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Nutrient Requirements of Growing Chicks

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Nutrition has been called the chemistry of life. The chemistry of life is indeed very complex and many questions about its phenomena still remain unanswered. Much progress in establishing principles of nutrition has, however, been made during the past two decades and those producers of animal products who have made use of the new information have been able to lower production costs quite markedly.

Progress in establishing principles of nutrition has been especially rapid since 1912. About that time several investigators in the field of nutrition began earnestly to use the biological method of evaluating foodstuffs and rations. The biological method of studying nutritional principles consists, in essence, of using, as the analytical laboratory, the animal of the species to be studied. The biological method of analysis is necessary because no other laboratory methods are yet available for obtaining the information which is so much needed about the principles of nutrition.

Factors which must especially be watched when the biological methods of analysis are used for studying feedstuffs and rations for chicks are:

1. Proper incubation of chick stock used for the experiment.
2. Genetic similarity of chicks used.
3. Elimination of disease factors which may of course influence the growth rate even more than does the ration.
4. Maintenance of as nearly ideal environmental conditions as possible. Temperature control is of special importance for young growing chicks.
5. Only one variable should be introduced in each lot of each series of experiments.

HISTORICAL

Early attempts at a study of the nutrient requirements of chicks were uniformly unsuccessful. Even so recently as 1916 Drummond (2)† reported failure to rear chickens in confinement on rations which were known to suffice for other laboratory animals used for nutrition research work. The disorder most commonly reported was given the rather broad classification of leg weakness and its problems remained unsolved until several experiment station investigators rec-

* C. W. Ackerson, Paul M. Bancroft, Roscoe Hill, and J. A. Rosenbaum have aided materially in carrying out certain parts of the biological work herein described.

† These references are to the bibliography, page 19.

ognized the analogy between leg weakness of chicks and rickets of other animals. Rickets is a disease in which faulty calcium and phosphorus assimilation produce bone abnormalities and other physiological disturbances. Hart, Steenbock, Lepkovsky, and Halpin (3) observed that the exposure of chicks for short periods to direct sunlight prevented and cured leg weakness. Hughes (4) reported that chicks receiving an accepted standard ration plus direct sunlight for a few hours daily developed normally while those receiving sunlight thru glass suffered from leg weakness. Mussehl and Bancroft (5) found that, on a ration otherwise complete except for the anti-rachitic factor, 45 minutes daily exposure to direct sunlight resulted in normal growth, while on the same ration, with an exposure of similar length to sunlight thru glass, rickets developed in about four weeks. The addition of 1.5 per cent of cod-liver oil to the basal ration resulted in nearly normal growth even when the radiant energy factor contributed by direct sunshine was not furnished.

Recently Pappenheimer and Dunn (6) have questioned the analogy of leg weakness in chicks and rickets in mammals, showing histological distinctions. They report, however, that the addition of a small amount of cod-liver oil prevented leg weakness and brought about normal bone structure. Hogan, Guerrant, and Kempster (7) conclude that growing chicks have an especially high requirement of Vitamin B. The exposure of chicks receiving synthetic rations to direct sunlight was of no apparent benefit in curing the leg weakness, but the addition of feedstuffs rich in Vitamin B was effective.

EXPERIMENTAL METHODS

The object of our experimental work was to establish if possible certain principles of poultry nutrition, permitting later a better combination of natural feedstuffs with the highest growth efficiency. In 1923 a new brooder house well equipped for experimental work was made available for our use. The experimental pens in this building are well lighted and ventilated, are 3 ft. x 13 ft. in size, and are equipped with steam and electric brooding units. Single Comb White Leghorn chicks were used for most of the experiments but for some of the later experiments American breed chicks were used. Week-old chicks were used, the thought being that a better selection for normality and vigor could be made after chicks were a week old and the availability of the unabsorbed yolk material precluded any effect of the ration during the first week. Our plan was to study the growth requirements for an eight weeks period, from the beginning of the second to the end of the ninth week. The chicks used were all hatched at the Agricultural College from eggs produced by the College poultry flocks.

Individual weights of all chicks were taken at the time the experiment started and each two weeks following. So far as was possible every factor was controlled during the experiment, the ration or the source of radiant energy being the only variables. Pens were thoroly steamed following each experiment and litter was renewed regularly. Wood shavings were used for litter.

In the earlier experiments the ration was divided into scratch and mash ingredients, a feeding schedule being organized which would result in the consumption of approximately equal parts by weight of scratch and mash feeds. For later experiments all the ingredients have been put into the dry mash mixture except when liquid milk products have been included, in which case a feeding schedule to include the desired amount of the milk nutrients has been worked out for each lot.

NUTRITIONAL PRINCIPLES AS ILLUSTRATED BY CORN AND ITS DEFICIENCIES

Under natural conditions birds are omnivorous but the greater share of their food requirements are satisfied with cereal feedstuffs. Of all the cereals which can be used for poultry feeding, none are so important from every standpoint as is corn. Corn research work is of especial interest to the poultryman because corn is the basic poultry feed, never indispensable of course, but generally available at a lower price per unit of nutrients than any of the other cereals. No other cereal yields for a given unit of land and labor so many units of nutrients. In Bulletin No. 1300 of the U. S. Department of Agriculture the estimate is given that over 85 per cent of our annual corn production amounting to about 25 bushels per person in the United States is used for animal feeding, only 10 per cent being used for human food. The time of keen competition between humans and food producing animals for the direct use of corn is probably more remote than with any other common feedstuff.

It is of course common knowledge that corn alone is not a complete nutrient and so it has seemed important that the nature of these deficiencies and the best methods of supplementing them be established. Building on the experience of investigators who have worked with the smaller laboratory animals commonly used for nutrition research, it has seemed that systematic inquiry should be made into the necessary (a) mineral supplements, (b) protein supplements (quality and quantity), and (c) vitamin supplements.

The growth curves shown in Chart I are of one lot of Single Comb White Leghorn chicks but the experiment was repeated three times with very consistent duplication of the growth rate so that it is believed to represent the growth experience which can be expected. Detailed information on the rations used follows:

	Per cent
Lot 740	
Yellow corn	100.00
Distilled water *ad libitum.*	
Lot 741	
Yellow corn	97.0
Ash No. 311 *	3.0
Lot 742	
Yellow corn	92.0
Egg albumen	5.0
Ash No. 311	3.0
Lot 743	
Yellow corn	92.0
Egg albumen	5.0
Ash No. 311	3.0
Green alfalfa twice daily.	
Lot 744	
Yellow corn	87.0
Egg albumen	5.0
Yeast	5.0
Ash No. 311	3.0

Mortalities are indicated by small crosses along the line representing the growth curve for each lot, these being placed so as to indicate the point at which mortality occurred.

Radiant energy requirements were satisfied in these experiments by exposure to direct sunlight on bright days. All lots were treated alike in this respect and no leg weakness developed in any of the lots.

We would especially call attention to the growth curves for Lots 742 and 744. The variable in these two lots is a 5

* The 311 salt mixture consists of 3 parts by weight of raw bone meal, 1 part ground limestone, and 1 part common salt.

per cent addition of feed yeast which was made to the ration for Lot 744. We conclude from this observation that growing chicks have a relatively high Vitamin B requirement and that this may be one of the early limitations when the ration is restricted largely to corn. The addition of green alfalfa offered twice daily did not perfectly make good this deficiency.

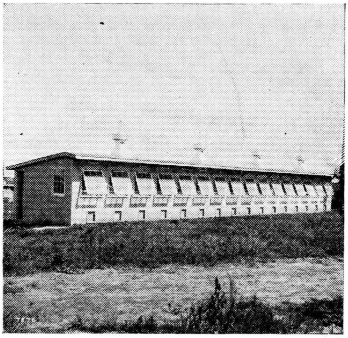
The great importance of the seemingly small things of nutrition is shown by the growth and mortality history of Lots 741, 742, and 744. The more complete the ration in all requirements save one, the more severe the shock due to that deficiency.

With this foundation we can advance the hypothesis that perfect chick nutrition is fundamentally similar to the experience of driving a six-horse team hitched to a heavily loaded wagon which must be moved a considerable distance. The horses may be named Energy (rarely lacking), Protein, Minerals, Vitamin A, Vitamin B, and Vitamin D. Perfect success in moving the load, we have only when all six horses are pulling evenly and one laggard not only may put more of the original load on each of the other animals but may even increase the load which the remaining workers must coöperatively pull. This admittedly is not a perfect picture of the situation but does aid in an understanding of the important principle that, the more complete the ration in all respects but one, the greater the shock because of that deficiency. Again nutrition, the chemistry of life, is very complex, and very interesting.

RADIANT ENERGY REQUIREMENTS FOR GROWTH

Mention has already been made of the importance of a certain type of radiant energy in the ration or in the environment for growing chicks. Probably no other contribution which the nutrition research worker has made has been so directly helpful to the poultry producer as has this information. Tho there is still some question as to the perfect analogy between avian leg weakness and mammalian rickets, the therapeutic action of cod-liver oil, egg yolk, and ultraviolet radiation indicates that they have at least several points in common.

As has been stated, rickets is a bone disorder caused either by a failure to assimilate calcium and phosphorus or to deposit it normally in the bones if assimilated. In a normal bone growth occurs at the point of junction of the epiphysis with the diaphysis and is preceded by certain changes in



Brooder house used for chick nutrition research work.

the cartilage of the epiphysis. Lime salts are carried by the vascular system and in some manner not yet fully understood these unite with the osteoid tissue (bone tissue without calcium salts) to form true bone. During growth and to a lesser extent after growth has ceased, the structure of the bone is subject to constant change probably influenced by nutritional as well as other environmental factors. In the animal suffering from rickets the calcification of the osteoid tissue does not take place.

McCollum and Simmonds (reference 1, pp. 386-403) describe three types of rickets which they designate as (1) low calcium rickets, (2) low phosphorus — high calcium rickets, (3) low calcium — low phosphorus rickets.

It is not to be hoped that we can for many years duplicate with chicks the great number of observations on which these conclusions are based, so it has seemed to us most feasible to take a typical chick ration and to study its vitamin and radiant energy deficiencies. The basic ration used we have called NE. The composition of ration NE is as follows:

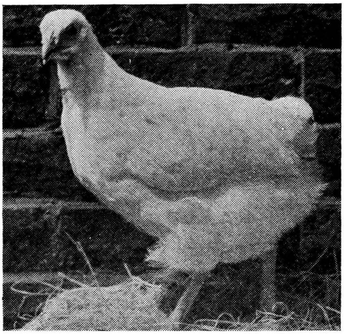
Scratch feed	
Cracked yellow corn	50 per cent
Cracked wheat	50 per cent
Mash feed	
Yellow corn meal	21.25 per cent
Wheat bran	21.25 per cent
Wheat shorts (gray)	21.25 per cent
Pulverized barley	21.25 per cent
Sifted meat meal	15.00 per cent

Sprouted oat tops were furnished as green feed, these being fed twice daily. Approximately equal parts of scratch and mash feeds were given, the consumption of mash being controlled by the amount of the more palatable scratch feed offered.

The meat meal used in these experiments contained nutrients in percentage as follows: Water, 6.65; ash, 23.51; protein, 51.76; ether extract, 13.72; fibre, 1.25; nitrogen free extract, 3.11.

Single Comb White Leghorn chicks restricted to this ration and with no other source of radiant energy except sunlight diffused thru glass developed leg weakness after from four to five weeks.

One of the evidences of rickets in other animals is a lowering of the calcium and phosphorus content of the blood. Ackerson of this Station (8) made calcium and phosphorus determinations on the blood of 56 birds apparently normal and not suffering from leg weakness and likewise on 51 chicks suffering from leg weakness. The average values are given in Table 1.



Ration NE plus sunshine results in normal growth.

TABLE 1.—*Calcium and Phosphorus Content of Blood of Chicks*

	No. chicks for calcium determinations	Ca.*	No. chicks for phosphorus determinations	P.*
Normal	56	10.61	68	4.60
Showing leg weakness	51	7.49	66	3.91

* Expressed in terms of mg. of calcium and inorganic phosphorus per 100 c.c. of blood serum.

Chart II gives the growth curves of 665 Single Comb White Leghorn chicks which were given ration NE as a base, the variable being as indicated above each curve. The nonconformity of the chicks represented by Curve C is probably explained by the fact that a prolonged period of cloudy weather from the third to the fifth week of the experiment restricted the amount of radiant energy available to the chicks.

Shipley, Kinney, and McCollum (9), working with rats, report that extracts of alfalfa meal made with boiling water are anti-rachitic. We therefore added to ration NE the water extract of 250 gms. of well cured green alfalfa meal per kilo of basal ration and to another the water extract of 500 gms. of alfalfa meal. These additions did not prevent leg weakness, so the hydraulic extract of 450 gms. of fresh green cut alfalfa grown in direct sunshine was added to each kilo of ration. Leg weakness developed with perfect consistency in every chick in these lots. The chicks represented by Curve G in Chart II were of course confined back of glass at all times during the experiment.

A comparison of Curves A, B, and E shows the possibility of substituting cod-liver oil for radiant energy during cloudy weather and early in the season when sunshine does not have the intensity of ultra-violet radiation necessary for optimum growth.

Cod-liver oils are known to vary in their vitamin content and Drummond (10) suggests in the lack of a better measure of Vitamin D content that oils of a pale lemon yellow color are generally of higher vitamin value than the colorless oils. On the other hand, a dark brown color indicates that the oil has been made by the rotting process during which the vitamin content is reduced by oxidation.

WHEN IS COD-LIVER OIL FEEDING PRACTICAL?

The question of whether cod-liver oil additions are necessary when plenty of direct sunshine is available has often been asked. Chart III gives the growth curve of Single Comb White Leghorn chicks hatched and brooded at the same time in parallel pens. A comparison of the growth curve for lots 618 and 619 shows no evident advantage in cod-liver oil additions when plenty of sunshine radiant energy is available. This experiment was carried on during October and November, months when the ultra violet of the sun's radiations is not at its greatest intensity.

WAS RATION NE DEFICIENT IN VITAMIN B?

In view of the generally accepted high requirements of growing chicks for Vitamin B we made an addition of 5 per cent of feed yeast to ration NE. Chart IV shows the growth curve of two lots of Single Comb White Leghorns, the only variable being the yeast addition to the ration for Lot 717. Ration NE was apparently not lacking in the Vitamin B factor.

CAN IRRADIATED FEEDSTUFFS PREVENT LEG WEAKNESS IN CHICKS?

Interesting possibilities in the therapeutics of leg weakness are suggested by the discovery of Hess (11) and Steenbock and co-workers (12) that certain substances can be endowed with anti-rachitic properties on irradiation with ultra violet. Hess (11) reports that cottonseed oil and linseed oil, irradiated in thin layers for an hour at a distance of 12 inches from a quartz mercury vapor lamp, acquired anti-rachitic properties for rats. Steenbock (12) reports success in activating lard, butterfat, olive oil, cocoanut oil, cottonseed oil, and corn oil. The hypothesis is offered that a chemical change is effected in certain of the sterol compounds in these substances which affects bone calcifying properties. Substances high in cholesterol and phytosterol should therefore lend themselves most effectively to irradiation.

Anderson (13) reports that crude corn oil contains a relatively high percentage of unsaponifiable matter, amounting in the crude oil to 2.01 per cent, this consisting largely of phytosterol.

We have investigated the leg weakness preventing properties of fresh crude corn oil, liver meal, yellow corn, and white corn, both before and after irradiation. These products were irradiated as indicated in the description of each ration with a quartz enclosed mercury vapor lamp at a distance of 12 inches.

All chicks in this series (749 to 762) were kept back of glass at all times. The ash mixture used was the one which we have designated as No. 311 and consisted of bone ash 3 parts, calcium carbonate 1 part, and sodium chloride 1 part. The yeast used for the Vitamin B additions was a commercial grade of feed yeast.

Charts V, VI, and VII list the rations and the growth curves of the chicks used for this series of experiments. This experiment was twice repeated, with the results essentially as shown by the graphs.

Reflection on the outcome of this experiment leads us to ask whether the common leg weakness of chicks is fundamentally the same as rickets in rats. Another possible explanation of the non-conformity of chicks and rats in radiation requirements is that rats, naturally a burrowing animal, and having evolved under environmental conditions unlike those which are natural for birds, may have different nutritive requirements.

Our conclusions based on this series of experiments are:

1. The liver meal which is available as a commercial product does not contain any appreciable amount of the leg weakness preventing factor.
2. The irradiation of liver meal with ultra-violet light did not greatly enhance its leg weakness preventing properties.
3. Irradiation of yellow corn and white corn for 30 minutes before grinding did not enhance its leg weakness preventing values to any appreciable degree.
4. Irradiation of fresh crude corn oil for 30 and 60 minutes slightly improved its leg weakness preventing property,

but the addition of 3 per cent of such irradiated corn oil did not protect chicks when given a ration otherwise complete except for the leg weakness preventing factor.

THE EFFECT OF THE QUANTITY OF PROTEIN ON CHICK GROWTH

It is now generally recognized that the quality of the proteins in the chick ration have a marked influence on the rate of chick growth. The protein requirement is essentially an amino acid requirement, these groups, about twenty in number, constituting the "building stones" from which new tissue is constructed. Just where the law of diminishing returns begins to operate as measured in growth rate and in tolerance for proteins has, we believe, not yet been determined, tho the question is of great practical importance.

The common judgment of practical feed men seems to indicate that a relatively low protein ration is desirable for the first part of the growth period of chicks. Clark (14) reports the average protein analysis of 32 commercial chick starters to be 16.7 per cent, while 53 samples of chick growing mashes contained 18.9 per cent protein. These feeds are usually fed in combination with scratch grains, so that the actual protein level of the complete ration is from 2 to 3 per cent less than that of the mash feeds given.

We therefore planned an experiment to determine the optimum amount of a standard animal protein concentrate which should be added to a ration made up basically of corn, wheat, and barley nutrients. The basic ration we have designated as NEW. This ration will be recognized as the previously described ration NE with the addition of 4 per cent of a mineral mixture, this addition being made so that an improvement noted on the addition of meat and bone meal would not be accredited to mineral contributions. This ration then consisted of the following ingredients:

Scratch feed	
Cracked yellow corn	50 per cent
Cracked wheat	50 per cent
Mash feed	
Yellow corn meal	24 per cent
Wheat bran	24 per cent
Wheat shorts (gray)	24 per cent
Pulverized barley	24 per cent
311 salt mixture *	4 per cent

* The 311 salt mixture consists of 3 parts, by weight, of raw bone meal, 1 part ground limestone, and 1 part common salt.

Sprouted oat tops were offered daily to lots 723 to 728 inclusive, as much as the chicks would clean up daily in 15 minutes.

The scratch feed was given to each unit of 35 Single Comb White Leghorn chicks according to the following schedule:

	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Grams per day	100	100	200	200	300	300	300	300

To the mash mixture as listed above were added varying amounts of a standard meat and bone meal mixture containing 53.5 per cent protein and 23.8 per cent ash. The additions to the six lots given the same basal ration were as follows:

Lot No.	723	724	725	726	727	728
Per cent	0	5	10	15	20	25

It was planned at the same time to obtain information on the plane of protein intake when chicks were fed the relatively simple ration which is known as the Wisconsin chick ration (15).

The Wisconsin ration for chicks (Lot 729) consists of 80 parts yellow corn meal, 20 parts wheat middlings, 5 parts raw bone, 5 parts of pearl grit, 1 part of common salt, and skimmed milk at all times. No scratch grains are fed.

Total feed consumption, mortality, and the plane of protein intake for each lot are given in Table 2.

TABLE 2

Lot No.	723	724	725	726	727	728	729
Scratch consumption entire experiment, *gms*	12,400	12,400	12,400	12,400	12,400	12,400	0
Mash consumption entire experiment, *gms*	25,340	29,385	33,970	37,035	42,990	44,590	40,030
Skim milk consumption, *gms*	....	....	....	....	....	....	105,300
Percentage meat and bone meal in mash portion of ration	0	5	10	15	20	25	
Plane of protein intake, *per cent*	12.5	13.2	15.5	17.1	18.3	20.5	16.95
Mortality during entire experiment	4	4	6	1	0	0	2

Our conclusions based on this experiment are as follows:

1. Growing chickens, during the first nine weeks of their growth period, can tolerate protein at a plane of at least 20 per cent.
2. The plane of protein intake with the Wisconsin ration was 16.95 per cent, this being estimated on the basis of dry mash consumed plus dry matter in the milk.

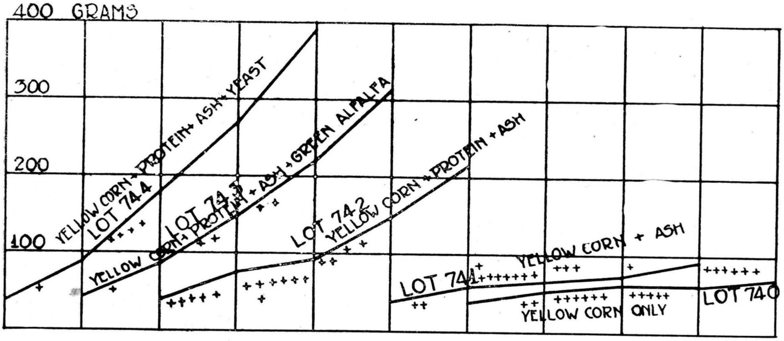


CHART I.—Yellow corn is deficient in minerals, proteins, and in at least one of the vitamins.

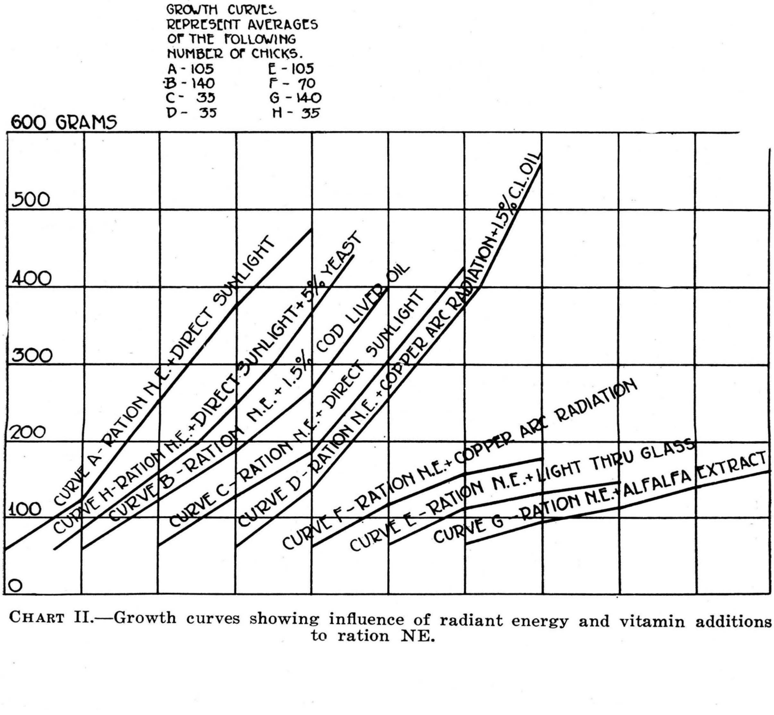


CHART II.—Growth curves showing influence of radiant energy and vitamin additions to ration NE.

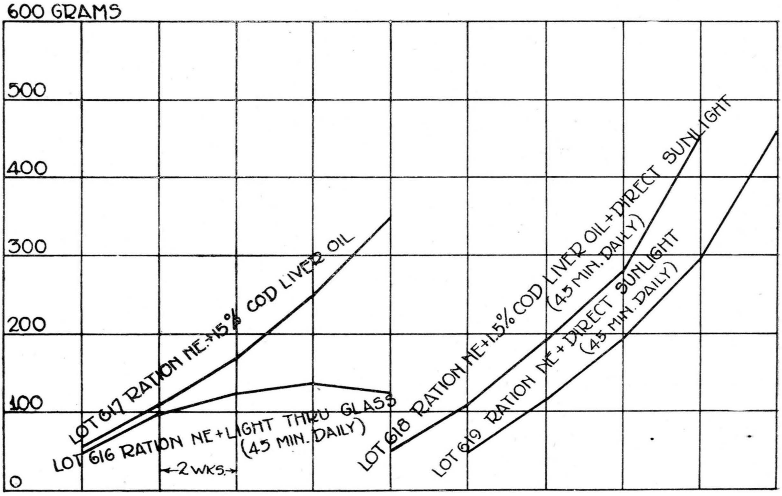


CHART III.—Growth curves for Lots 618 and 619 show that ration NE plus direct sunshine is sufficient for growth. When sunshine is available cod liver oil is unnecessary.

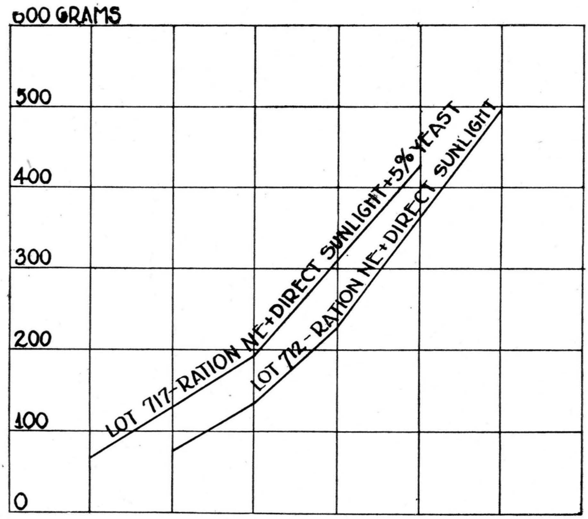


CHART IV.—Ration NE was not deficient in vitamin B.

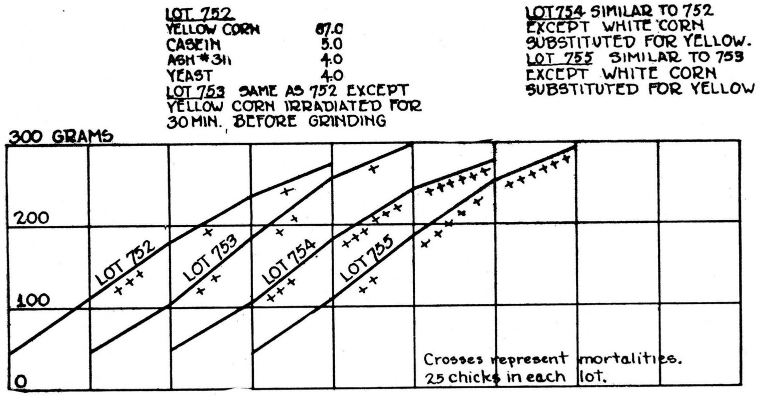


CHART V.—The irradiation of the corn used for Lots 753 and 755 did not enhance its nutritive value. Failure was more rapid on the white corn than on the yellow corn lots.

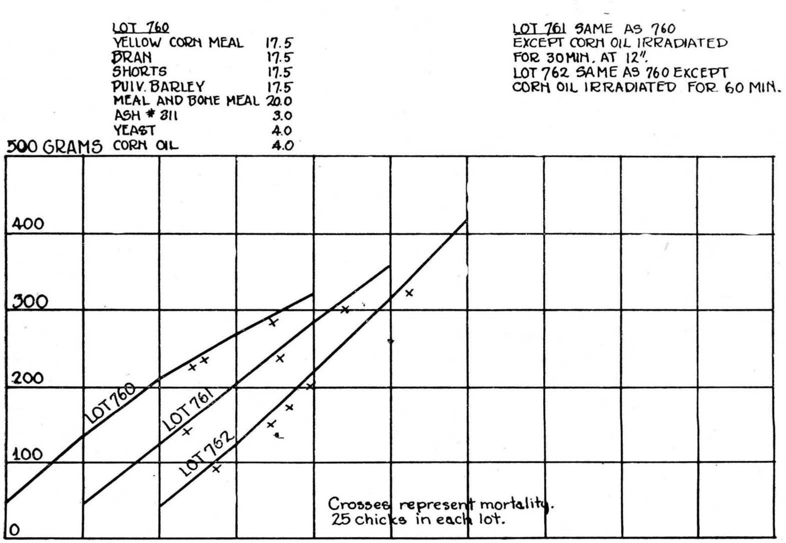


CHART VI.—The irradiation of corn oil slightly enhanced its anti-rachitic properties but the addition of 4 per cent of the irradiated corn oil did not prevent leg weakness.

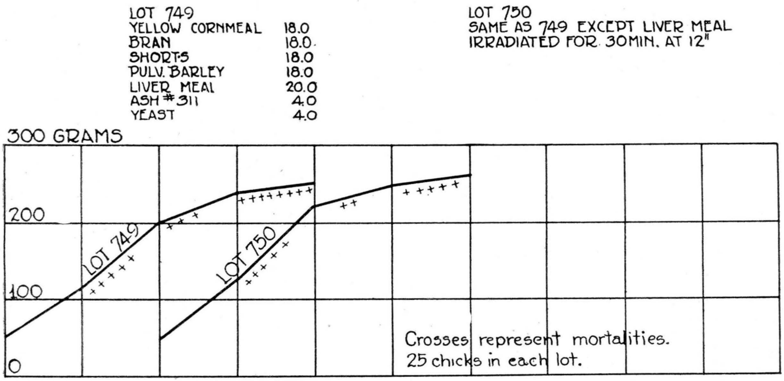


CHART VII.—Neither irradiated nor non-irradiated liver meal prevented leg weakness. Chicks were kept back of glass at all times.

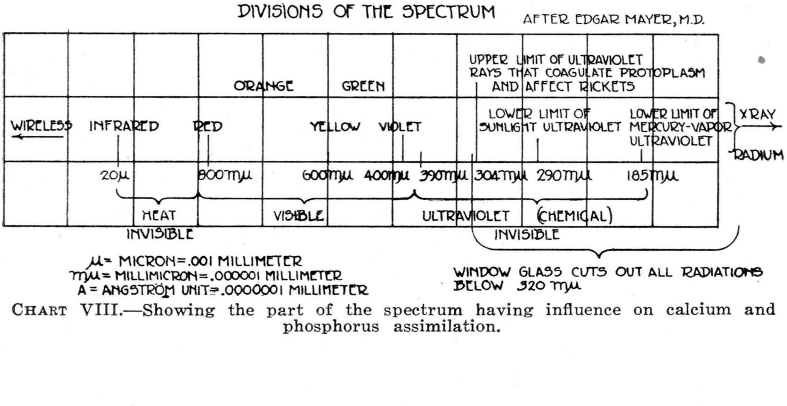


CHART VIII.—Showing the part of the spectrum having influence on calcium and phosphorus assimilation.

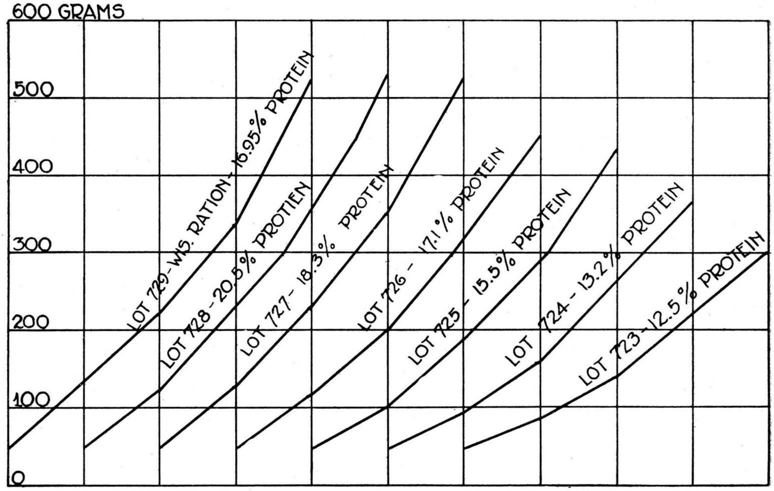


CHART IX.—Showing growth rate at varying planes of protein intake..

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