25.57
20	6.74	2.13	0.11	2.02	30.03
21	8.47	2.55	0.11	2.44	28.85
23	9.72	2.66	0.11	2.55	26.21
24	10.12	2.69	0.11	2.58	25.48
25	10.38	3.01	0.11	2.90	27.96
26	10.64	3.04	0.11	2.93	27.50
28	12.30	3.07	0.11	2.96	24.06
29	13.08	3.73	0.11	3.62	27.66
30	15.12	3.96	0.11	3.85	25.46
				Mean	27.26

TABLE 7.—*Summary of nitrogen, calcium, and phosphorus data.*

Item	Seventeen females	Thirteen males	All 30 chicks	Coefficient of variation
	Per cent	*Per cent*	*Per cent*	*Per cent*
Nitrogen in chicks	3.12	3.07	3.10±0.166	4.35
Calcium in chicks	0.76	0.77	0.76±0.0074	7.92
Phosphorus in chicks	0.55	0.56	0.55±0.0037	5.38
Ratio Ca:P in chicks	1.37	1.37	1.37±0.007	4.13
Nitrogen in gain	3.17	3.12	3.15±0.185	4.88
Calcium in gain	0.78	0.80	0.79±0.0081	8.31
Phosphorus in gain	0.57	0.58	0.57±0.0041	5.79
Ratio Ca:P in gain	1.37	1.38	1.37±0.0065	3.84
Rate of gain	41.05	42.04	41.48±0.167	3.27
Gain per gram nitrogen	11.88	12.17	12.00±0.055	3.70
Nitrogen retained	37.69	37.91	37.78±0.185	3.98
Calcium retained	42.61	44.39	43.38±0.410	7.71
Phosphorus retained	26.81	27.83	27.26±0.185	5.60

DISCUSSION

These figures do not give the biological value of the ration in the sense in which the term is usually interpreted, for the biological value measures the efficiency of conversion of ingested protein to body protein.

A schematic diagram of the course of the nitrogen in the body is presented in Figure 1. A factoring of the food nitrogen according to this scheme makes it possible to point out the main differences between various methods of determining the value of feeding stuffs for animals.

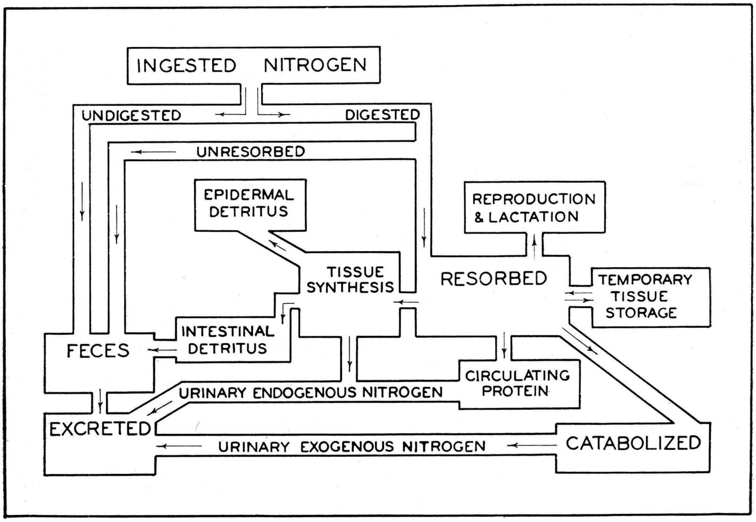

FIG. 1.—Diagram of the course of nitrogen in the body.

The usual digestion trial theoretically distinguishes between the undigested and digested material; actually in the measured undigested portion is included the unresorbed portion of the material digested as well as the metabolic nitrogen of the feces. As a consequence, the digestion coefficient is in error by these amounts.

In the determination of the biological value of proteins it is necessary to ascertain, in a preliminary nitrogen-free feeding period, the endogenous nitrogen excreted in the urine and feces. The animal is then fed a ration containing the protein it is desired to test and the total nitrogen excreted in the urine and feces is again determined. The figures obtained in the preliminary period are applied as corrections in the proper sense and the biological value can then be stated. Referring to Figure 1, it is apparent that this method is concerned with the problem of finding the amount of protein which is deposited in the tissues. This amount is calculated by measuring during two different experimental periods the following nitrogen fractions: (1) undigested portion, (2) unresorbed portion, (3) protein catabolized, (4) daily loss of circulating protein, and (5) metabolic nitrogen of the feces.

As previously stated, the method is theoretically sound, yet in work with mature hens (9, 14), a high variability in the results led to the use of a slaughter test based on two direct determinations, namely, the amount of ingested nitrogen and the amount of nitrogen contained in the carcass. Only one trial is involved with each bird, and no assumption is necessary as to the constancy of the endogenous nitrogen excretion of a bird on diets which do and do not provide nitrogen.

Naturally this procedure is most readily applied to small birds, as the mechanical work involved is not so great, but it may be extended to adult birds as well. In the work shown in Table 3 one chick was carried to nearly 800 grams without difficulty. In the trials summarized in Table 7 individual analyses were made on each chick in order to test the variability of the results.

From the data accumulated during the 60-day feeding trial involving 30 chicks, the composition of the chicks and the gains at the slaughter weights were calculated. Correlating these figures with the intakes of nitrogen, calcium, and phosphorus yields figures representing the retention of these elements by each bird. These data are presented in Tables 3 to 6 and summarized in Table 7. The agreement in the results is good, as evidenced by coefficients of variability ranging from 3 to 8 per cent.

CONCLUSIONS

Under the conditions of the experiment and with the ration fed it is evident that:

1. Forced feeding of the pelleted ration permits accurate control of the food intake of baby chicks.

2. Feeding the ration in pellet form permits the estimation of the percentage retention of nitrogen, calcium, and phosphorus with a low coefficient of variability.

3. The percentage rate of gain and the gain per gram of nitrogen fed approach constant values regardless of differences of 500 grams in gains during a 60-day feeding period.

4. No significant sex differences in the utilization of the nutrients were observed.

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