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THE NUTRITIVE VALUE OF WHEAT IN THE RATIONS OF YOUNG CHICKS

by

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A Thesis submitted in Partial Fulfilment of

The Requirements for the Degree of

MASTER OF SCIENCE IN AGRICULTURE

in the Department

of

POULTRY HUSBANDRY

accepted and approved

Oct 19, 1942

The University of British Columbia
October, 1942.

ACKNOWLEDGMENTS

The writer wishes to express appreciation and gratitude to Mr. Jacob Biely, of the Department of Poultry Husbandry, for his kindly guidance in the conduct of this study. Thanks are also due to Professor E. A. Lloyd, Head of the Department of Poultry Husbandry, for his constructive criticism in the preparation of the manuscript; and to Dr. V. C. Brink, of the Department of Agronomy, and Mr. R. P. Forshaw, of Agricultural Trade Relations (Canada) Limited, for direction in connection with the statistical analysis of the experimental data.

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THE NUTRITIVE VALUE OF WHEAT IN THE RATIONS OF YOUNG CHICKS

A. INTRODUCTION

Grain and grain by-products constitute the greater part of poultry rations. At the beginning of the twentieth century and until thirty years ago, comparatively simple feeding mixtures were fed to poultry. The favorite grain of the poultryman was wheat, and the mashes that were used consisted chiefly of wheat mill feeds.

Until the advent of the First World War, wheat was very widely used in the feeding of poultry, and it was highly prized for this purpose. During the war, however, since wheat had to be used more extensively as food for humans, it became relatively high in price. This economic situation was responsible for the adoption of the greater use of corn and the coarser grains in the feeding of poultry. Later a great change and expansion in the wheat-growing countries built up a surplus of wheat. As a result, efforts were made to try to balance the shortage of corn and the over-supply of wheat. In the United States, for example, the Federal Farm Board of Washington, D.C., published a bulletin (1930) on "Practical Experiences in Feeding Wheat", demonstrating the possibilities of incorporating more wheat in the rations of livestock.

More recently (14), the United States Department of Agriculture (1942) has been urging feed manufacturers to include more wheat in their feed mixtures, besides asking farmers to feed more wheat. In many cases it has been said that heavier wheat mixtures can result in even better quality commercial feeds at no increase in price.

In Canada, since Canada is a wheat-growing country, wheat is one of the cheapest feedstuffs available. Hence under normal conditions it is naturally the basic grain in Canadian poultry rations. One of the most important phases of poultry production is the feeding of young chicks. In realization of this fact, a study was undertaken to find the maximum amount of wheat that may be included in the rations of growing chicks.

B. REVIEW OF LITERATURE

1. Wheat

(a) Structure of Wheat

The kernel of wheat is a seed which in structure resembles a nut. It is botanically a caryopsis comprising pericarp and seed proper (6).

The pericarp consists of four layers -- epicarp, mesocarp, endocarp, and inner epidermis. These make up 4% of the entire kernel.

The seed proper consists of, firstly, the seed coat, which is composed of three separate layers -- the testa

and hyaline layers (2.5% of the entire kernel), and the aleurone layer (6.7% of the entire kernel). Secondly, there is the germ or embryo, comprising 2.5% of the entire kernel. The third part is the endosperm, which comprises 85-90% of the kernel.

Wheat bran, according to Girard (16), is 14.35% of the wheat kernel, of which 4.45% is taken from the pericarp, 1.1% from the testa, and 8.8% from the hyaline and aleurone layers.

(b) Composition of Whole Wheat and Wheat By-Products

In common with plant products generally, wheat shows a considerable range in composition according to variety, climate, and cultural conditions. Most important commercially are the variations in quantity and quality of the endosperm proteins. The average percentage composition of wheat and wheat by-products used for poultry is as follows: (26)

The Average Composition and Digestible Nutrients of Wheat and Its By-Products (26)

FEEDING-STUFF	Total Dry Matter	Dig. Protein	Total Dig. Nutrients	Nutritive Ratio	AVERAGE TOTAL COMPOSITION				
					Protein	Fat	Fibre	Nitrogen-free Extract	Mineral Matter
	%	%	%	1:	%	%	%	%	%
Wheat, recent analyses ...	89.8	11.3	83.6	6.4	13.1	1.7	3.0	70.0	2.0
Wheat, Pacific Coast States.	89.1	8.5	83.6	8.8	9.9	2.0	2.7	72.6	1.9
Wheat, shrunken	91.4	10.2	82.9	7.1	11.9	2.6	4.6	70.2	2.1
Wheat bran, all analyses .	90.6	13.1	70.2	4.4	15.8	5.0	9.5	54.3	6.0
Wheat bran, chiefly hard spring wheat	90.9	13.2	70.9	4.4	15.9	5.5	9.6	53.9	6.0
Wheat bran, winter	90.9	13.0	69.5	4.3	15.7	4.2	9.1	55.1	6.4
Wheat bran and screenings, all analyses	90.8	13.2	69.5	4.3	16.1	4.9	9.6	54.2	6.0
Wheat bran and screenings, chiefly hard spring wheat .	91.2	12.7	70.7	4.6	15.6	5.6	9.8	54.5	5.7
Wheat-flour middlings	89.6	15.0	79.5	4.3	17.0	4.9	4.4	59.9	3.4
Wheat-flour middlings and screenings	89.5	14.4	75.7	4.3	17.1	5.0	5.3	58.4	3.7
Wheat-germ meal	91.1	26.2	92.9	2.5	28.5	10.7	2.5	44.9	4.5
Wheat grey shorts	90.1	15.0	78.9	4.3	17.9	4.5	5.6	57.8	4.1
Wheat grey shorts and screenings	90.1	14.6	77.5	4.3	17.7	4.5	5.9	57.7	4.3
Wheat mixed feed	90.6	13.9	73.5	4.3	16.8	4.9	7.2	56.9	4.8
Wheat mixed feed and screenings	90.1	13.4	71.1	4.3	16.6	4.7	7.9	55.9	5.0
Wheat screenings	90.4	9.7	64.0	5.6	13.9	4.7	9.0	58.2	4.6
Wheat standard middlings, all analyses	90.0	14.4	78.4	4.4	17.4	5.5	6.8	56.1	4.2

(26) "Feeds and Feeding", 20th ed., by F.B. Morrison.

Below is given the approximate coefficients of digestibility of wheat feeds by poultry (13):

Feeding-Stuff	Protein	Carbohydrates	Fat
Wheat	74.0	88.9	47.1
Wheat bran	59.9	54.1	50.0
Wheat shorts	69.2	71.0	85.2
Wheat middlings	50.0	49.7	52.6
Wheat middlings (8.5% fibre)	76.2	59.6	52.6

Wheat is fed to poultry mainly to provide the bulk of the carbohydrate in the ration. The nitrogen-free extract content of wheat, according to Morrison, is 70%, and according to the Texas investigators (13) it is 88.9% digestible.

Wheat contains almost as much total digestible nutrients as corn. According to Morrison (26) the protein equivalent of wheat is higher than that of corn, ranging from 7.5% in low-protein wheats to 18% in high-protein wheats. In a more recent survey of the protein contents of the wheats in British Columbia, Moe (25) describes wheat with a protein content as high as 22%. The average protein content of the wheat usually included in poultry rations runs about 13.2%. Shrunken or shrivelled wheat is higher than plump wheat in percentage protein. Boas Fixsen et al. (5) concluded that the chemical figures for protein content of wheats did not give a complete picture of their relative values in nutrition.

That the outer portions of the wheat kernel are much higher in protein content has been shown in the preceding tabulation. Chick and Work (10) and many other investigators have demonstrated the fact that the biological value of whole-wheat protein is higher in both protein sparing action and growth promotion than is the protein of wheat flour.

In studying the proteins of the wheat kernel, Osborne and Mendel (29) found that the greater portion of the protein is stored in the wheat endosperm. Of this, about 80% consists of two kinds of protein, namely, gliadin and glutenin. These proteins unite to form the gluten characteristic of wheat, which is physically and chemically unlike any protein product obtainable from other seeds. Gliadin is an incomplete protein, lacking quantitatively in the amino acid, lysine. However, all of the amino acid deficiencies of gliadin are to some extent offset by the amino acids contained in glutenin. Wheat glutenin, then, affords a mixture of proteins on which young animals grow fairly well.

Besides gliadin and glutenin, which are found mainly in the endosperm of the kernel, leucosin, globulin and proteoses are found in the wheat germ, while prolamin, globulin and albumin are found in the wheat bran.

It is well known that wheat is not particularly rich in any of the mineral elements known or suspected to be

of importance to poultry nutrition. Wheat is shown to be particularly low in calcium content (6):

	Total Ca (Mg. per 100 gm.)	Total P (Mg. per 100 gm.)	Phytin P (Mg. per 100 gm.)	Phytin P as % of Total P
Mixed Wheat	38.4	324.5	233.1	71.8
Bran	90.4	1,358.0	1,200.0	88.4
Germ	46.7	1,201.0	573.1	47.7
White Flour	15.9	-	-	-

The vitamin content of wheat and wheat products has recently received considerable attention. This has been largely confined to the B group of vitamins. Wheat is entirely lacking in vitamin D, and normally contains no C (although this vitamin is produced when wheat is germinated), and no appreciable amount of vitamin A. Until recently the carotene pigment fairly evenly distributed throughout the whole wheat grain (and largely destroyed in flour bleaching) was thought to be a vitamin A precursor. Zechmeister and Cholonsky (43) have summarized the most up-to-date information on the matter and have added the evidence of chromatographic analysis, all of which points to the fact that this pigment is for the most part xanthophyll and that the vitamin A value of wheat is negligible.

Wheat germ is a rich source of vitamin E (tocopherol), containing 0.2 to 0.4 micrograms per gram, and is also rich in thiamin (28). It is moderately potent in riboflavin, and rich in pantothenic and nicotinic acids (39).

The average vitamin contents of wheat and its by-products are as follows:

PRODUCT	VITAMINS							
	A	D	B_1 (28)	E	Ribo-flavin	Panto-thenic Acid (39)	Nico-tinic Acid (39)	Pyri-doxine (39)
	Micrograms per pound							
Whole Wheat	140	-	650	++	400	6038	26786	2088
Wheat Bran	150	-	1440	++	1000	11768	-	-
Wheat Shorts	120	-	2700	+++	900	6174	-	-
Feed Middlings	100	-	2200	+++	700	6174	-	-
Wheat Germ	1900	-	3300	++++	1800	6946	15436	4358
First Patent Flour	-	-	80	-	-	-	4540	-
Low-Grade Flour	60	-	800	-	450	-	25778	-

2. Wheat as Compared With Other Grains

The California investigators (2) have calculated, as an aid to the selection of the common grains for poultry feeding, the digestible energy values (total digestible nutrients) from recent digestibility results obtained with the chicken by improved methods. Both Morrison's Total Digestible Nutrients (26) and Kellner's Starch Equivalent Values were arrived at through work with other animals.

On the basis of such calculations, 100 pounds of

yellow corn is found to contain digestible nutrients equivalent in energy-producing value to 75.5 pounds of starch. Wheat has a corresponding value of 72.1; barley, 66.1; oats, 63.6. Thus from the energy standpoint it may be computed that 105 pounds of wheat, 114 pounds of barley, and 119 pounds of oats are each equal to 100 pounds of corn. To express this comparison in another way, wheat has 95.5%, barley, 87.5%, and oats, 84.3% of the digestible energy value of corn. According to the California investigators (2) the comparative equivalent prices per 100 pounds of good grades of grains based on the Digestible Energy Values of the grains for poultry are:

Corn	Wheat	Barley	Oats
$1.20	$1.15	$1.05	$1.01
1.25	1.19	1.08	1.05
1.30	1.24	1.14	1.09
1.35	1.29	1.18	1.14
1.40	1.34	1.22	1.18
1.45	1.38	1.27	1.22
1.50	1.43	1.31	1.26
1.55	1.48	1.37	1.30
1.60	1.53	1.40	1.35
1.65	1.57	1.44	1.39
1.70	1.62	1.49	1.43
1.75	1.67	1.53	1.47
1.80	1.72	1.57	1.51
1.85	1.77	1.62	1.57
1.90	1.81	1.66	1.60
1.95	1.86	1.71	1.64
2.00	1.91	1.75	1.68
2.05	1.96	1.79	1.72
2.10	2.00	1.84	1.77
2.15	2.05	1.88	1.81
2.20	2.10	1.92	1.85
2.25	2.15	1.97	1.89

Barley is taken as the standard in the Scandinavian Feed Unit (3). Under this standard, one feed unit for poultry is considered as one kilogram of normal barley or the quantity of any other feedstuff which is calculated to give 2,712 calories of metabolizable energy. One kilogram of barley yields 2,712 calories; of wheat, 2,904 calories; of oats, 2,303 calories; and of corn, 3,086 calories of metabolizable energy.

The cereals are all good sources of vitamin B and of vitamin E, but contain little vitamin C and practically none of vitamins A and D, except yellow corn, which is rich in vitamin A. The average vitamin content of the grains used in feeding poultry is as follows (20):

Grain	Vitamin A per lb. (Units)	Vitamin B per lb. (Units)	Vitamin D per lb. (A.O.A.C Units)	Vitamin E per lb.	Vitamin G per lb. (Micro-grams)	Panto-thenic Acid (Units)
Yellow Corn	3,180	270	-	++	450	.7
White Corn	-	270	-	++	450	.7
Wheat	140	340	-	++	400	.7
Oats	80	270	-	++	400	.7
Barley	400	250	-	++	400	.7

3. Physiological Effect of Feeding Wheat

(a) Growth

Most of the pioneer work on the nutritive value of wheat has been carried out with rats rather than with

chicks. The work of Osborne and Mendel (29) shows that wheat protein ranks well toward the top of cereal products in biological value. According to Murphy and Jones (27), wheat-bran proteins are particularly high in the nutritionally essential amino acids -- arginine, lysine, tryptophane, tyrosine and cystine.

Poley (31) found that wheat appeared superior to corn in stimulating growth of chicks during the first eight weeks. This was substantiated by the work of Wilcke and Hammond (42), who reported that the feed consumption was low and the rate of growth on the corn-fed chicks correspondingly slow. These investigators concluded that although the ration containing corn as the sole grain had larger quantities of vitamins A and G complex than the other rations, the one with oats as the sole grain produced the most rapid gains of any of the rations containing single grains. However, this was not in agreement with Biely (4), who found that chicks which were fed wheat or corn as the sole grain in their rations grew at the same rate and attained practically the same average rate at eight weeks of age. Moreover, he found that the chicks which were fed rations that contained the ground oats grew at a somewhat slower rate and averaged slightly less in weight. This slightly lower rate of growth of the oat lot was perhaps partially explained by the fact that the chicks had some difficulty in eating the coarsely ground oats during

the first two weeks of brooding. Wilcke et al. (42) also found that the addition of 20% of ground oat hulls or ground whole oats to the wheat ration greatly improved the rate of growth. This would seem to indicate that the addition of the fibre to the ration was of considerable value to the chick.

The influence of whole wheat, wheat bran and shorts on body weight and feather growth in chicks was studied at the Nebraska Agricultural Experiment Station (1). It was found that the proteins of the entire wheat kernel and of the bran and shorts were apparently utilized with equal efficiency by growing chicks when combined with a good basal ration.

Several investigators have reported that there is a good concentration of a "feather growth factor" in wheat bran. The Nebraska experiments indicate that as much as 40% of bran can be used in chick rations with good results. Taylor and Lerner (38), studying the effects of various levels of wheat bran on the age of pullets at sexual maturity, found that the inclusion of either 15% or 25% levels of bran resulted in more rapid growth of the chicks and earlier sexual maturity of the pullets. However, Poley (31) did not find any appreciable increase in the rate of gain in weight when 10% to 25% of ground wheat was replaced with wheat bran. Poley also found the same to be true when 10% each of bran and middlings were used to replace an equal amount of ground

wheat. He did observe, however, that the chicks which received both bran and middlings had normal plumage structure, although more than 50% showed defective barring (the work was carried out with Barred Plymouth Rock chicks). This would indicate that nutritional factors that are essential for growth, proper feather structure and uniform barring are not necessarily identical.

Poley (31) found that with a basal ration consisting of 67% wheat, the addition of 3% of good quality alfalfa meal provided sufficient vitamin A for normal growth and the necessary factors for normal feather structure and color as well.

The high mortality found by Branion (8) among chicks raised on wheat as the sole cereal is baffling. On post-mortem examination of these chicks it was found that the ductless glands in the neck -- the thymus, thyroid, and parathyroid -- were markedly enlarged and inflamed. The peak of the mortality occurred during the second and third weeks. Branion concluded that it was impossible to find the part of the grain responsible, since wheat by-products showed similar high mortality. Poley (31) also had some trouble with mortality in chicks fed on all-wheat rations, but did not report the characteristic lesions observed by Branion. He described the trouble as a new type of paralysis which was corrected by the addition of alfalfa meal. Poley was

feeding a ration quite high in protein (24.5%). However, Biely (4) did not encounter any such mortality in a study of corn, wheat and oats respectively as the sole grains contained in chick rations. In fact, there was no mortality in the wheat lot, while only two chicks died out of the corn lot and one out of the oat lot.

Crampton (11) states that wheat is much lower in vitamin A than is yellow corn, and this deficiency must be corrected if young birds are to be kept alive. This confirms the findings of Hart et al. (15). Poley (31) found that 3% of good grade alfalfa meal was sufficient to supplement the vitamin A deficiency of a basal ration consisting of ground wheat and meat scrap.

Crampton (11), after stating that mortality of chicks on wheat rations may be high, with necrosis of the beak as the major cause, added that some of this mortality could doubtless be eliminated by coarser grinding. It is a well-known fact that the gluten of the wheat kernel, when it is ground too finely, may stick to the beaks of the chicks, causing necrosis, a pressure compaction of the beak, as described by Conklin and Maw (12). Branion (8) also evidently had some trouble with mortality from necrosis. Poley, in studying the effect on chicks of the fineness of ground wheat, found that with the wheat comprising 75% of the ration, when medium or coarsely ground wheat was fed

there was no appreciable difference in the growth rate or feed consumption per unit of gain to eight weeks of age. However, when very finely ground wheat was fed, 75% of the chicks developed necrosis within three weeks' time, due to the sticky feed adhering to the mouth parts of the chicks.

(b) Fattening

Maw et al. (22) found that yellow corn, wheat, oats or barley in ground form, supplemented with protein and salt, were equally good for fattening Leghorn broilers for short periods (14 days). Such factors as the age of the stock being fed and the length of time of the feeding period seemed to have a bearing on the results obtained. With mature roaster stock, wheat and corn were found to be superior to oats in a 21-day feeding period, although in a 7-day period wheat and oats were of equal value, with wheat superior to barley or corn. The single cereals were equal to the best combinations of two or three cereals. Corn was superior to all other single or combined cereals in producing fats. The corn ration produced more fat in the flesh and less fat in the skin and abdominal regions. The wheat ration tended to show the opposite effect - that is, producing more fat in the skin and abdominal regions and less in the flesh. This was not in complete agreement with Gutteridge (19), who found that the fat was distributed in definite and similar ratio in the depot areas regardless of the feed given. The character of body

fats was found to differ widely, the corn producing a softer, yellow fat, and the wheat producing a firmer, white fat.

Poley et al. (33) reported that when judged by the amount of feed required to produce a unit of gain in body weight of fryers during the growing period, wheat was most efficient, followed by barley and then by corn. In finishing rations tested by these investigators, corn, wheat, barley was the rank in order of efficiency.

The corn- and wheat-fed fryers and roasters had significantly more total edible meat on the carcasses than the birds receiving barley. The wheat- and barley-fed fryers and roasters had a somewhat higher percentage of light meat in the total edible meat than those receiving corn. This could be due to the fact that the corn group had the highest percentage of abdominal fatty tissue in the edible meat. There was a somewhat higher moisture content found in the corn-fed, and a lower moisture content in the wheat-fed birds.

These same investigators (34) later reported that there was no significant difference between the dressing and cooking percentages of the fryers or roasters receiving either wheat or barley as the principal constituent of the fattening ration, and those receiving corn. Furthermore, no appreciable differences in aroma, flavor, juiciness or tenderness of either the light or the dark meat could be detected.

(c) Egg Production

Extensive studies, involving 30 trials, 99 lots, and a total of 5,269 chickens, were carried out over a period of four years at South Dakota (32) with growing chicks, laying stock and breeders. They showed that low-test wheat (ave. 48.8 pounds per bushel) was equally as efficient as high-test (58 pounds per bushel), as judged by the rate of growth of the young chicks, egg production, and hatchability. This is in complete agreement with Goodearl (18), who found that shrunken wheat with a test weight of 40 pounds to the bushel was not inferior to plump wheat with a test weight of 60 pounds to the bushel, when each was used in equal amounts by weight in a ration for laying hens. Goodearl also found that the mortality was slightly less among birds fed shrunken wheat, and that feed consumption was a little less; consequently hens fed shrunken wheat required less feed over a three-year period to produce a dozen eggs than hens fed plump wheat. That is, the feed cost per dozen eggs was definitely lower among birds fed the ration containing the shrunken wheat. Equally good results in incubation were secured. Crampton (11) reports that when wheat is properly supplemented it is about equal to either yellow corn or white corn for egg production, maintenance of body weight, and feed requirements per 100 eggs.

C. EXPERIMENTAL

Wheat and wheat by-products have been, and are still, extensively used in poultry rations. The wheat kernel as a whole, according to McCollum (21) contains sufficient water-soluble vitamins, as well as protein suitable to promote normal growth in rats, provided that the grain is supplemented with adequate salts and fat-soluble vitamins. Osborne and Mendel (29) found that the protein of whole wheat is adequate for normal growth in rats if it is eaten in sufficient amounts (92% wheat supplying 10% wheat protein). Further, they concluded that for maintenance the proteins of wheat are nearly as good as those of casein. Hart et al. (15) demonstrated a vitamin A deficiency when chicks were fed rations composed largely of wheat.

Wheat was usually spoken of as the best of the grains for poultry feeding prior to 1918-1919, when its high cost, due to the heavy demand for flour-making, forced poultrymen to consider that wheat was not indispensable. During this period such titles as "Wheatless Mashes for Feeding Poultry" were frequently found in the literature.

Notwithstanding the common use of wheat and its products, relatively little research work has been done on their biological value in poultry rations.

At the present time it seems inevitable that there will be a swing back to the popularity of wheat as a feed for poultry, for economical if not for nutritional reasons.

Since there was experimental evidence available to indicate that it is not advisable to feed wheat alone to poultry (7, 8, 11), although excellent results have been obtained from the feeding of wheat to rats, it seemed expedient to determine the maximum amount of wheat that could be fed with safety to growing chicks. Thus this study was conducted in order to estimate the nutritive value of wheat as a feed for growing chicks from hatching time to eight weeks of age, and to determine the minimum protein, mineral and vitamin supplements necessary to balance the ration when wheat is used as the only grain.

(a) Materials and Methods

For the purpose of these experiments, rations were formulated to include as much wheat as possible, after all of the known necessary mineral and vitamin requirements were supplied.

The wheat used in both series of the experimental work was a Manitoba 4 Northern wheat, quite common in commercial poultry feeds. In Series 1 the wheat analysed 13.7% protein, and in Series 2 it analysed 14.0% protein. Both lots of wheat were ground to a medium coarse consistency. In this connection it might be stated that one lot of wheat was rejected because it had been ground too finely.

The source of the animal protein used in these experiments was a Herring Fish Meal of high quality. This feed was also rather coarsely ground. The fish meal used in Series 1 was analysed as having 61.7% protein, and that used in Series 2 was analysed as having 73.6% protein.

The same mineral supplement was used in all the experimental rations, and consisted of 1% of iodized salt and 2% of limestone. Manganese sulphate was added at the rate of four ounces to each ton of mash. Vitamin A and vitamin D requirements were supplied by the addition of 1% of 100-D and 1000-A fish oil.

In setting up the rations, the protein content of each ration was standardized to 19%, and the quantity of additional supplement that was added replaced an equal quantity of wheat. The mineral-vitamin supplement was constant throughout -- that is, 4% of the ration.

The following supplements were used in both series:

(1) Dried skim milk.
(2) Dehydrated grass, of good quality.
(3) Wheat bran.
(4) B-Y Feed.

The last supplement mentioned, the B-Y Feed, is a new product obtained from the fermentation of molasses. The B-Y Feed in Series 1 contained 60 micrograms of riboflavin per gram, while that used in Series 2 contained 240 micrograms of riboflavin per gram. B-Y Feed is a patent feed manufactured by

Commercial Solvents Corporation of Chicago.

The chicks in each series of the experiment (total of 1,329 chicks) were obtained from the same source and from the same breeding stock. The strain was known to have been of high quality and to have been fed a standard ration.

At the beginning of each experiment the chicks were weighed individually and selected at random into lots, which were placed in separate compartments of standard four-tier electric battery brooders in the Poultry Nutrition Laboratory at The University of British Columbia. The brooder building was well insulated, allowing the room to be kept at a fairly uniform temperature. The humidity was maintained in the room by moistening the floor regularly. An electric fan was used to aid in ventilating the room. Lights were used for twelve hours of each day and were controlled by an automatic electric switch. As far as possible, each group was kept under identical environmental conditions.

To encourage maximum consumption, an adequate supply of feed was kept in the troughs before the chicks at all times, as the rations were fed ad libitum. The battery brooders used in these experiments were so constructed that it was impossible to keep an accurate record of the net feed consumption. Fresh water was available at all times.

The duration of the experimental work was largely determined by the following facts. Firstly, chicks make such rapid growth during the first eight weeks that they are extremely sensitive to any deficiency which might occur in a ration during this period. Secondly, there are data available to indicate that there is positive correlation between the growth attained by chicks during the first four to six weeks of age and subsequent development after eight weeks. Thirdly, chicks are usually let out on green range at this age, and consequently any possible deficiency in a ration would be corrected. Fourthly, broilers usually attain a marketable weight at eight weeks of age. In general, then, the interval from hatching time to eight weeks of age seemed to be sufficient for most of the experiments, since the rations were designed primarily as starting rations.

(b) Experimental Data

The criterion followed in interpreting results of each individual experiment could be divided into three general headings:

(1) The general condition and appearance of the chicks.

(2) The rate of mortality.

(3) The rate of gain in weight.

All data were analysed statistically in order to evaluate the results satisfactorily. Minimum significant

differences between means were calculated from the analysis of variance as outlined by Snedecor (37).

The square root of the variance for error is equal to the standard deviation, which is actually the Standard Error of a single determination:

$$SE_s = \sqrt{\text{variance for error}}$$

$$SE_{\text{mean of n}} = \frac{SE_s}{\sqrt{n}}$$

$$SE_{\text{Difference between 2 means (e.g. Rations 1 and 2)}} = \sqrt{\frac{(SE_s)^2}{\sqrt{n_1}} + \frac{(SE_s)^2}{\sqrt{n_2}}}$$

The necessary difference between two lots is:

$$SE_{\text{Difference between two means}} \times t$$

S E R I E S I

Series I

The rations for the first series of these experiments were composed mainly of wheat, fish meal, a mineral-vitamin supplement (4%), and one or two supplementary products. The composition of the rations will be found in Table 3. It will be noted that there was more than 75% of wheat in all the rations, and that in Ration 2, which contained only wheat and fish meal besides the mineral-vitamin supplement, there was 83.75% of wheat. Ration 1 consisted of 82.5% of wheat, fish meal, and 2.5% of dried skim milk. Ration 3 was supplemented with 3% of dehydrated grass. In this connection it might be stated that Poley (31) concluded that at least 3% of a good grade of alfalfa meal was necessary to supplement the vitamin A deficiency of a basal ration containing 67% of ground wheat, supplemented with meat and bone scrap and dried skim milk. It will be observed that Ration 3 contained 80% of ground wheat. Ration 4 was supplemented with 5% of wheat bran, and Ration 5 with 3% of dehydrated grass plus 5% of wheat bran. Ration 6 was made up only of the wheat, fish meal, and B-Y Feed. Ration 7 was made up of a variety of the common grains and was designed to resemble a typical commercial chick starter.

Three hundred pounds of each ration were mixed at the beginning of the experimental work, thus ensuring uniformity of the feed throughout.

It is interesting to note that the rations were quite distinct in their appearance. Moreover, the over-all texture was good, in that the coarsely ground fish meal was complementary to the wheat, which in turn was of a moderately coarse grind. The whole made a rather open mixture of substantial weight.

The coloring of each ration was affected by the presence or absence of dehydrated grass; at the same time, the bran tended to make the mixture looser and lighter, as well as to increase the volume. Since Ration 7 was ground to a much finer consistency, it was found to differ considerably in appearance from any of the other six rations.

Experiment 1

The first experiment in Series 1 was started on May 29th, with 420 day-old cockerel chicks. They were divided into seven lots of 30 chicks each, and each lot was duplicated, making a total of 60 chicks on each of the experimental rations. The chicks were individually weighed and placed at random in their respective compartments. Thereafter they were weighed individually at the end of each week. The average weekly weights are given in Table 5.

Care was taken to make observation of any abnormalities during each time of weighing and throughout the whole period of the experiment. A weekly summary of the mortality will be

shown in Table 6. So that the cause of the mortality could be determined, post-mortem examinations of the chicks were made promptly.

It may be of interest to note that at no time during the course of the experiment was there a single instance of necrosis, that is, of the wheat meal sticking to the beaks of the chicks and causing compaction of the beak as described by Conklin and Maw (11), Branion (7), and Poley (31). The feathering appeared to be normal in all lots, and at no time during the course of the experiment was there any trouble with cannibalism, feather-pulling or toe-picking. However, the chicks, evidently in order to clean their beaks, were observed to wipe them quite frequently through the feathers of other chicks. This habit should not be confused or associated with ordinary feather-picking, which generally leads to cannibalism and mortality.

It is also of considerable interest to note that there was not a single case of perosis. There was a complete absence of curled-toe paralysis, indicating an adequate supply of riboflavin in the rations. Moreover, that the supply of vitamin D was sufficient to ensure proper bone composition was shown by the ash analysis reported in Table 19. That an adequate supply of vitamin A was provided through the fish oil in rations 1, 2, 4 and 6 was indicated by the fact that there was no evidence of avitaminosis A. There were, however, a few

cases of defective kidneys found, but these were so few that they could be explained as inability on the part of the individual chick to assimilate properly, and as such cases were found equally in the lots containing dehydrated grass, they could not be diagnosed as a vitamin A deficiency.

There was a decided difference in the color of the skin, shanks and beaks of those lots receiving dehydrated grass from that of those lots receiving no grass. Thus the lots fed Rations 1, 2, 4, and 6 had extremely pale to almost white skin, shanks and beaks, but appeared just as healthy as the lots fed Rations 3, 5 and 7, which had deep yellow skin, shanks and beaks.

Results

With the exception of skin, shank and beak color, there were no noticeable differences between the lots.

Mortality, however, was a problem, and at least fifty per cent of the mortality was found in the chicks fed the first three rations. Post-mortem examinations revealed unabsorbed yolks as the cause of death in the majority of the cases; otherwise there seemed to be nothing the matter with the chicks. It would seem that these chicks had been chilled or otherwise set back during their first few days of life.

As regards the gains in weight as shown in Table 5, it may be of interest to note that the final weights attained in the various lots are comparable to those reported by other

investigators (7, 31, 40). Appendix A gives the final weights at eight weeks of age of each individual chick in each lot. From an examination of Table 5 it will be observed that the addition of 2.5% of dried skim milk did not increase the average weight of the chicks fed Ration 1 over the average weight of the chicks fed Ration 2. It will be recalled from Table 3 that Ration 2 contained wheat, fish meal, and the mineral-vitamin supplement. The addition of 3% of dehydrated grass as fed in Ration 3, however, was responsible for a marked increase in the average weight of the chicks, much more marked, in fact, than that brought about by the inclusion of 5% of bran in Ration 4. The chicks on Ration 5, which included both the 3% dehydrated grass and the 5% of wheat bran, were decidedly heavier in their average weight. The average weight of the chicks fed on Ration 6, which was the same as Ration 2 except that it included 3% of B-Y Feed, was considerably greater than that of those fed on Ration 5. This weight was equal to that of the chicks fed on Ration 7, the commercial chick starter. (See Graph I.)

A statistical summary of the data is shown in Tables 7, 8 and 9. An interpretation of these tables will be found in the discussion of the three experiments in Series 1.

Experiment 2

The results of the first experiment led to an inquiry into the response of chicks of the heavier breeds. With this object

in mind, on June 10th 159 New Hampshire pullet chicks were individually weighed and placed at random in their respective compartments. There were 6 lots of 23 chicks each, while a seventh lot contained only 21 chicks and these did not appear quite so lively as the chicks in the other lots. This experiment was kept under the same conditions as the previous one, and the chicks were fed the same rations (see Table 3).

Results

The New Hampshire pullet chicks grew very well, and during the course of the experiment followed the same general trend as did the chicks in the first experiment. A summary of the weekly mortality is given in Table 11.

Since chicks of the heavy breeds are extremely susceptible to perosis, it was interesting to note that there was no incidence of this occurring in the New Hampshire pullet chicks. Furthermore, there were no signs of avitaminoses A, D, or G.

Since heavier breeds feather out more slowly than do the lighter breeds, careful observations were made as to the rate of feather growth and extent of feathering. It is a matter of interest to note that the New Hampshires as a breed have been selected for their rapid feathering characteristics. The rations fed seemed to help this breed characteristic, as feathering was excellent in all lots. In fact, except for the marked difference in the coloring of the skin, shanks, and beaks of those chicks fed on rations with and without dehydrated grass, there was no distinguishable difference in

the appearance of any one chick from one lot from that of any one chick from any other lot.

Since they had some difficulty in getting their heads through the wires in order to eat comfortably, the New Hampshire pullets did not gain as much as they possibly could have gained during the seventh week. The experiment was therefore terminated at the end of the seventh week rather than at the end of the eighth week as in the case of the Single Comb White Leghorn chicks.

The average weekly weights are given in Table 10. The individual weight for each chick for each lot is shown in Appendix B, from which the statistical analyses in Tables 12, 13, and 14 were worked out.

Experiment 3

The excessive mortality encountered in Experiment 1 made it important to decide whether the rations were the cause of such mortality or whether it was due to other factors. Thus on June 30th, 210 carefully selected Single Comb White Leghorn cockerel chicks were started on the seven rations (Table 3).

Results

The general appearance and condition of the chicks in this experiment were good, and again there was no perosis, necrosis, avitaminosis A, or curled-toe paralysis.

At the end of the third week, four chicks were taken from each lot, at random, for the purpose of determining the ash analysis. The results are given in Table 18.

This experiment, as it had quite definitely shown that the rations were not responsible for the excessive mortality encountered in the first experiment, was terminated at the end of the fourth week.

The average weekly weight of the chicks to the fourth week is given in Table 15. A summary of the weekly mortality, including the four chicks taken from each lot for the purpose of ash analysis, is shown in Table 16.

Discussion

As a result of the three experiments in Series 1, it has been shown that wheat, if properly supplemented, can be fed as the only grain in chick rations until eight weeks of age, even when it composes from 75% to 83.5% of the ration.

The supplement in the main consisted of fish meal, which served chiefly as a source of protein, and a mineral-vitamin mixture consisting of 1% of iodized salt, 2% of limestone, and 1% of fish oil, with manganese sulphate added to the ration at the rate of 4 ounces per ton. Other supplements used in the rations were milk, grass, bran, and B-Y Feed. Of these, B-Y Feed proved to be the most satisfactory.

It will be recalled that B-Y Feed is an exceptionally good source of riboflavin and pantothenic acid. The former vitamin plays an important rôle in promoting the normal growth of chicks (30) as well as the maximum utilization of feed.

The feed mixture used in these experiments was apparently high in riboflavin content, as evidenced by the fact that no cases of curled-toe paralysis occurred in any of the lots. However, the fish meal did not provide sufficient riboflavin to promote optimum growth, as B-Y Feed (a rich source of riboflavin as well as of pantothenic acid) considerably enhanced the rate of growth in each of the three experiments of the series.

The results obtained in this series are in accord with those of McCollum and Davis (21), who found that to obtain normal growth with rats the wheat kernel required protein, mineral and vitamin supplements. Sherman (36) found that a mixture of five-sixths ground whole wheat and one-sixth dried whole milk, with table salt, and distilled water, was adequate in that it supported normal growth and health with successful reproduction and rearing of young generation after generation.

All the experimental rations appeared to be quite palatable to the chicks, as judged by the relative rate of consumption and eagerness with which they were eaten. The

digestibility of the rations was presumably good, as two very highly digestible products - namely, wheat and fish meal - were used to make up the greater part of the rations.

Due to the coarse grind of the wheat and of the fish meal, the texture of all the rations was good, but was possibly improved by the inclusion of the 3% dehydrated grass or of the 5% of wheat bran. However, the texture was much different from the flour-like consistency of Ration 7, the commercial chick starter.

As previously stated, it is a well-known fact that the gluten found in wheat, particularly if the wheat is ground very fine, will stick to the beaks of chickens, causing the condition known as "compaction of the beak", or necrosis, as described by Conklin and Maw (12) and other investigators (7, 31). However, due to the coarse grind of the wheat, in this series of experiments no necrosis was encountered.

From observation of Table 3 it will be noticed that Ration 1 contained only 2.5% of dried skim milk besides the wheat and fish meal contained in Ration 2. The average weekly weights point out (Table 5) that although the rate of growth of the chicks was good on both rations there was no advantage in the feeding of the 2.5% of dried skim milk. Apparently the fish meal provided sufficient riboflavin for normal growth, thus detracting from the supplementary effect of the milk. As judged by the average weights of the chicks

fed on these rations, the 3% of dehydrated grass that was added to Ration 3 made a great improvement over Rations 1 and 2, which were apparently adequate for normal growth, but not optimal.

When 5% of wheat bran was added to Ration 1 the average results were slightly better, but certainly not so good as when the grass was added. This would seem to indicate that the improvement was due to the physiological effects of the wheat bran, rather than to nutritional effects. That wheat bran is one of our best poultry feeds is substantiated by Almquist et al. (2), who demonstrated the nutritional value of pentoses and pentosans (bran is 20% pentosans) for the chick; and by Taylor and Lerner (38), who concluded that either 15% or 25% levels of wheat bran resulted in more rapid growth of the chicks. Experiments at Nebraska (1) indicated that as much as 40% of bran can be used in chick rations with good results.

According to Girard (16), 14.35% of the wheat kernel is composed of bran. At the bottom of Table 3 will be found the calculated percentage of bran in each of the experimental rations. Thus it is shown that each ration actually contains well over the 10% of wheat bran recommended by Lloyd and Biely (20).

That bran acts as a laxative in a quantitative fashion, and that increasing amounts of bran produce increasing

weights of feces was demonstrated when Ration 4, which contained a total of 16.12% of bran, was compared with Rations 1 and 2, which contained minimum amounts (11% and 12% respectively) of bran.

Ration 5, which contained both the 3% of grass and the 5% of bran, had a much higher average than did the ration containing the grass alone, which was obviously open to further improvement.

Ration 6, which was composed only of wheat, fish meal and B-Y Feed, was equal to the standard commercial Ration 7. It is obvious, then, that although the wheat and fish meal were adequate in that they supported normal growth and health, more of some factors -- probably riboflavin and pantothenic acid, which are found in grass but especially in B-Y Feed -- is necessary to support optimum growth.

From an examination of Table 4 it will be noted that the Ca:P ratio is good in every instance. Since there was not a single case of perosis encountered, it is believed that sufficient manganese was added to the rations, that the phosphorus was in a highly usable form, and that (since choline helps to prevent perosis) there must have been sufficient choline in the rations.

In agreement with Branion et al. (8) and Wilcke (42), there were no symptoms of rickets observed, as is shown by

the Tables 18 and 19, on ash analysis of the chicks at three weeks and again at eight weeks of age.

There was no avitaminosis A or G. Thus the fish oil must have provided a sufficient amount of vitamin A, as well as of vitamin D. The fish meal used was high in riboflavin, evidently sufficiently so to maintain normal growth, but not to obtain the optimum growth which was attained by the use of B-Y Feed and the standard commercial Ration 7, and partially attained by the inclusion of 3% of good quality dehydrated grass. Such results would obviously not have been experienced had meat scrap been used as the source of protein.

The mortality in Experiments 2 and 3 was almost negligible, so the excessive mortality in Experiment 1 must be attributed to undetermined factors.

S E R I E S 2

Series 2

The first series of feeding tests demonstrated that wheat could be used as the only grain in rations of growing chicks until they were eight weeks of age, provided that it was supplemented with the essential protein and mineral-vitamin concentrates. Since B-Y Feed gave such excellent results when supplementing wheat and fish meal, a second series of experiments was undertaken to discover if the addition of wheat bran, of dehydrated grass, of B-Y Feed, or of dried skim milk would improve the results obtained. These feeds are the common sources of mineral and vitamin supplements required by poultry.

Experiment 1

In the second series of feeding trials the protein content of the experimental rations was raised to 20%. The fish meal used in this series was shown to contain 73.6% protein.

The purpose of this experiment was to compare the efficiency of the above-mentioned supplements, separately or in combination.

Table 21 represents the chemical composition of the feeds used in the experimental rations; Table 22 gives the composition of the experimental rations; Table 23 reports the calculated mineral and vitamin content of the

experimental rations. From Table 22 it will be observed that each of the eight rations was composed of more than 74 pounds of wheat. The same mineral-vitamin supplement, consisting of 1% 100-D, 1000-A fish oil, 1% iodized salt, and 2% limestone, was used as in Series 1.

Besides this mineral-vitamin supplement, Ration 1 consisted only of wheat and fish meal, the wheat comprising 83.5% of the total mixture. All of the other rations except Ration 6 contained 5% of wheat bran. Rations 3, 5, 7 and 8 contained 3% of dehydrated grass. Rations 4, 5, 6 and 7 were each supplemented with 1% of B-Y Feed, while only Rations 7 and 8 were supplemented with 2.5% of dried skim milk.

On July 14th 240 Single Comb White Leghorn pullet chicks were individually weighed and leg-banded, and placed at random in their respective compartments. On the same day, 200 Single Comb White Leghorn cockerel chicks were individually weighed, banded, selected at random and divided into eight lots to be fed the same experimental rations as those received by the pullets. These chicks were individually weighed at two weeks of age, at four weeks, and every week thereafter until the experiment was terminated at the end of the seventh week.

The texture of these eight rations was similar to that of the rations of the first series.

Experimental Data

Since the protein content of the experimental rations in the second series was slightly higher than that of the rations in the first series, the chicks grew at a somewhat more rapid rate. However, the fish meal used in this series was evidently more complete in the "growth-promoting food factors", since the addition of supplements did not increase the average weight of the chicks, either in the pullet or in the cockerel lots. This sample of fish meal showed an analysis of 73.6% protein. Since the addition of 3% of dehydrated grass, which had increased the average weight of the chicks in the previous experimental work, had no extra beneficial effects above that of the unsupplemented ration of fish meal and wheat, it was assumed that there was sufficient riboflavin and other growth-promoting factors provided by the fish meal. This assumption was confirmed by the fact that the rations which were supplemented by 1% of B-Y Feed did not increase the average weights of the chicks to which they were fed. It will also be observed that the feeding of either the bran or the milk did not result in any increase in the average weight of the chicks. A summary of the average weekly weights will be found in Table 26, and the analysis of variance in Table 27, with a summary of the statistical significance in Table 28.

Discussion

No differences in the outward appearance of the chicks could be detected, except that the chicks fed on rations containing dehydrated grasses had very yellow skin, shanks and beaks, while those fed on rations containing no grass had white skin, shanks and beaks (Plate 1). To confirm the apparent healthy condition of the chicks, it seemed of interest to make observations on the internal organs. Accordingly, three chicks were selected at random from Experiment 1, Series 1, at eight weeks of age. Weight and volume measurements were made on the different organs, as is shown in Table 17.

While no significant differences were observed in the different organs, it is interesting to note that the intestinal tracts of the birds fed on Ration No. 7, the commercial chick starter, were considerably greater both in weight and volume. Ration 7 was a much bulkier feed than the six all-wheat rations, and the intestinal tracts of the chicks fed on Ration 7 had evidently adjusted themselves to take care of the large amount of fibre.

The ash analyses of the tibia of the above chicks, as shown in Plate 2 and Tables 18 and 19, indicate that the vitamin D supplied was sufficient for normal calcification.

Wheat as a food is definitely lacking in vitamin A. In the rations used in the experiment this deficiency was corrected by the addition of 1% of 1000-A fish oil. Wheat is low in calcium. This deficiency was supplied by the addition of 2% limestone. Although wheat is a fairly good source of manganese, it does not contain quite enough for normal development of the chicken. The manganese content of the rations was therefore raised by the addition of four ounces of manganese sulphate to every ton of mash used. Wheat is known to be quantitatively deficient in the proteins necessary for the promotion of normal growth. This deficiency was corrected through the addition of animal protein - namely, fish meal.

When all of these deficiencies were corrected, wheat gave just as good results as a variety of grains. This seems to indicate that variety is not an important factor in the compilation of poultry rations.

SUMMARY

Studies involving two series of experiments, 44 different lots, and a total of 1,329 chicks, were carried out to determine the nutritive value of wheat.

The rations were made up of a mineral-vitamin mixture, an animal protein, and wheat as the sole source of Nitrogen-Free Extract.

The results of the study show that wheat alone can be used as a base in making up balanced poultry rations. In the use of wheat, however, it is important to have a thorough knowledge of the various nutrients which it contains, as well as of those in which it is deficient or lacking.

Through the judicious use of the various mineral, vitamin, and protein supplements, it is possible to include as much as 83.5% of wheat in the ration of young chicks from hatching time to eight weeks of age, with satisfactory results.

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Table 1

Chemical Composition of Feeds Used in Experimental Rations (Series 1)

Feedstuff	Protein	Fat	Fibre	Nitrogen-free Extract	Mineral Matter	Ca	P	Mn (p.p.m.)
Wheat	13.79	1.7	3.0	70.0	2.0	.04	.39	39
Wheat Bran	15.80	5.0	9.5	39.8	12.2	1.92	.22	30
" Middlings	17.00	4.9	4.4	59.9	3.4	.07	.69	113
Oats	9.30	5.4	11.0	62.2	3.6	.10	.36	34
Corn	10.00	4.4	3.0	70.1	1.7	.01	.29	5
Fish Meal	61.70	6.8	0.7	3.6	14.7	9.09	4.70	40
Meat Scrap	55.00	10.7	2.2	1.2	24.6	8.25	4.00	18
Dried Skim Milk	34.80	0.9	-	50.1	8.0	1.27	.96	0.6
Dehydrated Grass	21.10	2.8	16.1	39.8	12.2	1.92	.22	30
BY	25.00	-	-	60.0	11.0	-	-	-
Fish Oil	-	100	-	-	-	-	-	-
Limestone	-	-	-	-	-	39.20	-	200
Iodized Salt	-	-	-	-	-	-	-	-
Manganese Sulphate	-	-	-	-	-	-	-	36.3%

Table 2

The Estimated Vitamin Content of Feeds Used in Experimental Rations

Feedstuff	Vitamin A	Vitamin D	Ribo-flavin (micrograms)	Thi-amin	Panto-thenic Acid
Wheat	140	-	400	340	.7
Wheat Bran	150	-	1,000	450	1.8
Wheat Middlings	100	-	700	800	.7
Oats	80	-	400	270	.7
Corn	3,180	-	450	270	.7
Fish Meal	-	-	4,500	-	.2
Meat Scrap	-	-	2,200	-	.2
Dried Skim Milk	130	-	9,500	400	3.0
Dehydrated Grass	95,000	-	8,000	400	2.5
B-Y	-	-	27,240	6,810	136,200
Fish Oil	454,000	45,400	-	-	-
Limestone	-	-	-	-	-
Iodized Salt	-	-	-	-	-
Manganese Sulphate	-	-	-	-	-

Table 3

Composition of Experimental Rations (In Pounds)

Feedstuff	1	2	3	4	5	6	7
Fish Oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Iodized Salt	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wheat (gr.)	82.50	83.75	80.00	77.50	75.00	81.00	35.50
Fish Meal	11.00	12.25	10.50	11.00	10.50	12.00	8.00
Dried Skim Milk	2.50	-	2.50	2.50	2.50	-	2.50
Dehydrated Grass	-	-	3.0	-	3.0	-	5.00
Wheat Bran	-	-	-	5.00	5.00	-	10.00
B-Y	-	-	-	-	-	3.00	-
Meat Scrap	-	-	-	-	-	-	5.00
Oats (gr.)	-	-	-	-	-	-	10.00
Corn (gr.)	-	-	-	-	-	-	10.00
Wheat Middlings	-	-	-	-	-	-	10.00
$MnSo_4$ added at the rate of 4 oz. per ton.							
Protein Content (%) Calculated	19.034	19.097	19.013	19.134	19.113	19.234	19.716
Protein Content (%) Analysis	18.56	18.89	18.79	18.57	18.69	18.86	18.90
Bran Content (%) Calculated	11.84	12.02	11.48	16.12	15.76	11.62	15.09

Table 4

The Calculated Mineral and Vitamin Content of the Rations

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 1							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	82.50	.0330	.3217	-	11,450	33,000	57.750
Fish Meal	11.00	.6380	.3608	-		49,500	2.200
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Total	100.00	1.4345	.6855	45,400	465,775	106,250	66.100
	1.00	.01434	.00685	454	4,657.75	1,062.50	.661
RATION 2							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	83.75	.0335	.3266	-	11,725	33,500	58.625
Fish Meal	12.25	.7005	.3993			55,125	2.450
Total	100.00	1.4930	.7259	45,400	465,725	88,625	61.075
	1.00	.0149	.0072	454	4,657.25	886.25	.610

(continued next page)

Table 4 (cont.)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 3							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	80.00	.0320	.3120	-	11,200	32,000	56.000
Fish Meal	10.50	.6090	.3444	-	-	47,250	2.100
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
Total	100.00	1.4615	.6660	45,400	750,525	127,000	73.250
	1.00	.0146	.0067	454	7,505.25	1,270	.732
RATION 4							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	77.50	.0310	.3022	-	11,850	31,000	54.250
Fish Meal	11.00	.6380	.3608	-	-	49,500	2.200
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Total	100.00	1.4085	.7320	45,400	466,925	109,250	71.600
	1.00	.0141	.0073	454	4,669.25	1,092.50	.716

(continued next page)

Table 4 (cont.)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms) per lb.	Pantothenic Acid (Units per lb.)
RATION 5							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	75.00	.0300	.2925	-	10,500	30,000	53.500
Fish Meal	10.50	.6090	.3444	-	-	47,250	2.100
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Total	100.00	1.4655	.6725	45,400	750,575	130,000	79.750
	1.00	.01465	.0067	454	7,505.75	1,300	.797
RATION 6							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	81.00	.0324	.3159	-	11,340	32,400	56.700
Fish Meal	12.00	.6960	.3916	-	-	54,000	2.400
B-Y	3.00	-	-	-	-	81,720	90,000
Total	100.00	1.4884	.7075	45,400	465,340	168,120	147,100
	1.00	.01490	.0071	454	4,653.40	1,681.20	1.471

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Table 4 (concl.)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 7							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	35.50	.0142	.1384	-	4,970	14,200	24.500
Wheat Bran	10.00	.0110	.1210	-	1,500	10,000	18.000
Wheat Middlings	10.00	.0070	.0690	-	1,000	7,000	7.000
Oats	10.00	.0100	.0360	-	800	4,000	7.000
Corn	10.00	.0010	.0290	-	31,800	4,500	7.000
Fish Meal	8.00	.7272	.3760	-	-	36,000	1.600
Meat Scrap	5.00	.4125	.2000	-	-	11,000	1.000
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Dehydrated Grass	5.00	.0965	.0110	-	475,000	40,000	15.000
Total	100.00	2.0429	.9834	45,400	969,395	150,450	87.250
	1.00	.0204	.0098	454	9,693.95	1,504.50	.8725

Table 5. Average Weekly Weights of Cockerel Chicks - May 28-July 23,1942

RATION*		0		1		2		3		4		5		6		7**		8	
		No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.
1	a	30	36.00	25	67.00	23	104.26	18	157.77	17	228.65	17	301.29	15	373.86				
	b	30	35.83	30	69.66	29	112.27	28	167.96	27	238.48	26	325.00	26	410.42				
	***	60	35.92	55	68.45	52	108.73	46	163.98	44	234.68	43	315.63	41	392.05	39	486.89	35	604.77
2	a	30	36.33	26	70.96	21	111.52	16	146.81	15	211.86	15	287.71	15	364.53				
	b	30	36.03	28	69.85	23	109.52	20	162.15	20	227.85	19	320.11	19	417.63				
		60	36.18	54	70.38	44	110.48	36	155.33	35	221.00	34	306.36	34	394.20	29	491.96	28	614.14
3	a	30	36.46	28	73.82	26	118.00	24	173.12	24	235.95	24	325.67	20	445.95				
	b	30	35.80	24	69.87	22	116.23	20	178.40	20	252.50	20	349.40	20	459.55				
		60	36.13	52	72.00	48	117.22	44	175.52	44	243.47	44	334.18	40	452.75	40	555.52	37	667.46
4	a	30	36.36	27	72.74	26	120.00	25	179.00	25	249.24	25	346.88	25	434.68				
	b	30	36.17	28	77.61	28	119.64	28	171.57	26	247.26	26	329.96	25	433.34				
		60	36.20	55	75.22	54	119.81	53	175.07	51	248.23	51	338.25	50	434.02	50	532.92	50	658.94
5	a	30	36.23	29	76.14	29	124.45	28	191.71	28	268.32	28	365.00	27	484.55				
	b	30	35.90	28	71.34	27	113.11	27	177.15	26	254.08	24	354.29	23	457.04				
		60	36.07	57	73.79	56	118.98	55	184.56	54	261.46	52	360.05	50	471.90	48	571.47	48	694.19
6	a	30	36.20	26	73.00	24	121.17	24	187.00	24	260.42	23	374.00	24	481.00				
	b	30	35.60	28	69.61	25	115.64	24	181.92	23	268.17	22	373.95	20	505.50				
		60	35.90	54	71.24	48	118.35	48	184.46	47	264.21	45	373.97	44	491.93	44	610.54	43	733.86
7	a	30	36.03	29	70.76	28	117.32	26	189.15	26	265.76	26	381.31	25	497.72				
	b	30	34.93	28	67.54	28	109.50	28	177.86	27	271.22	27	391.41	26	510.69				
		60	35.48	57	69.17	56	113.41	54	183.30	53	263.57	53	386.43	51	504.33	50	619.62	50	735.82

*For composition of rations, see Table 3.

**Lots a and b combined at end of sixth week.

***Averages based on total weight of total number of chicks.

Table 6

Weekly Mortality of Chicks
(Experiment 1, Series 1)

Rations:	1	2	3	4	5	6	7
No. of Chicks Started:	60	60	60	60	60	60	60
WEEKS							
1	5	6	8	5	3	6	3
2	3	10	4	1	1	5	1
3	6	8	4	1	1	1	2
4	2	1	-	2	1	1	1
5	1	1	-	-	2	2	-
6	2	-	4	1	2	1	2
7	2	5	-	-	2	-	1
8	4	1	3	-	-	-	1
No. of Chicks Finished:	35	28	37	50	48	43	50

Table 8

Analysis of Variance

(Series 1)

Variation Due to	Degrees of Freedom	Sum of Squares (SX^2)	Variance	Standard Deviation
Rations or Treatments	6	637,973		
Error	284	3,148,007	1,108.45	33.29
TOTAL ...	290	3,785,980		

Table 9

Statistical Summary

Analysis of Significance of Differences
(Experiment 1, Series 1)

RATION	1	2	3	4	5	6	7
1	-	N	S	S	S	S	S
2	N	-	S	S	S	S	S
3	S	S	-	N	S	S	S
4	S	S	N	-	S	S	S
5	S	S	S	S	-	S	S
6	S	S	S	S	S	-	N
7	S	S	S	S	S	N	-

S = Significant
N = Non-significant

Table 10

Average Weekly Weights of New Hampshire Pullet Chicks
June 10-July 5, 1942

(Experiment 2, Series 1)

RATION*	0		1		2		3		4		5		6		7	
	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.
1	23	36.52	21	60.71	17	102.64	17	155.59	17	231.00	17	313.12	15	435.20	15	691.80
2	23	35.13	21	60.70	21	95.24	18	145.50	17	223.18	17	324.94	17	439.35	16	686.50
3	23	35.48	23	57.13	23	100.32	23	158.86	23	242.50	23	341.18	23	464.47	22	699.04
4	23	36.52	22	60.59	22	105.32	22	165.77	22	250.68	22	340.41	22	473.04	19	726.10
5	23	36.69	23	61.52	23	105.91	23	174.04	21	266.33	21	362.28	20	490.00	20	709.70
6	23	34.61	22	61.64	21	106.19	21	172.33	21	263.57	21	357.66	20	474.35	19	724.47
7	21	34.00	18	55.94	18	95.05	18	164.44	18	258.00	18	362.00	18	469.44	18	722.78

* For composition of rations, see Table 3.

Table 11

Weekly Mortality of New Hampshire Pullet Chicks

(Experiment 2, Series 1)

Rations:	1	2	3	4	5	6	7
No. of Chicks Started:	23	23	23	23	23	23	21
WEEKS							
1	2	2	-	1	-	1	3
2	4	-	-	-	-	1	-
3	-	4	-	-	-	-	-
4	-	-	-	-	2	-	-
5	-	-	-	-	-	-	-
6	2	-	-	-	1	1	-
7	-	1	1	2	-	1	-
No. of Chicks Finished:	15	16	22	19	20	19	18

Table 13

Analysis of Variance

Variation Due to	Degrees of Freedom	Sum of Squares (SX^2)	Variance	Standard Deviation
Rations or Treatments	6	1,462,008.10		
Error	122	218,704.95	1,792.67	42.34
TOTAL ...	128	1,680,714.05		

Table 14

Statistical Summary

Analysis of Significance of Differences

New Hampshire Pullet Chicks
(Experiment 2, Series 1)

RATION	1	2	3	4	5	6	7
1	-	N	N	S	S	S	S
2	N	-	N	S	S	S	S
3	N	N	-	A	S	S	S
4	S	S	A	-	N	N	N
5	S	S	S	N	-	N	N
6	S	S	S	N	N	-	N
7	S	S	S	N	N	N	-

S = Significant
N = Non-significant
A = Approaching Significance

Table 15

Average Weekly Weights of Cockerel Chicks
June 30-July 29, 1942.

(Experiment 3, Series 1)

RATION*	0		1		2		3		4	
	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.
1	31	34.83	31	75.61	30	106.63	30	176.07	25	241.32
2	31	35.32	30	71.17	28	102.17	28	163.82	22	234.14
3	30	36.80	30	78.37	30	112.67	30	186.57	25	260.88
4	30	34.73	28	76.18	28	106.39	28	172.93	23	223.56
5	30	35.83	26	75.42	26	107.54	26	174.88	22	255.45
6	30	35.93	30	74.47	30	110.40	30	182.80	25	264.04
7	30	36.03	29	74.45	28	120.21	28	192.92	24	279.54

* For composition of rations, see Table 3.

Table 16

Weekly Mortality

(Experiment 3, Series 1)

Rations:	1	2	3	4	5	6	7
No. of Chicks Started:	31	31	30	30	30	30	30
WEEKS							
1	-	1	-	2	4	-	1
2	1	2	-	-	-	-	1
3*	-	-	-	-	-	-	-
4	1	2	1	-	-	1	2
5	-	-	-	1	-	1	1
No. of Chicks Finished:	25	22	25	23	22	24	23

*Four chicks taken from each lot for analysis at end of third week.

Table 17

Average Weight of Parts of Representative Chicks from Experiment 1, at Eight Weeks

(July 28, 1942)

RATION NO.	CHICK BAND NO.	WEIGHT OF CHICK	WEIGHT IN GRAMS OF						VOLUME IN C.C. OF		
			Testes	Spleen	Heart	Liver	Bursa Fabricius	Gizzard	Gizzard	Proventriculus	Intestine
1	112	780	.70	2.00	4.90	21.8	2.90	22.69	20.00	6.50	58.0
	121	919	1.00	1.50	5.40	22.0	5.40	29.40	25.20	6.60	60.0
	180	815	2.40	1.60	5.45	21.3	1.90	21.20	22.50	5.10	61.0
Ave.		838	1.36	1.70	5.23	21.7	3.40	24.43	22.57	6.07	59.6
2	278	822	1.10	1.90	4.80	28.0	3.20	25.05	24.60	6.40	53.0
	272	589	.20	1.60	4.30	17.3	1.30	21.10	20.00	4.90	58.0
	294	599	.48	2.60	4.90	17.1	.59	20.49	20.10	4.70	51.0
Ave.		670	.59	2.03	4.67	20.8	1.69	22.36	21.56	5.30	54.0
3	325	885	.80	2.10	4.70	25.0	.80	21.50	20.50	4.40	74.0
	302	935	.60	2.90	5.89	24.0	1.90	23.20	22.30	4.60	68.0
	335	817	.80	2.40	5.00	23.5	4.30	24.90	24.80	5.10	70.0
Ave.		879	.73	2.80	5.19	24.2	2.30	23.20	22.50	4.70	70.6
4	400	724	.70	2.00	4.80	21.8	3.30	23.50	23.20	5.40	60.0
	408	718	.65	1.70	4.80	20.7	2.80	22.20	20.50	5.10	65.0
	453	897	.90	2.70	6.10	23.1	3.20	27.40	26.20	7.30	64.0
Ave.		779.6	.73	2.10	5.20	21.8	3.10	21.30	23.30	5.90	63.0
5	520	970	1.50	2.20	6.60	25.6	2.70	27.20	26.20	6.00	73.0
	561	835	.30	1.50	6.80	21.8	2.50	24.70	20.00	4.60	69.0
	570	772	.40	1.70	4.30	24.4	1.90	25.39	25.00	5.10	71.0
Ave.		859	.73	1.80	5.90	23.9	2.30	25.76	23.60	5.20	71.0
6	604	794	.75	2.50	5.50	19.09	5.10	20.90	20.00	5.60	54.0
	622	862	.60	2.90	5.80	24.5	4.20	24.30	24.20	5.70	62.0
	690	949	.90	2.50	6.30	25.1	4.30	26.40	25.60	5.60	63.0
Ave.		868.6	.75	2.60	5.80	22.89	4.50	23.80	23.20	5.60	59.6
7	704	919	4.40	1.60	5.60	22.2	3.70	26.40	24.10	5.60	78.0
	777	610	.20	1.45	4.10	18.0	.60	30.80	29.40	5.40	73.0
	786	836	1.70	1.60	4.20	23.4	4.30	26.29	24.70	6.40	79.0
Ave.		788.6	2.10	1.55	4.60	21.2	2.80	27.83	26.60	5.80	76.6

Table 18

Ash Analysis of Chicks Taken at Three Weeks of Age from Experiment 3, Series 1

Ration No.	Chick Band No.	Weight in Grams	Bone	Ash	Per Cent Ash
1	228 234 235 240	145 189 155 205	3.8405	1.7520	45.61
2	243 265 280 461	135 172 162 124	3.1995	1.4930	46.66
3	293 304 306 301	194 185 154 118	3.3552	1.5774	47.01
4	317 329 332 341	143 155 172 159	3.3533	1.5542	46.34
5	385 407 408 411	157 149 120 150	3.0687	1.4340	46.72
6	349 356 371 379	184 184 149 178	3.6324	1.7262	47.52
7	423 436 438 473	173 172 187 181	3.9346	1.8658	47.42

Table 19

Ash Analysis of Chicks Taken at Eight Weeks of Age from Experiment 1, Series 1.

Ration No.	Chick Band No.	Weight in Grams	Bone	Ash	Per Cent Ash
1	112	780	3.1778	1.5572	49.0024
	121	919	3.8197	1.9825	51.9019
	180	815	3.1195	1.5588	49.9695
Ave.		838			50.2912
2	278	822	3.2353	1.5332	47.3897
	272	589	3.3472	1.7366	51.8821
	294	599	2.3120	1.1145	48.2050
Ave.		670			49.1589
3	325	885	3.3110	1.6662	50.3231
	302	935	3.8618	1.9765	51.1808
	335	817	2.4794	1.2407	50.0403
Ave.		879			50.5147
4	400	724	2.8304	1.3393	47.3184
	408	718	2.8491	1.4405	50.5598
	453	897	3.4073	1.6875	49.5260
Ave.		779.6			49.1347
5	520	970	3.5673	1.7582	49.2866
	561	835	2.8040	1.3898	49.5649
	570	772	2.7979	1.4397	51.4564
Ave.		859			50.1026
6	604	794	2.8822	1.4527	50.4025
	622	862	3.6475	1.9012	52.1234
	690	949	3.8866	1.8911	48.6569
Ave.		868.6			50.3616
7	704	919	3.7313	1.8635	49.9424
	777	610	2.1772	1.0838	49.7795
	786	836	3.3332	1.6106	48.3199
Ave.		788.6			49.3472

Table 21

Chemical Composition of Feeds Used in Experimental Rations (Series 2)

Feedstuff	Protein	Fat	Fibre	Nitrogen-free Extract	Mineral Matter	Ca	P	Mn (p.p.m.)
Wheat	14.0	1.7	3.0	70.00	2.0	.04	.39	39
Fish Meal	71.5	4.8	0.7	-	14.7	9.09	4.70	40
Wheat Bran	15.8	5.0	9.5	5.43	6.0	.11	1.21	119
Dehydrated Cereal Grass	21.1	2.8	16.1	39.80	2.2	1.92	.22	30
Dried Milk Powder	34.8	.9	-	50.10	8.0	1.27	.96	.6
Limestone	-	-	-	-	-	39.20	-	200
Fish Oil	-	100	-	-	-	-	-	-
Salt	-	-	-	-	-	-	-	-
B-Y	25.0	-	-	60.00	11.0	-	-	-

B-Y: 240 micrograms of vitamin G per gram
= 108,960 micrograms per pound.

Table 22

Composition of Experimental Rations (In Pounds)
(Series 2)

Feedstuff	1	2	3	4	5	6	7	8
Fish Oil	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Iodized Salt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wheat	83.50	78.75	76.00	78.00	75.50	83.00	74.00	74.50
Fish Meal	12.50	12.25	12.00	12.00	11.50	12.00	10.50	11.00
Wheat Bran	-	5.00	5.00	5.00	5.00	-	5.00	5.00
Dehydrated Grass	-	-	3.00	-	3.00	-	3.00	3.00
B-Y	-	-	-	1.00	1.00	1.00	1.00	-
Dried Milk Powder	-	-	-	-	-	-	2.50	2.50
	$MnSO_4$ added at the rate of 4 oz. per ton.							
Protein Content (%) Calculated	20.627	20.57	20.64	20.51	20.43	20.42	20.38	20.59
Bran Content (%) Calculated	11.99	16.30	15.90	16.19	15.83	11.91	15.61	15.69

Table 23

The Calculated Mineral and Vitamin Content of the Rations
(Series 2)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 1							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	83.75	.0250	.3590	-	11,690	33,400	58.480
Fish Meal	12.50	.7250	.4100	-	-	56,250	2.500
Total	100.00	1.5100	.7690	45,400	465,690	89,650	60.980
	1.00	.0151	.00769	454	4,656.90	896.50	.609
RATION 2							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	78.75	.0236	.3386	-	11,025	31,500	55.125
Fish Meal	12.25	.7105	.4018	-	-	55,025	2.450
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Total	100.00	1.5001	.8064	45,400	465,775	91,525	66.575
	1.00	.0150	.0080	454	4,657.75	915.25	.666

(continued next page)

Table 23 (cont.)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 3							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	76.00	.0228	.3268	-	10,640	30,400	52.300
Fish Meal	12.00	.6960	.3916	-	-	54,000	2.400
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
Total	100.00	1.5418	.7910	45,400	750,390	113,400	72.700
	1.00	.01542	.0079	454	7,503.9	1,134.0	.727
RATION 4							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	78.00	.0234	.3354	-	10,920	31,200	53.700
Fish Meal	12.00	.6960	.3916	-	-	54,000	2.400
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
B-Y	1.00	-	-	-	-	108,960	90.150
Total	100.00	1.4854	.7930	45,400	465,670	199,160	155.250
	1.00	.01485	.0079	454	4,656.7	1,991.6	1.553

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Table 23 (cont.)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 5							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	75.50	.0226	.3246	-	10,570	30,200	51.600
Fish Meal	11.50	.6670	.3770	-	-	51,750	2.300
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
B-Y	1.00	-	-	-	-	108,960	90.150
Total	100.00	1.5126	.7742	45,400	750,320	219,790	162.050
	1.00	.01513	.0077	454	7,503.2	2,197.9	1.620
RATION 6							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	83.00	.0249	.3569	-	11,620	33,200	58.100
Fish Meal	12.00	.6960	.3916	-	-	54,000	2.400
B-Y	1.00	-	-	-	-	108,960	90.150
Total	100.00	1.4809	.7485	45,400	465,620	196,160	150.650
	1.00	.01481	.0075	454	4,656.2	1,961.6	1.506

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Table 23 (concluded)

Feedstuff	Amount (lbs.)	Calcium	Phos-phorus	Vitamin D (Units per lb.)	Vitamin A (Units per lb.)	Riboflavin (Micrograms per lb.)	Pantothenic Acid (Units per lb.)
RATION 7							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	74.00	.0222	.3182	-	10,360	29,600	51.800
Fish Meal	10.50	.6090	.3444	-	-	47,250	2.100
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
B-Y	1.00	-	-	-	-	108,960	90.150
Total	100.00	1.4577	.7382	45,400	740,435	238,560	168.200
	1.00	.01457	.00738	454	7,404.35	2,385.6	1.682
RATION 8							
Fish Oil	1.00	-	-	45,400	454,000	-	-
Iodized Salt	1.00	-	-	-	-	-	-
Limestone	2.00	.7600	-	-	-	-	-
Wheat	74.50	.0235	.3203	-	10,430	29,800	52.500
Fish Meal	11.00	.6380	.3608	-	-	49,500	2.200
Wheat Bran	5.00	.0060	.0660	-	750	5,000	9.000
Dehydrated Grass	3.00	.0570	.0066	-	285,000	24,000	9.000
Dried Skim Milk	2.50	.0035	.0030	-	325	23,750	6.150
Total	100.00	1.4880	.7567	45,400	750,505	132,050	78.850
	1.00	.01488	.0076	454	7,505.05	1,320.5	.788

Table 24

Average Weekly Weights of Pullet Chicks
July 14-Sept. 3,1942.
(Experiment 1, Series 2)

RATION*	0		2		4		5		6		7	
	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.
1	28	38.67	28	115.75	27	252.37	25	328.08	23	413.61	23	546.22
2	28	36.90	28	110.11	26	229.58	21	291.90	21	363.19	21	461.09
3	28	36.60	27	105.59	25	235.84	23	309.04	23	388.52	23	514.00
4	28	37.50	23	122.26	21	267.81	21	347.81	21	409.24	21	549.90
5	28	37.50	27	116.41	27	272.21	26	350.23	25	415.84	25	534.52
6	28	39.50	24	118.25	19	255.10	19	334.21	19	418.63	19	537.42
7	28	38.90	26	117.62	24	259.33	24	338.12	24	410.25	24	539.21
8	28	37.80	27	109.00	26	249.69	26	339.23	26	412.96	26	540.38

* For composition of rations, see Table 22.

Table 25

Statistical Summary

Analysis of Significance of Differences
(Experiment 1, Series 2)

RATION	1	2	3	4	5	6	7	8
1	-	S	S	N	S	S	A	N
2	S	-	S	S	S	S	S	S
3	S	S	-	S	S	S	S	S
4	N	S	S	-	S	S	S	S
5	S	S	S	S	-	N	N	N
6	S	S	S	S	N	-	N	N
7	S	S	S	S	N	N	-	N
8	S	S	S	S	N	N	N	-

S = Significant
N = Non-significant
A = Approaching Significance.

Table 26

Analysis of Variance - Final Weights of Pullet Chicks

(Series 2)

Variation Due to	Degrees of Freedom	Sum of Squares (SX^2)	Variance	Standard Deviation
Rations or Treatments	7	771,245.7		
Error	174	384,030.2	2,207.06	49.05
TOTAL ...	181	1,155,275.9		

Table 27

Average Weekly Weights of Cockerel Chicks
July 14-July 31, 1942.
(Experiment 2, Series 2.)

RATION*	0		2		4		5		6		7	
	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.	No. Chicks	Wt. in Gms.
1	25	38.10	24	116.25	21	266.57	20	351.05	20	445.25	20	592.90
2	25	38.10	21	119.52	19	272.63	18	372.94	18	450.14	18	573.83
3	25	38.81	20	112.70	19	260.74	19	358.10	19	442.89	19	561.84
4	25	38.20	22	116.36	20	269.40	20	367.10	20	455.30	20	597.30
5	25	38.81	23	123.52	23	279.09	23	382.56	23	458.08	23	585.83
6	24	39.04	18	105.83	18	242.67	16	327.44	15	425.13	15	558.53
7	27	38.96	27	112.33	27	275.04	27	369.92	27	477.00	27	631.18
8	25	38.44	22	114.45	22	269.54	18	344.61	16	415.75	16	561.00

* For composition of rations, see Table 22.

Table 28

Statistical Summary

Analysis of Significance of Differences
(Experiment 2, Series 2)

RATION	1	2	3	4	5	6	7	8
1	-	A	S	N	N	N	S	S
2	A	-	N	S	N	N	S	N
3	S	N	-	S	S	N	S	N
4	N	S	S	-	N	S	S	S
5	N	N	S	N	-	S	S	S
6	N	N	N	S	S	-	S	N
7	S	S	S	S	S	S	-	S
8	S	N	N	S	S	N	S	-

S = Significant
N = Non-significant
A = Approaching significance.

Table 29

Analysis of Variance - Final Weights of Cockerel Chicks (Series 2)

Variation Due to	Degrees of Freedom	Sum of Squares	Variance	Standard Deviation
Rations or Treatments	7	93,615.14		
Error	150	1,761,374.40	1,160.91	34.07
TOTAL	157	1,854,989.54		

Plate 1

Showing Differences in Shank Color

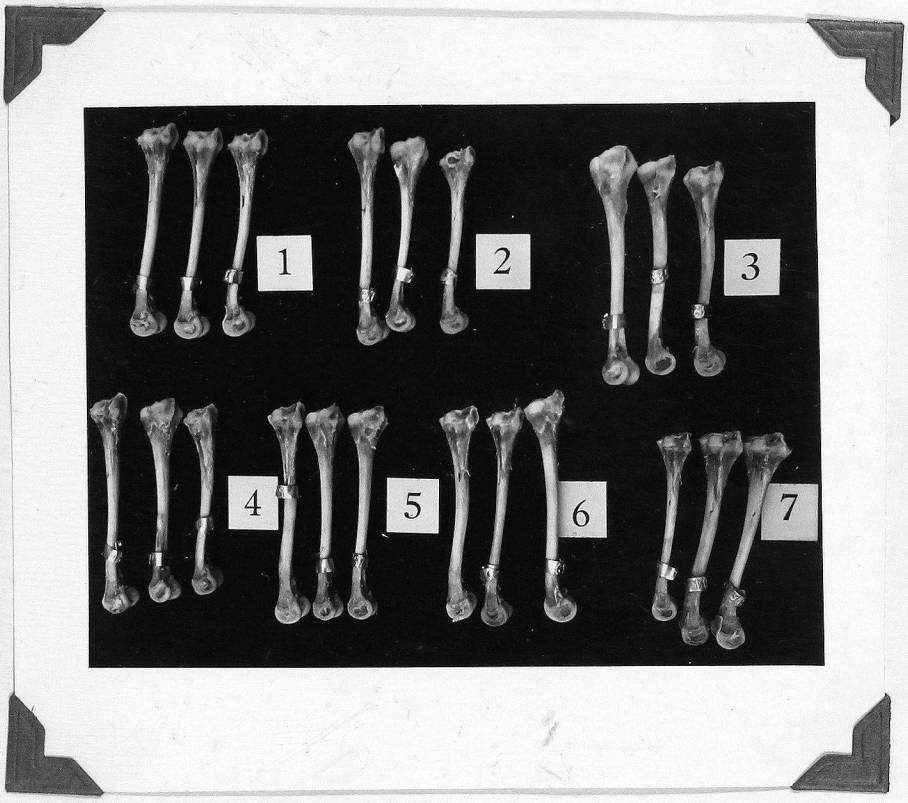


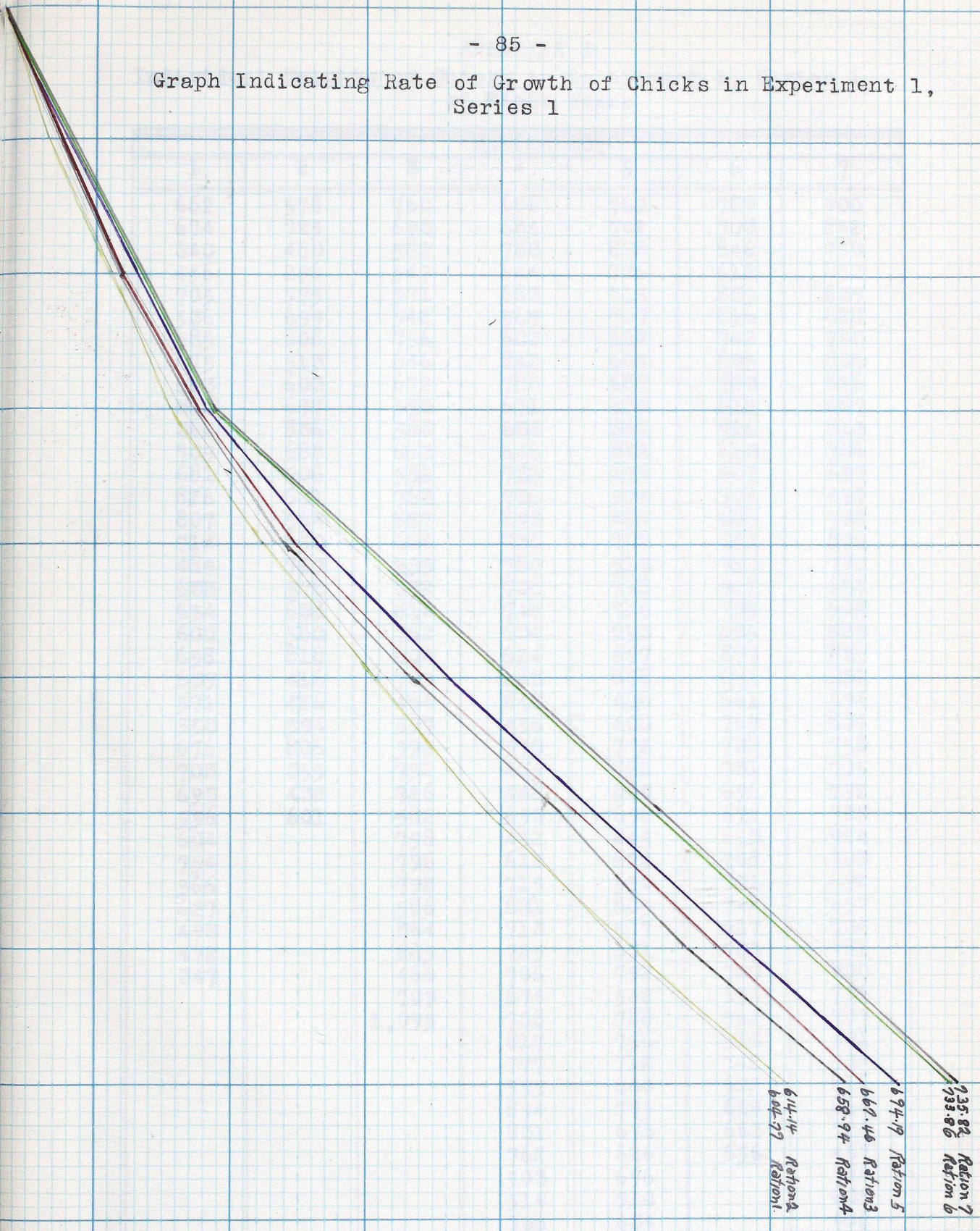
Plate 2

Tibia of Chicks Taken at Eight Weeks of Age from Experiment 1, Series 1, for Ash Analysis

Plate 3

A Section of the Battery Brooder

Graph Indicating Rate of Growth of Chicks in Experiment 1, Series 1



APPENDIX A

Individual Weights of Chicks in Experiment 1, Series 1, at Eight Weeks

RATION NO.						
1	2	3	4	5	6	7
662	578	760	606	762	789	900
674	725	693	685	702	903	852
640	480	582	780	838	846	753
446	296	547	644	736	612	853
705	775	571	683	715	835	839
536	699	542	569	707	856	828
585	808	756	603	662	742	793
475	513	646	842	604	805	806
683	603	672	788	687	723	826
380	677	590	671	635	812	687
362	836	588	634	867	816	813
709	688	663	646	832	813	736
681	706	552	732	694	867	657
826	631	763	736	574	774	492
807	564	827	898	492	686	708
714	650	664	736	708	687	806
484	729	555	780	513	727	790
632	572	872	708	758	921	698
654	638	814	748	746	792	688
600	580	762	604	753	605	825
658	818	604	624	697	879	836
639	416	709	683	878	671	630
571	426	464	843	466	661	594
553	594	597	456	400	769	837
676	806	592	570	772	730	758
703	355	752	435	722	731	775
693	432	726	448	860	696	792
556	601	582	653	696	672	783
604		758	452	445	653	924
754		796	612	822	708	703
566		792	715	690	701	692
627		586	631	805	748	657
493		384	713	577	917	734
472		665	725	631	783	781
347		466	706	792	700	830
		709	675	542	674	736
		1,095	708	788	563	707
			817	756	513	591
			777	712	742	534
			595	640	502	818
			894	775	614	864
			831	676	662	726
			762	626	656	457
			503	696		788
			514	910		806
			708	634		482
			325	632		600
			467	696		623
			384			731
			626			752

APPENDIX B

Individual Weights of New Hampshire Pullets in Experiment 2, Series 1, at Seven Weeks

RATION NO.						
1	2	3	4	5	6	7
836	640	851	929	869	783	741
480	731	849	807	773	724	723
692	762	741	732	817	772	760
711	681	683	682	557	743	863
714	702	569	723	570	862	853
691	793	689	802	728	675	834
661	704	702	806	756	884	725
905	711	807	774	692	739	764
720	714	824	664	760	654	685
789	723	843	635	770	797	854
532	760	601	534	670	851	741
578	639	810	868	598	635	860
638	640	570	680	849	644	601
750	591	595	605	604	774	495
680	604	645	670	703	484	723
	589	606	738	600	725	754
		570	709	704	735	484
		555	689	720	704	550
		735	749	630	580	
		678		815		
		752				
		704				

APPENDIX C

Individual Weights of Chicks in Experiments 1 and 2, Series 2, at Seven Weeks

Ration No. 1		Ration No. 2		Ration No. 3		Ration No. 4		Ration No. 5		Ration No. 6		Ration No. 7		Ration No. 8	
♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
660	610	425	610	590	501	507	635	564	645	520	607	464	620	585	660
513	720	508	600	541	460	550	585	500	670	503	640	552	725	735	440
524	763	500	385	391	460	611	500	554	711	493	530	650	637	500	610
558	652	585	760	415	420	565	610	549	623	452	618	570	591	478	549
494	453	400	490	595	480	531	635	468	650	539	447	475	685	490	638
411	382	549	465	528	321	560	612	643	499	465	448	401	670	625	510
580	652	320	810	455	470	570	670	411	540	570	475	640	460	465	614
500	610	310	665	583	410	640	650	589	605	501	490	610	751	481	695
590	584	590	611	498	628	598	650	549	530	520	728	550	511	521	685
475	709	670	654	488	658	485	650	490	589	550	501	683	670	449	522
554	660	495	595	520	958	461	475	551	661	675	630	610	751	370	508
623	752	440	532	507	549	585	650	564	555	560	634	580	683	483	475
645	695	530	595	495	538	408	410	453	649	600	490	583	450	570	521
411	614	297	540	625	611	740	620	631	728	591	460	551	760	550	710
549	373	482	440	518	710	583	790	560	555	498	680	470	780	575	438
464	580	340	752	350	611	420	540	560	495	440		435	741	628	401
601	469	324	375	598	770	710	559	425	605	673		544	485	638	
539	425	490	450	472	450	625	595	613	485	560		560	590	580	
582	460	528		650	670	449	570	449	499	501		400	500	549	
708	695	430		495		440	540	579	507			471	607	585	
500		470		520		510		485	503			501	670	618	
563				620				524	570			570	600	530	
519				368				625	600			641	690	406	
								591				430	485	584	
								436					500	560	
													770	495	
													660		