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by

W. C. Tully and K. W. Franke*

Introduction

During the past few years inquiries have been made regarding the use of several native limestones of South Dakota as substitutes for imported oyster shell and other limestone products used in the feeding of poultry. As a result of these requsts, a series of experiments were carried out and the results are herewith presented.

Review of Literature

It is easily recognized that it is difficult to separate the use of calcareous poultry feeding materials into the part which is used in growth and maintenance and that which is used in the production of the egg shell. It must also be made clear that this work is concerned with the supply of calcium and not with the materials used from the standpoint of a mechanical assistance in the grinding of food, namely, grit, which we prefer to think of in terms of the geologist as being composed of crushed, hard, silicious sandstone, or granite. True grit, therefore, is unable to supply anything but a very small fraction of soluble mineral substance. The term grit seems to be used in many reports in several ways, so that it includes mineral-bearing substances rather than only those products functioning as an aid in digesting foodstuffs by grinding them.

Wheeler (45) found 94.56 per cent of calcium carbonate in oyster shells and 94.34 per cent in egg shells. He stated that: "An unlimited supply of pounded glass has been attended with no bad results when the food and other grit available to fowls contained an abundance of lime, but, when food was deficient in lime and no other grit was obtainable, hens ate an injuriously large amount of glass". He also reported (46) that the ordinary feed and water supplied about 15 per cent of the lime required for egg shell formation. It is of interest to note that Buckner and Martin (5) came to the conclusion that in the normal food supply furnished to the wild progenitor of our modern fowl, all the necessary calcium and other materials for the production of its relatively small number of eggs were present, but that the addition of grit became necessary to its domesticated descendants to assist in the digestion of the large quantities of food required for intensified egg-laying. In further work in connection with the question of the use of grit, Buckner, Martin, and Peter (10) came to the conclusion that the addition of grit to a grain, mash, and buttermilk ration did not materially change the rate of the birds' growth, nor influence the production of eggs up to eight months of age. They felt that there was a tendency on the part of chickens to consume more grit than necessary. Bethke and Kennard (2) came to the conclusion that no benefit resulted from the use of grit in baby chicks

* K. W. Franke was in charge of the first two years' experimental work.

raised to twelve weeks of age or maturity, and that the birds not receiving any were able to utilize coarsly ground feeds, whole corn, and wheat as effectively as those that had free access to grit. They also concluded that under natural environment the chicken is obliged to eat grit to satisfy its mineral requirements. Buckner and Martin used a granite grit which contained some calcium and magnesium. Buckner, Martin and Peter used sand and coarse gravel, while Bethke and Kennard used a granite grit.

It is of interest to note that Hesse (22) has called attention to the fact that absorbtion of calcium salts from the intestine depends both on the water solubility of these salts and the acidity (pH) of the intestinal contents. This brings up a factor which we will have to admit has not been considered in our work, and that is the influence of the constituents of the diet on this acidity. Common (14) found in studies on calcium and phosphorous balances in laying pullets, that the pullets displayed a decrease in the calcium and phosphorous content in their droppings over a period of about two to three weeks before laying, together with a corresponding increased retention of these elements. He also correlated egg-laying with the relatively heavy voiding of phosphorus in the droppings, confirming and amplifying the results of other workers on this subject. In a later publication (15) he showed that calcium-phosphorous retention is shown to be related to the amount of sodium chloride in the food and that the extra phosphorus excretion which accompanies egg-laying involves no marked concommitant change of the amount of the potassium in the droppings. Hanssen (18) felt that the ordinary foodstuffs did not contain enough calcium and phosphorus, but that this was increased by the addition of meat or fish meal. He also showed the necessity for the addition of sodium chloride and felt that the rest of the minerals were supplied in the ration except during the egg-laying period, when he advised the use of snail shells.

Taylor and Martin (42) stress three factors, hereditary, pathological, and nutritional, as entering into the production of strong egg shells, and summarized their work by stating that some hens showed an inherited inability to produce heavy-shelled eggs under normal conditions. They showed that there were no relative factors involved between eggs of different shapes and sizes; that thin-shelled eggs might be produced by a pathological condition; and finally, that the lack of calcium supply and vitamin D will tend to produce thin-shelled eggs. Platt (36), in an experiment regarding the effect of individuality, came to the conclusion that the individual bird had a marked effect on the egg weight, shell texture, and albumen consistency. The sources of the calcium in his experiment were "Oyster Shell and Limestone Grit (85 per cent Calcium Carbonate)." Buckner and Martin (3) came to the conclusion that a laying hen whose supply of calcium is limited to that naturally occurring in the food will continue to lay eggs until there is a general depletion of calcium, magnesium, and phosphorus in its bones and certilages. They also found that the continued laying of eggs under these calcium restrictions does not materially alter the mineral composition of the egg shells or their contents, but that there is, however, a gradual thinning of the egg shells. They also came to the conclusion that since no shell-less eggs were laid in their experiments, the lack of calcium is not a fundamental cause of their formation. In their experiments they also noticed that in hens receiving no mineral material, there was no noticeable change in the general condition of the hens before the end of a ten-week period. Waite (44) reported that limestone and oyster shells were practically equal in value. This was determined by the breaking strength of the eggs and thickness of the shells. Buckner, Martin, Pierce, and Peter (4) came to the conclusion from experiments, that the hen can utilize the calcium in calcium carbonate for the production of both egg-shell and bone, but that the calcium of tricalcium phosphate can be utilized only for the growth of bone and not egg-shell production. They confirmed their previous work that calcium starvation is not the determining factor in the production of shell-less eggs. The California Agricultural Experiment Station (13) reported in a trial to determine the difference between oyster shell and limestone grit as sources of lime for poultry, that these were of equal value. Buckner, Martin, and Peter (6), in continuing their experiments, came to the conclusion that hens receiving limestone produced larger eggs than those not receiving it; that hens receiving corn, buttermilk, and limestone, produced larger eggs than those receiving corn, mash-containing tankage, and limestone, both the egg-shell and the liquid part being heavier; and that the deficiency of calcium in the diet does not materially change the liquid content of the liquid portion of the eggs, but that it materially decreases the number of eggs laid and the production of egg-shell.

Buckner, Martin, and Peter (83 found that a wholly deficient supply of calcium carbonate markedly diminished the hatchability of eggs. They also found (9) that the total contents, yolks, and whites of eggs produced by hens that received oyster-shell during the first six months of experimentation, weighed distinctly more than those produced by the corresponding hens that had not received calcium carbonate. In addition, when oyster-shell was added to the diet of the latter group, the weights of the total contents, whites and yolks, were not increased, but the number of eggs per hen was trebled. When the oyster-shell was removed from the former lot, the weight of total contents was decreased, and egg production per hen was halved. Kennard (26), on the basis of experiments, came to the conclusion that "oyster-shells appeared to be superior to limestone (95 per cent calcium carbonate) grit".

In still later work, Buckner, Martin, and Peter (11) found that in using different sources of calcium, namely carbonate, sulfate, lactate, chloride, and precipitated tricalcium phosphate, the carbonate was the most effective of the materials tried, judging by the degree to which it was utilized by the hens in the production of eggs, its influence on the weight of the egg, contents, and shells, and the quantities consumed. The sulfate was not as effective, shown by decreased egg production and lower weight of egg content and egg-shell. The lactate seemed to be utilized readily when based on the number of eggs produced, but the consumption was variable and small when compared to the carbonate and sulfate. The chloride was not consumed by the hens in sufficient quantity to justify definite conclusions, and its addition to the basal ration caused only a small increase in egg production. They again found that the phospate does not serve as a source of calcium in the production of eggs, as shown by decreased egg production and decreased weight. Martin and Insko (29) compared a dull, gray-brown limestone with a shiny, white limestone, and inferred from their results that it was possible to depend entirely on the usual type of ground limestone as a source of calcium for egg-shell formation. The white shiny limestone seemed somewhat more attractive to the fowls than the average type of limestone. They stated that there was very little difference in the chemical makeup of the two materials; the chief difficulty encountered would be that of getting the fowls to consume enough of the darker colored lime. Russell and MacDonald (38), from their experiments, came to the conclusion that the laying pullet can utilize calcium from citrate just as well as from the carbonate for egg formation, and found that the breaking strength for eggs, egg weights, and percentage of calcium in the shell were equal in these respects for both sources of calcium.

Hendricks, Lee, and Godfrey (21) came to the conclusion that the feeding of cod liver oil or administering ultra-violet radiation to laying hens confined without access to direct sunlight or green feed increased egg production and the thickness of egg-shells, and improved the general condition of the bird. When no cod liver oil was included in the diet, and birds were without access to direct sunlight, the addition of oyster shell increased egg production and thickness of egg-shell, even though a mineral supplement was present in the basal diet. Oyster shell either is a source of easily available mineral or contains a small amount of some factor which is present in cod liver oil.

The Wisconsin Agricultural Experiment Station (48) reports that thin-shelled eggs are due to rickets and that by giving either cod liver oil or exposing the chicken to artificial ultra-violet rays, the birds recovered and laid normal eggs. The same effect was obtained by turning the birds out into direct sunlight. They later (49) reported that thin-shelled eggs were probably due to a lack of vitamin D, as 28 per cent to 40 per cent of the eggs laid by hens in a pen with closed windows were cracked or broken, while only two per cent were defective where hens had been irradiated or exposed to direct sunlight.

Hart, Steenbock, and Morrison (19) reported: "Experiments conducted at the Wisconsin Experiment Station proved that the best form of lime to feed chickens is oyster-shells, with clam-shells a close second. Why one source of lime should be superior to another (oyster-shells over ground limestone) is not known, but it has been shown that oyster-shells are a superior source of lime for laying hens." Later (20) they find that their Wisconsin limestone (Waukesha) gave nearly as good results as when high calcium marble was used as pearl grits for growing chicks. Later in this publication, they state: "Laying hens should always receive extra amounts of lime. Present knowledge and practice indicate that its best sources are oyster-shells or clam-shells".

Iowa Station (24) tested a hard, low-magnesium limestone, oyster-shell, and clam-shell as sources of calcium for laying hens. On the basis of production, oyster-shell and the limestone were equally satisfactory, but clam-shell significantly poorer. Later (25) they reported that calcium in the carbonate form is apparently the only kind of calcium that can be utilized by the hen in the manufacture of the egg-shell.

Halpin and Lamb (17) found that the use of rock phosphate (lime phosphate) did not harm egg production when this product was used in the growing ration of the pullets. Voelcker (43), on the basis of feeding trials and analyses, came to the conclusion that there was no difference between cockle, and oyster shells, but did not give any results as to egg production or egg-shell strength.

In the production and handling of eggs for market, much loss occurs through breakage due to weak shells. This may be on the farm, handling in packing plants, or in transportation. It has also been stated that thin-shelled eggs have too great a loss of moisture during incubation and, therefore, have a lower hatchability. The question of egg-shell strength is, therefore, of importance, and it was felt a problem worth while for experimentation. No difference of "shell-texture," Holst, Almquist, and Lawrence (23), that is, the presence of areas of greater translucency, was noticed in these feeding trials.

Kennard (26) tested the strength of the egg-shell by a crushing test of eggs. In the first test the egg was placed endwise in sockets so shaped as to distribute the pressure over a considerable area of the egg. In the two other tests, the eggs were placed endwise against the flat surface on each end, instead of sockets. In all tests, the ends of the eggs were placed against 1/16 inch thickness of soft rubber, and they came to the conclusion, from these crushing tests, that a lack of lime causes weaker shells.

The New Jersey Station (34) tested eggshells for strength by recording the pressure needed to break the eggs when standing on end and state: "In general, to date, all that can be said is that the eggs from pens containing calcium carbonate grit or oyster-shell grit have produced the strongest shells, capable of withstanding ordinary handling, packing, and shipping."

Morgan (32) reports that the feeding of cod liver oil increased the breaking strength of the egg-shell, the per cent shell, and the per cent of calcium carbonate in the shells. The amount of increase is slight, so it is doubtful if there is any practical value in the use of cod liver oil from improving the quality of egg shells under average flock conditions. For the breaking test, the egg is placed under a plunger and water is added to a cylinder on top of the plunger until the shell is broken.

Romanoff (37) found a positive relation between egg-shell breaking strength and thickness of the egg-shell. Pores of the thick shell are small and numerous, while those of the thin shell are large and few in number.

Morgan (33) tested the breaking strength by gradually increasing the weight applied to the egg at right angles to the long axis until the shell cracked. He noted that a heavy spring production was accompanied by a smaller per cent shell and a decrease in breaking strength of the shell. He came to the conclusion that a definite positive correlation exists between the per cent shell of an egg and its breaking strength. Larro Research Farms (28) test the strength of egg-shells by crushing the entire egg, similar in procedure to that of Kennard (loc. cit.).

Swenson and James (41) tested the breaking strength of eggs by dropping a steel ball of known diameter and weight, and from this computed the force required to break the egg, and claim that this test is of value in determining the resistence of egg-shells to cracking as most shells in common are cracked by light impact with resistant objects such as other eggs, wooden cases, etc.

Almquist and Burmester (1) determined the breaking strength of egg-shells as follows: "Strips of shell with a minimum curvature were cut by a small, fine carborundum disc to dimensions of approximately five by twenty millimeters. The strips were free from membranes and cuticle, and were kept in a covered vessel over saturated calcium chloride solution until used. Then one end of a strip was placed in a small brass cup containing molten Woods' metal (melting point at 65.5°C.) and held in place until the metal had solidified. The brass cup containing the shell was placed in a clamp in the testing apparatus. The testing apparatus consisted of a balance having an empty beaker on one pan and a small metallic rod attached vertically under the center of this balance pan. The beaker and rod were accurately counterbalanced. The lower end of the rod touched the strip of shell at a standard distance of 5 mm. from the Woods' metal surface. Water was slowly run into the beaker from a burette thus applying an increasing force at right angles to the length of the strip until it was broken. The volume of water required to break the strip, together with the thickness and width of the strip of shell at the line of breakage, were measured and recorded."

Experimental

Part I

Sixty one-year-old White Leghorn hens used in this experiment were all picked from the same flock and were of the same breeding. When the experiment began on January 19, 1929, they were all in normal condition. These were so located that no feed or mineral matter would be obtained but that which was fed. The pens were approximately 4x16 feet and had windows that could be opened, thereby allowing the hens to be exposed to direct sunlight on most days.

a. Scratch feed:

Yellow corn, cracked	five parts
Wheat	two parts
Oats	one part

At the rate of two ounces per bird per day.

b. Dry Mash—hopper fed ad libitum:

Wheat bran	100 parts
Yellow corn meal	100 parts
Ground oats (heavy)	100 parts
Meat scraps	100 parts
Salt	3 parts

Free choice at all times.

c. Plenty of clean water.

d. Green food given twice a week. (Mangles or sprouted oats.)

The time of the experimentation was divided into three periods, preliminary of twelve weeks, and two experimental of twelve weeks each. During the preliminary period, Pens No. 1-5 received no calcium except that contained in the feed. This was carried out so as to remove as much as possible any accumulated or excess calcium that might be present in the body. Pen No. 6 had free choice of oyster shells. After 84 days, the pens were given the following types of calcareous materials; all of which were screened so that they passed through a sieve with 4 mm. openings and remained on a sieve with 2 mm. openings.

Pen No. 1 Oyster-shell.
Pen No. 2 Clam-shell.
Pen No. 3 Chalkstone (Southeastern South Dakota).
Pen No. 4 Limestone (Black Hills).
Pen No. 5 Limestone (Dolomitic).
Pen No. 6 No calcium except as in feed.

The feed, hens and calcerous materials were weighed every seventh day. A trap nest record of eggs was kept throughout the experiment. The difference between the average weight of the eggs for a given period, and the average weight of the shell for the sam priod, is taken as the average weight of the contents.

The average weights of the hens per pen showed that when the hens did not receive calcium they lost weight quite rapidly, while the pen receiving a calcareous material, even with high egg production, had only a small loss. After receiving calcium they held their weights quite well, and again the lack of calcium in Pen No. 6 resulted in a steady decline in weight to the end of the experiment. The average weight for the twelve-week periods for each pen is given in table 1.

Table 1 also gives the average mash consumption per twelve-week period for each pen. Relative percentage is based on the feed consumption of the pen producing the greatest number of eggs. It is well to note that the mash consumption was at least 25 per cent lower in all cases where the chickens did not receive calcium during the first twelve-week period. Some of the individuals in the first five pens lost as high as two pounds during the first twelve weeks. A number showed distinct leg-weakness. These recovered just as soon as they were able to obtain calcium. Miller, Dutcher, and Knandel, (31), studied the rate of ossification as influenced by a leg-weakness producing ration, by a normal ration, by sunlight transmitted through a window glass substitute, by direct irradiation with a quartz mercury vaor lamp, and by cod-liver oils. It is to be noted that in their ration a limestone was used as a part of the source of calcium. Their results indicate that irradiation for 15 minutes daily with the quartz, mercury vapor lamp and with the blue-flame carbon arc lamp, and by means of sunlight transmitted through vita glass and cel-o-glass, produced results in growth response and skeletal development comparable with those obtained with Newfoundland and Norwegian cod-liver oils.

Comparing the average weights of the hens in each pen, the thirteenth week it was noticeable that a gain was made in all except Pen No. 6, where a loss occurred as would be expected. A few of the hens gained as much as seven-tenths of a pound. On the last day of the eighth week, the hens were wormed, and the result was a decided disturbance in metabolism. The mash consumption decreased abnormally in Pens 2, 3, 4, and 6 during the ninth week followed by an increase in the tenth week.

During the next two periods, some interesting figures are to be noticed. First, that the average mash consumption of Pen No. 6 was 73.52 per cent higher than in Pen No. 1, which had the highest egg production and best egg-shell strength. Part of this increase may have been due to waste, as these chickens seemed to pick over their feed much more than

TABLE 1.—Summary of Results for Experiment Starting January 19, 1929 and Ending September 28, 1929

	Average Live Weights in Pounds					
Pen	1	2	3	4	5	6
1.						
Calcium Supplement:	**None**	**None**	**None**	**None**	**None**	**Oystershell**
1st Period	3.75	3.89	3.54	3.89	3.75	3.81
Lime Supplement:	**Oystershell**	**Clamshell**	**Chalkstone**	**B. H. Limestone**	**Dolomite**	**None**
2nd Period	3.69	3.73	3.45	3.85	3.59	3.47
3rd Period	3.67	3.58	3.42	3.72	3.51	3.46
2.	**Average Mash Consumption per Bird in Pounds**					
1st Period	7.16	5.81	5.06	6.21	7.00	9.72
2nd Period	7.97	7.93	7.18	6.63	14.08	13.83
3rd Period	6.70	7.53	5.90	6.81	9.33	8.63
3.	**Percentage Mash Consumption Based on Pen Producing Highest Number of Eggs**					
1st Period	73.66	59.77	52.06	63.89	72.02	100.00
2nd Period	100.00	99.50	90.09	83.19	176.66	123.52
3rd Period	100.00	112.39	88.06	101.64	139.25	128.81
4.	**Average Calcareous Material Consumption in Pounds**					
1st Period	—	—	—	—	—	+
2nd Period	0.66	0.60	1.05	0.97	1.79	0.0
3rd Period	0.22	0.43	0.33	0.46	0.54	0.0
5.	**Percentage of Calcareous Material Consumption Based on Pen Producing Highest Number of Eggs**					
1st Period	—	—	—	—	—	+
2nd Period	100.0	90.91	159.09	146.97	271.21	0.0
3rd Period	100.0	195.45	150.00	209.09	245.45	0.0
6.	**Total Number of Eggs Laid**					
1st Period	77	80	56	50	99(a)	167(b)
2nd Period	426	321	315	334	381	236
3rd Period	177	157	122	139	80	61
Total	680	554	493	523	560	466
(a) 10 wks.						
(b) 6 wks						
7.	**Average Number of Eggs Laid Per Pen Per Week**					
1st Period	6.42	6.67	4.67	4.17	9.9	27.83
2nd Period	35.50	26.75	26.25	27.83	31.75	19.83
3rd Period	14.75	13.08	10.17	11.58	8.67	5.08
8.	**Percentage Production Calculated on the Average Number of Eggs Laid per Pen**					
1st Period	23.07	23.97	16.78	14.98	35.57	100.00
2nd Period	100.00	75.35	73.94	78.39	89.44	56.86
3rd Period	100.00	88.68	68.95	78.51	45.22	34.44
13-36th wk.	100.00	82.01	71.45	78.45	67.33	45.15
9.	**Average Breaking Strength in Grams**					
1st Period	927.12	997.68	877.14	1172.07	1294.54	2667.19
2nd Period	1929.98	1800.59	1637.21	1793.34	1575.37	1155.39
3rd Period	1396.61	1610.28	1504.06	1602.34	1514.63	1194.57
13-36th wk.	1813.30	1705.44	1570.64	1697.84	1545.00	1174.98
10.	**Percentage Breaking Strength**					
1st Period	44.85	48.26	42.43	56.70	62.62	100.00
2nd Period	100.00	93.30	84.83	92.92	81.63	59.87
3rd Period	100.00	94.91	88.65	94.44	89.27	70.41
13-36th wk.	100.00	94.05	86.62	95.63	85.20	64.80
11.	**Average Egg Weight in Grams**					
1st Period	52.049	51.059	50.539	55.809	54.409	54.489
2nd Period	55.86	55.98	53.65	56.74	54.80	52.21
3rd Period	55.02	53.47	51.69	58.47	52.21	52.50
Average	54.31	53.60	51.96	57.00	53.80	53.06
12.	**Average Shell Weight in Grams**					
1st Period	3.279	3.299	3.299	3.439	3.929	5.109
2nd Period	5.43	5.24	4.64	5.17	4.67	3.56
3rd Period	5.21	4.55	4.35	5.08	4.36	3.81
13-36th wk.	5.32	4.89	4.49	5.13	4.52	3.69
13.	**Average Egg Content Weight in Grams**					
1st Period	48.779	48.379	47.239	52.389	50.489	49.389
2nd Period	50.43	50.74	47.87	51.57	50.13	48.65
3rd Period	49.81	48.92	47.34	53.39	47.95	48.69
Average	49.67	49.34	47.48	52.45	49.52	48.91

the first four pens, and some unpreventable waste may have occurred. The droppings of this pen had a soft and abnormal appearance.

Buckner, Martin, and Peter (7) showed that when hens had a free choice of oyster-shells, 25.7 per cent to 33.2 per cent of calcium oxide would be found in the ash of droppings, while only 4.5 per cent to 5.4 per cent would be found when the hens were denied calcium. This amount of calcium in the latter case, is probably nearly all present as phosphate.

Pen No. 5 also had a 76.66 per cent higher mash consumption than Pen No. 1. While the higher consumption of Pen No. 6 may be explained as due to the craving for calcium and, thereby, large mash consumption, this same factor is not plausible unless we can give the idea that here the well-known calcium-magnesium antagonism influences, or produces, the same craving as a lack of calcium would.

Wheeler (47) states: "The functions of calcium are very important, and some of them are directly antagonistic to those of magnesium, the nearest to calcium chemically of the recognized elements of the body and of ordinary foods. But the two elements are associated in nature in many ways, and magnesium, seemingly, might serve to some extent in place of calcium for such purposes as egg-shell material when calcium is lacking. No instance was found where magnesium did this to any significant extent, or replaced calcium in the bones from which it was withdrawn for shell material, although both elements are normal constituents of these structures". Kramer, Shelling and Orent (27 and 39) and Shipley and Holt (40) have shown that magnesium in low concentration can inhibit in vitro calcification of rachitic bones. Palmer, Eckles, and Schutte (35) showed that intakes of magnesium sulfate comparable to that present in water from some localities, may cause serious and continuous loss of calcium from the body tissues of cattle when the phosphorus content of the ration is low.

Haag and Palmer (16) concluded that magnesium in high concentration was shown to be a disturbing factor in nutrition based on growth and mineral balance data. Buckner, Martin, and Insko (12) stated: "It is evident from these results that the addition of magnesium carbonate to the rations fed to the chicks in this experiment disturb the calcium and phosphorus balance necessary for the normal formation of bones during the first six weeks growth." In addition to this, one has to consider the fact that magnesium salts, such as magnesium sulfate, citrate, carbonate, and oxides, etc.., are used to cause catharsis with soft or fluid stools. The cathartic action is mainly the result of the retention of fluid in the intestines by the osmotic action of the unabsorbed salt. May it not then be possible that the magnesium content of dolomitic limestones may be high enough to produce this cathartic action, and thereby cause a fairly rapid movement of the calcium ions through the system so that the fowl cannot absorb enough for normal egg production or strength? Mendel and Benedict (30) showed that the urinary excretion of calcium was increased by magnesium ions. It was also noted, as in the case of Pen No. 6, that the droppings from this pen were of a soft consistency, not at all normal.

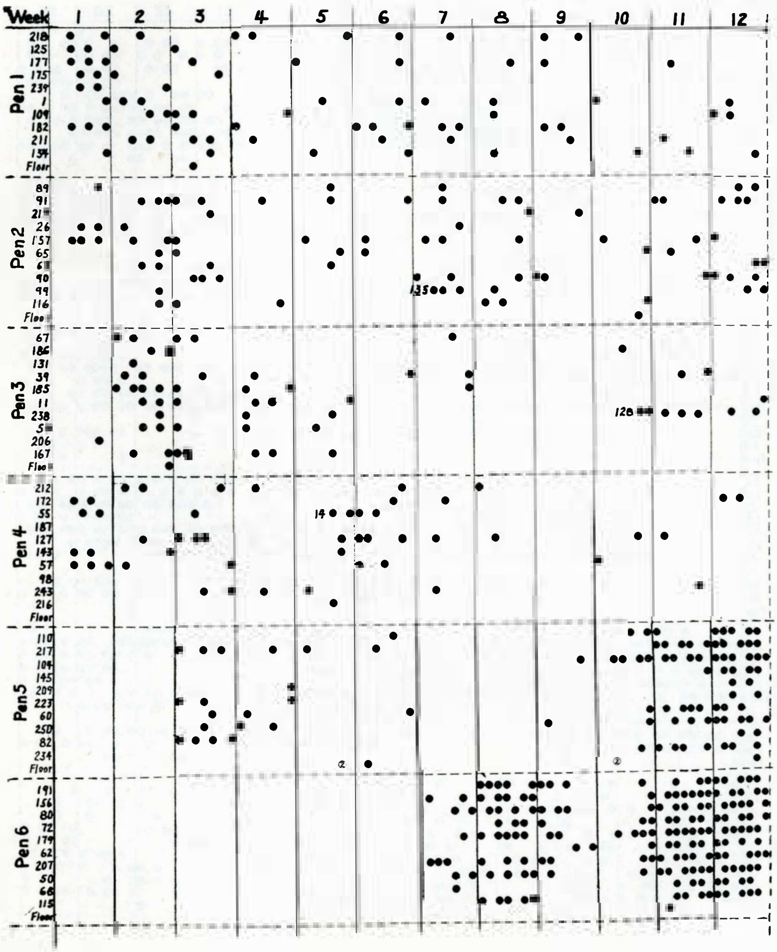

Chart 1.—Trapnest record of the individual hens in each pen for the first period, (12 weeks), of experimentation. Pens 1 to 5, no calcium except naturally in food. Pen 6, oyster-shell available.

NOTE: Pen 5 not started until 3rd week and Pen 6 until 7th week.

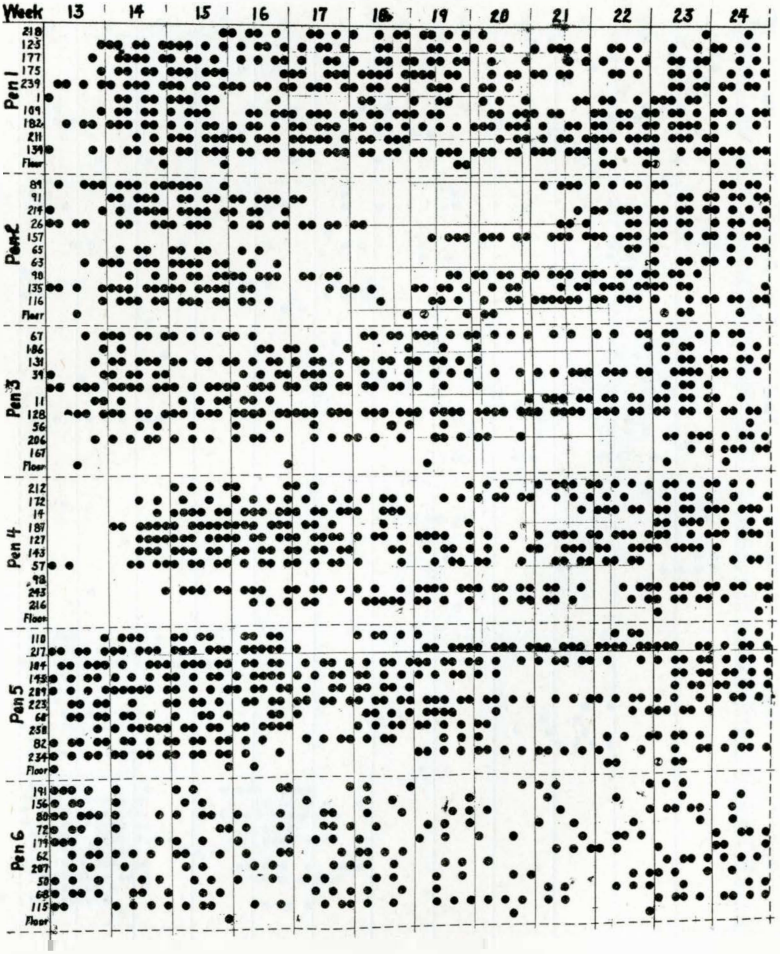

Chart 2.—Trapnest record of the individual hens in each pen for the second period (12 weeks) of experimentation. Calcium available as oyster-shell, Pen 1; clam-shell, Pen 2; Chalkstone, Pen 3; Limestone, Black Hills, Pen 4; Limestone, Dolomitic, Pen 6; none, Pen 6.

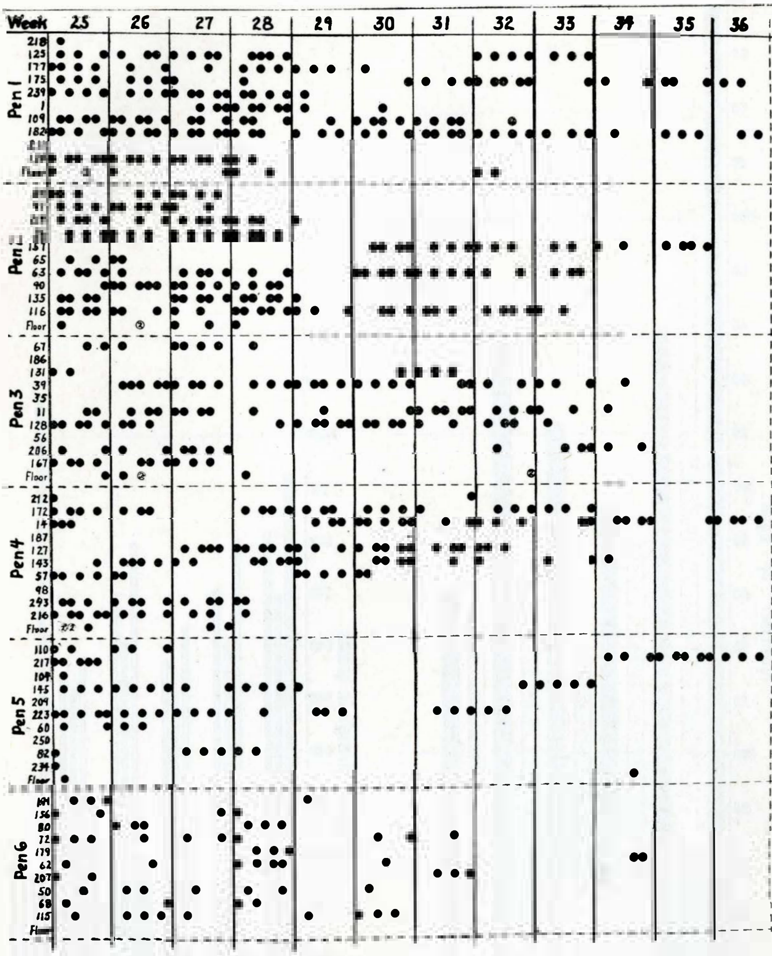

Chart 3.—Trapnest record of the individual hens in each pen for the third (12 weeks) period of experimentation. Some minerals as second period: calcium available as oyster-shell, Pen 1; clam-shell, Pen 2; chalkstone, Pen 3; limestone, Black Hills, Pen 4; limestone, Dolomitic, Pen 5; none, Pen 6.

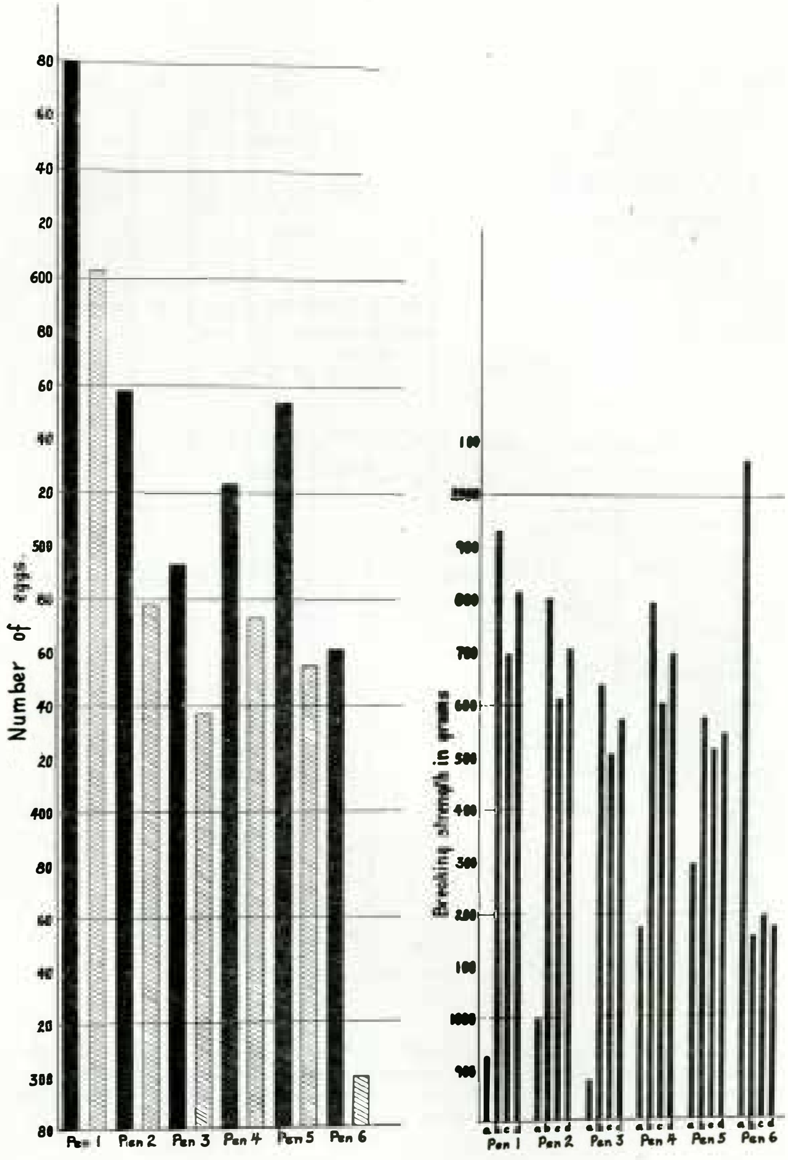

Chart 4.—Graph showing the total number of eggs laid (solid black) and eggs laid during 13th–36th weeks, (cross hatched) for each pen. Also showing the average breaking strength per pen: a, 1–12th week! b, 13–24th week; c, 25–36th week; d, average of 13--36th week.

Table 1 gives the average consumption of the calcareous materials, and relative percentage for each pen during the periods.

Charts 1, 2, 3, and 4, and Table 1 give the egg production. The graphic method of showing egg production in charts 1, 2, 3, and 4 indicate very clearly the decreased egg production due to lack of calcium or type of calcium in Pens 1-5 in the first period (1-12th week), and Pen No. 6 in the 2nd (13th-24th week). and third (24th-36th week) periods. The increased egg production in Pen No. 5 after the ninth week was found, after observations were made, to be due to the fact that this pen was adjacent to Pen No. 6, and as they scratched, they kicked enough oyster shell over into Pen No. 5 to cause this increase. The error in experimentation shows how slight changes produce great errors in results. The decreased egg production shown by the pens, especially No. 5 and No. 6 after the eighth week, was due to a treatment for worms, showing the detrimental effect of the treatment. The irregular egg production as shown by Chart No. 1 can easily be contributed to the fact that the hens had to accumulate enough calcium from their feed. They would then lay again until this calcium or any other reserve supply in the body was again used up. Chart 2 shows how quickly the hens respond to the addition of calcium. There is one exception, and that is in Pen No. 4, which received Black Hills limestone. This pen had a so-called induction period of ten days before production started. Another interesting fact to note is the decreased egg production of Pen No. 2 (clam-shell). After the 16th week, this pen went through a partial molt. It is not probable that clam-shell was the cause of this.

Table 1 and Chart 4 give the figures, percentages, and graphic representation of the difference in egg-shell strengths.

Determination of Egg Shell Breaking Strengths.

The need of a method for testing differences in the strengths of shells of eggs produced on different rations resulted in the development of the tester described below.

Having considered whether the egg as a whole should be placed under compression and broken, it was decided that as only one test per egg could be obtained by this procedure, it would be better to develop a method which would enable several tests to be made on the same egg.

The base of the tester is a piece of metal ½ inch thick by eight inches square, to which is fastened the bearing block. This block has a ½ inch diameter brass rod accurately ground in, so as to slide freely. To the bottom of this rod is fastened a chuck to hold a 1 mm. diameter pin, which should be made of tool steel and hardened, with the end surface exactly at right angles to the length. To the top of the rod is brazed a brass plate on which a container is placed to receive the shot. A hook is brazed on the edge of this plate and to it is fastened a trip cord which operates the trigger on the reservoir. It is best to add a layer of lead on the plate which can be scraped off so that the rod, chuck, needle and plate weigh 200 grams. The two containers receiving the shot are also made of copper, brass, or tin. Solder may be added to the bottom so they weigh exactly 50 grams.

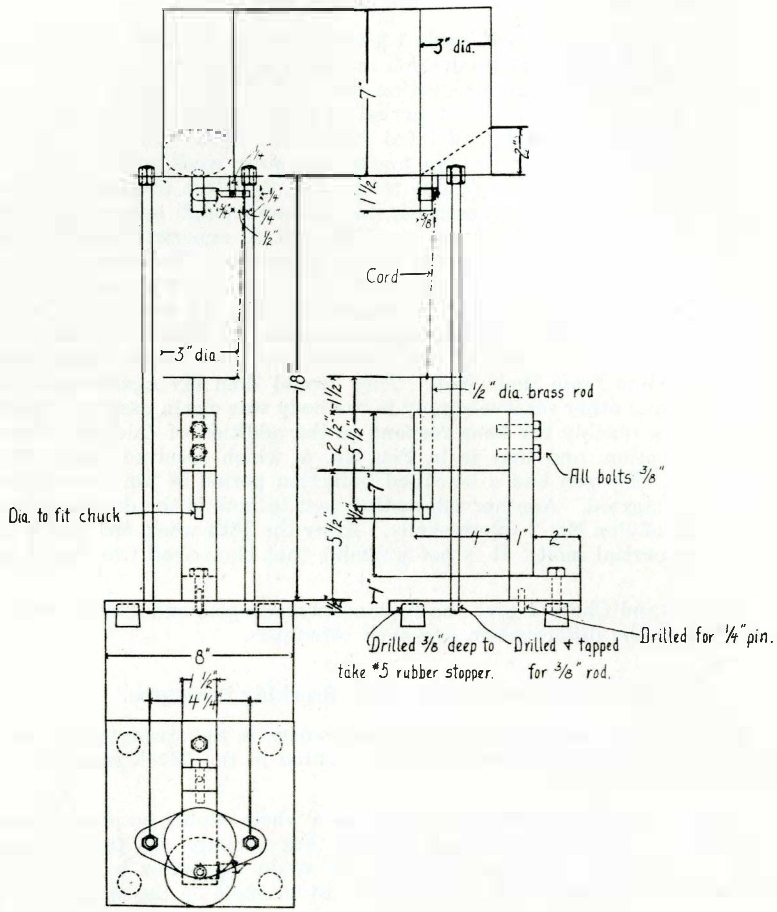

Fig. 1.—Figure 1 gives the dimensions of the present design. The container for receiving the shot from the reservoir on top is omitted, also a metal funnel which may have to be hung under the spout so that the shot will be directed into the receiver, and not scattered.

It is advisable to glue a rubber cushion to the bearing block. This cushion should have a ¾ inch diameter hole so the brass rod does not touch, and adjusted at a height that will allow the pin to penetrate the egg not more than ¼ inch. This will also absorb the shock of the dropping weight of the plunger and shot.

Two ⅜ inch rods are screwed into the base. The reservoir for holding the shot is fastened to the top of these rods. This reservoir has a false bottom sloped so that the shot will feed freely through the spout. A hood is hung to the spout by two pins. The end of the spout may have to be rounded off slightly to enable the hood to swing freely underneath. The pin which holds the hood up on the trigger bar should be soldered on with an extra amount of solder in order to give more weight so that when the hood drops it has enough force to shut off the flow of shot. To the bottom of the reservoir is brazed a small flat strip to which the trigger bar is fastened by a rivet loose enough to swing freely. The cord fastened to the hook on the plunger plate is tied to the outer end of the trigger, a small hole having been drilled ½ inch from the rivet. The inner end of the trigger bar is cut at an angle giving the pin of the hood space enough to swing freely past it.

The egg is supported on a rubber cushion made from a large rubber stopper with its top surface cut out so as to give a fairly large supporting area to the egg. It is also desirable to make lead disks three inches in diameter, which weigh exactly 100 grams. These are laid on top of the plunger plate under the shot receiver. This will save time when used to test eggs with strong shells.

The strength is determined by puncturing each egg three times with the blunt 1 mm. diameter rod. The force to puncture is applied evenly, as the zinc shot slowly runs out into the funnel with stem extending into containers with a baffle at end of stem to break the force of gravity. Just at the instant that the puncture takes place, the flow of shot is stopped by the trip. The amount of shot required to break the egg is weighed and the average of the three tests taken is the breaking strength of the egg.

During these tests two distinct types of breaks were noticed. The first were clear, sharp punctures, with no radiating cracks on the surface, made on all eggs from hens fed oyster-shell. The second were irregularly broken and radially cracked punctures, made on the eggs of those hens without a calcium supply, and also on some eggs produced in Pens 2-5. In the case of eggs produced in the no-calcium pens, it was interesting to note that in the case of a hen laying two or three eggs a week, the second egg punctured with less pressure than the first, and the third with less than the second. There were only a few exceptions to this during the time of this experiment. In the case of the calcium-fed chickens there was no loss of strength, even with eggs consecutively laid; the second would sometimes be higher than the first.

Table 1 gives the average weights of eggs, egg shell and egg content, for each period. The egg weight and egg content do not give any information that could be explained from the standpoint of source of calcium fed, the differences being due probably more to inherited characteristics than feed. The eggshell weights show, as would be expected, a decided increase when calcium is fed. The average egg-shell weight for Pen No. 5 for the first period is probably too high due to the factor already noted. It is quite interesting to note that the pen receiving dolomitic limestone made the lowest gain in egg-shell weight.

The gain of egg-shell weight is:

Pen No. 1		62.69 per cent
Pen No. 2		48.63 per cent
Pen No. 3		36.47 per cent
Pen No. 4		49.56 per cent
Pen No. 5		15.31 per cent
Pen No. 6	loss	27.65 per cent

Discussion

The fowls not receiving any calcareous material soon showed marked differences in their physical appearance; as the experiment progressed, they seemed to lose their vitality and plainly showed either malnutrition or looked as if they were suffering from worms. They felt light, were loose-feathered and slow in movements.

At the beginning of the ninth week leg-weakness, probably osteoporsis rather than rickets, was noticed in some of the fowls, but they partially recovered again within a week. From this time it was noticed that this weakness would almost invariably develop after the hens had laid an egg. They would not lay again and so recovered by slowly accumulating calcium from their feed.

Three fowls out of the five pens were so weak at the end of the twelfth week that they could not walk, and another so light and weak that she could scarcely hold up her body, although they all seemed to have good appetites. One of the hens that had leg weakness belonged in pen No. 1. When fed oyster shells, she recovered much more quickly than those receiving either clam-shells or chalkstone, and between these two the clam-shell-fed one recovered and laid eggs before the one receiving chalkstone.

After the tenth week, it was noticed that sores had developed where the leg bands rubbed. The check pen on oyster shell showed no such signs at this time. These sores disappeared just as soon as the hens received a calcium supplement.

Shortly after calcereous materials were fed, it was noticed that a number of hens lost their toe nails. The question arises—was this caused by lack of calcium?

It was also noticed that the hens not receiving any calcium lost the yellow pigment from their shanks much faster than those receiving a source of calcium, although they laid only about a fourth as many eggs.

During this first period of 12 weeks, three hens died in the pens not receiving calcium materials. These were autopsied by the Animal Health laboratory. Report on No. 55 was: "No evidence of disease or parasitic invasion, except was egg-bound." Report on No. 99 was: "Found fowl round worms and tape worms of the smallest varieties." It was on this report that the hens were wormed on the 16th day of March; the last day of the 8th week, No. 238 died from unknown causes, but it is to be noted that her death occurred just after the worm treatment.

The hens that died were replaced from a reserve pen except No. 167 which died in the 28th week. An autopsy on No. 167 reported: "Undetermined cause of death."

TABLE 2.—Summary of Results for Experiment Starting February 1, 1930 and Ending October 11, 1930

Pen	1	2	3	4	5	6	7	8
1.				Average Live Weights in Grams				
Calcium Supplement:	None	None	None	None	None	Oyster	Oyster	No Ca.
1st Period	1921.4	1962.4	1887.2	2052.4	1937.5	2011.3	1997.7	1937.5
Calcium Supplement:	Oyster	Clam	Chalkst.	B.H.Lim.	Dolomite	Oyster	None	No Ca.
2nd Period	1843.3	1867.7	1789.0	1937.1	1890.5	1898.7	1752.8	1786.6
3rd Period	1661.9	1825.0	1746.8	1820.2	1787.9	1832.8	1730.0	1686.6
2.				Average Mash Consumption per Bird in Grams				
1st Period	7220.0	6740.0	6567.5	6987.5	6870.0	7787.5	7942.5	10282.5
2nd Period	6857.5	6780.0	6035.0	6674.5	6127.5	6100.0	5817.5	7182.5
3rd Period	4397.5	5172.5	5010.0	5360.0	4875.0	5002.5	5247.5	5255.0
3.				The Percentage Mash Consumption Based on Pen Producing Highest Number of Eggs				
1st Period	92.71	86.55	84.33	89.73	88.22	100.00	101.99	132.04
2nd Period	101.14	100.00	89.01	98.44	90.38	89.97	85.80	105.94
3rd Period	90.21	106.21	102.77	109.95	100.00	102.62	107.64	107.38
4.				Average Calcareous Material Consumption in Grams				
1st Period	—	—	—	—	—	227.5	300.0	0.0
2nd Period	240.0	250.0	175.0	285.0	605.0	160.0	0.0	0.0
3rd Period	50.0	45.0	37.5	100.0	125.0	37.5	0.0	0.0
5.				Percentage of Calcareous Material Consumption Based on Pen Producing Highest Number of Eggs				
1st Period	—	—	—	—	—	100.00	131.87	—
2nd Period	96.00	100.00	70.00	114.00	242.00	64.00	0.0	0.0
3rd Period	40.00	36.00	30.00	80.00	100.00	30.00	0.0	0.0
6.				Total Number of Eggs Laid				
1st Period	180	163	109	144	161	305	254	134
2nd Period	311	336	214	301	245	259	156	138
3rd Period	77	55	41	72	82	54	59	42
Total	568	554	364	517	488	618	469	314
7.				Average Number of Eggs Laid Per Pen Per Week				
1st Period	15.0	13.6	9.1	12.0	13.4	25.4	21.2	11.2
2nd Period	25.9	28.0	17.8	25.1	20.4	21.6	13.0	11.5
3rd Period	6.4	4.6	3.4	6.0	6.8	4.5	4.9	3.5
8.				Percentage Production Calculated on the Average Number of Eggs Laid per Pen				
1st Period	59.01	53.44	35.74	47.21	52.79	100.00	83.28	43.93
2nd Period	92.56	100.0	63.69	89.58	72.92	77.08	46.43	41.07
3rd Period	93.90	67.07	50.00	87.80	100.00	65.85	71.95	51.22
9.				Average Breaking Strength in Grams				
1st Period	1347	1178	1161	1748	1300	1796	1231	1252
2nd Period	1768	1762	1486	1747	1552	1794	1210	1060
3rd Period	1519	1464	1319	1494	1468	1817	1166	1084
10.				Percentage Breaking Strength				
1st Period	75.00	65.59	64.64	63.92	72.38	100.00	68.54	69.71
2nd Period	98.55	98.22	82.83	97.38	86.51	100.00	67.45	59.08
3rd Period	83.60	80.57	72.59	82.22	80.79	100.01	64.17	59.66
11.				Average Egg Weight in Grams				
1st Period	54.38	53.34	51.35	55.70	55.41	57.88	53.98	52.71
2nd Period	54.18	53.31	52.12	55.83	54.64	56.11	51.71	49.95
3rd Period	53.78	53.41	49.93	54.11	55.06	53.64	50.66	49.51
12.				Average Shell Weight in Grams				
1st Period	3.92	3.85	3.50	4.01	3.91	5.44	4.95	4.20
2nd Period	5.14	4.97	4.51	5.09	4.73	5.20	3.81	3.36
3rd Period	5.09	4.66	4.10	4.40	5.04	5.38	3.58	3.74
13.				Average Egg Content Weight in Grams				
1st Period	50.46	49.49	47.85	51.69	51.50	52.44	49.03	48.51
2nd Period	49.04	48.34	47.61	50.74	49.91	50.91	47.90	46.21
3rd Period	48.69	48.75	45.82	49.71	50.02	48.26	47.08	45.77

Part II

The second year's work started Feb. 1, 1930 and was continued until Oct. 11, 1930. It varied from the previous year's in that an all mash ration was used which was as follows:

	Per cent or lbs.
Ground yellow corn	30
Ground oats	20
Ground wheat	10
Ground barley	10
Wheat bran	10
Meat scrap	10
Wheat middlings	10
Salt	0.5
Total	100.5

All hens used in this trial had been trapnested from the time they started to lay and were sorted in the pens according to their records. Trapnesting was continued throughout the experiment. All hens were given a worm treatment before the experiment started.

Two additional pens were added, one receiving oyster shells during the whole experimental period and the other receiving no calcium but that present in the mash.

The results of the second year's work are presented in Table 2.

Part III

1930-31 Experimental Work

Results of previous experiments had been extremely interesting but production records in favor of the pen receiving any particular lime supplement were not conclusive, though tending to favor the oyster shell, because only 10 birds made up each pen and total eggs were used as a criterion for production. Because of these criticisms the present experiment was changed so that each pen consisted of 25 pullets at the start and production records were computed on a hen-day basis, no birds that died being replaced.

Experimental

This trial started November 15, 1930, when 25 Buff Orpington pullets were used in each of four pens. Birds were weighted at the beginning of the experiment and thereafter at each four-week period. The experiment was continued until July 25, 1931, for nine periods.

Each pen was fed and managed the same except for the lime supplements used. Birds were confined to their pens throughout the experiment. The following all-mash ration, fed ad libitum, was used from the start of the trial until March 22, 1931:

Percent	
32	ground yellow corn
15	wheat bran
15	wheat middlings
10	ground oats
10	ground barley

7 meat and bone scrap
3 dried buttermilk
5 alfalfa meal
1 steamed bonemeal
1 salt
1 cod liver oil (not concentrated)

100 total

Because it was thought that on the March weigh-day pullets were losing too much weight, after careful consideration of the problem, on March 23, 1931 the system of feeding used was changed to that of mash and grain. The following mash was fed ad libitum, with specially constructed containers below the regular wall-type hoppers so that no wastage of mash occurred. These were used from the start of the experiment.

Percent
32 ground yellow corn
15 wheat bran
15 wheat middlings
6 ground oats
6 ground barley
13 meat and bone scraps
5 dried buttermilk
5 alfalfa meal
1 steamed bonemeal
1 salt
1 cod liver oil (not concentrated)

100 Total

The grain ration consisted of equal parts whole yellow corn and wheat. This was all fed in late afternoon at the rate of one and half pounds per pen per day, or on a basis of approximately 7½ pounds per 100 pullets per day. The grain ration was made purposely low at first so that less than 50 per cent of the daily total feed would be grain. On May 2 the grain ration was cut to one pound per pen per day and this continued until the end of the experiment. In order partially to deplete the birds' systems of lime, no supplements were given from November 13 to November 29, a sixteen day period. The lime supplements used commencing November 29 were as follows: Pen 1, a regular grade oyster shell; Pen 2, a red limestone obtained in the Black Hills of South Dakota; Pen 3, a dolomitic type limestone from Wisconsin; Pen 4, a very soft chalkstone obtained from Menno, S. D. All samples were screened before use so that they passed through a sieve with 4 mm. openings and remained on a sieve with 2 mm. openings. All lime supplements were fed in regular grit and shell hoppers but with a special pan beneath so that no wasting could occur. No granite or other insoluble grit was fed during the experiment.

On each weigh-day both feed and mineral supplements were weighed back and amounts consumed computed on a hen-day basis. Reference to Table 3 shows production per bird, feed consumption, and mineral supplements used for each period and for the experiment. All figures are on a hen-day basis.

TABLE 3.—Production per pen per bird on a hen-day basis for each period and for the entire experiment.

Average feed and mineral consumption per bird throughout the experiment. Hen-day basis.

Pen Number		Period I 11-15-30 to 12-12-30	II 12-13-30 to 1-9-31	II 1-10-31 to 2-6	IV 2-7 to 3-6	V 3-7 to 4-3	VI 4-4 to 5-1	VII 5-2 to 5-29	VIII 5-30 to 6-26	IX 6-27 to 7-24	Total	Total
		eggs	eggs	eggs	eggs	eggs	eggs	eggs	eggs	eggs	eggs	
Pen 1	Oyster shell	5.16	4.64	10.01	15.5	14.0	15.41	13.4	8.8	5.53	92.45	
Pen 2	Black Hills limestone	4.72	6.54	13.3	12.9	11.1	15.15	13.95	12.6	10.28	100.54	
Pen 3	Dolomitic limestone	4.2	4.76	11.83	12.5	14.05	11.92	13.1	10.3	5.61	88.27	
Pen 4	Menno chalkstone	3.24	3.88	13.79	14.8	15.53	11.7	11.42	10.8	7.24	92.4	
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	pounds
Pen 1	Grain	—	—	—	—	512	1090	838	978	1407	4875	10.73
	Mash	2020	3218	2134	2842	2247	1849	2011	2058	1084	19466	42.87
Pen 2	Grain	—	—	—	—	545	1271	1159	1471	1655	6101	13.43
	Mash	1876	3226	2128	3020	2585	1894	2716	1365	1299	20109	44.29
Pen 3	Grain	—	—	—	—	482	1048	957	1059	1171	4717	10.38
	Mash	1972	3179	1961	2581	2640	2397	2697	2338	1225	20990	46.23
Pen 4	Grain	—	—	—	—	522	1179	1190	1271	1374	5536	12.19
	Mash	2087	2393	2061	3300	2965	2550	1967	3285	2281	22889	50.41
		11-29-only, to 12-12										
Pen 1	Oyster shell	41	63	72	120	114	56	87	25	36	614	1.35
Pen 2	Black Hills limestone	59	102	175	129	48	52	73	61	49	748	1.64
Pen 3	Dolomitic limestone	119	292	521	490	179	143	162	246	166	2318	5.10
Pen 4	Menno chalkstone	45	68	153	84	42	73	59	55	40	619	1.36

TABLE 4.—Average Weights of Each Pen for Each Period

		11-15-30	12-13-30	1-10-31	2-7	3-7	4-4	5-2	5-30	6-27	7-25
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
Pen 1	Oyster shell	2461	2427	2473	2598	2407	2389	2314	2280	2156	2272
Pen 2	Black Hills limestone	2474	2490	2578	2595	2476	2376	2237	2283	2300	2189
Pen 3	Dolomitic limestone	2463	2442	2473	2532	2415	2333	2255	2410	2233	2223
Pen 4	Menno chalkstone	2449	2347	2516	2621	2491	2417	2248	2313	2320	2456

Table 4 shows the average weights of the birds in each pen for each period of the experiment. Pullets were of almost the same average weight per pen when the trial started and while there was a half pound average difference between the heaviest and lightest pens at the end of the experiment, this was not considered significant or due to the mineral supplements used, but was probably the result of the small number of birds remaining in some pens.

Mortalities in all pens was excessively high, and in Pens 1, 2, 3, 4, only 8, 7, 10, 9, pullets respectively survived. The quality of the stock used in this experiment was undoubtedly poor as 10 per cent of the birds which died showed no symtoms other than emaciation which possibly could have been partly caused by chronic coccidiosis but which probably was due largely to poor breeding in the Buff Orpington pullets used. An extreme heat wave at the end of June killed several more pullets. Because of this excessive mortality experimental results are by no means conclusive and the experiment will be repeated. Except that all records were computed on a hen-day basis, results would mean nothing, but under this system they are at least suggestive.

All eggs laid during the experiment were weighed to the nearest 0.1 gram. In addition egg shell breaking strength was tested on all eggs from each lot for three consecutive days, at regular intervals throughout the course of the experiment. A summary of this is shown in Table 4a.

TABLE 4A.—Egg shell breaking strength in grams (average of three consecutive days' eggs each month throughout the experiment)

	Pen I Oyster shell	Pen II Black Hills limestone	Pen III Dolomitic limestone	Pen IV Menno chalkstone
Average breaking strength in grams				
11-15-30 to 2-6-31	1710	1756	1701	1742
2-7-31 to 5-1-31	1948	1859	1691	1915
5-2-31 to 7-24-31	1736	1893	1671	1852
Breaking strength expressed as a percentage of highest test				
11-15-30 to 2-6-31	97.38	100.00	96.86	99.20
2-7-31 to 5-1-31	100.00	95.43	86.80	98.30
5-2-31 to 7-24-31	91.71	100.00	89.26	100.00

Discussion

Feed consumption varied to some extent, especially in Pen 1, which was slightly below average, and in Pen 4, which used almost five pounds of mash and grain per bird more than average.

The most interesting result obtained, however, and not previously reported, was the excessive amount of the dolomitic type limestone used, which was 3.1 times as much per bird as the next highest pen. As this type of limestone was as expensive as the others its use would be very uneconomical.

Concerning egg production no significant difference was found among any of the pens.

Part IV

1931-32 Experimental Work

This experiment was a repitition of the previous year's work. A few changes were made in experimental procedure all of which were considered as improvements. Because of the previous year's difficulty in maintaining equilibrium between grain and mash, an all-mash ration was used slightly different from that used in the first part of the previous experiment. The formula for this was:

Percent or lbs.

32 ground yellow corn
10 wheat bran
15 wheat flour middlings
10 ground oats
10 ground barley
10 meat scrap (50-55% protein)
5 dried buttermilk
5 alfalfa meal
1 steamed bonemeal
1 salt
1 cod liver oil

100 Total

This was fed ad libitum in hoppers arranged with receptacles underneath so that no feed wasting could occur.

The lime supplement used in each of the four pens of 25 S. C. Rhode Island Red pullets was the same as last year except that commercial calcite replaced Menno chalkstone. The latter no longer was being produced commercially. Lime additions were fed as in the previous trials so that entirely no wastage occurred. No granite or other insoluble grit was used at any time. This trial started November 1, 1931 and was continued ten months until August 31, 1932. All calculations were made on a monthly basis, as the birds were weighed the last of each month.

An outbreak of infectious bronchitis in December caused the death of 34 of the 100 pullets and resulted in a severe set-back in egg production. However, apart from this the experimental results were not affected in any way as the disease was equally severe in all pens and all figures were computed on a hen-day basis.

Table 5 shows detailed results of the feed consumption, mineral consumption, and egg production.

TABLE 5.—Summary of Experiment from November 1, 1931 to August 31, 1932

	Pen I Oyster shell	Pen II Black Hills limestone	Pen III Commercial limestone	Pen IV Commercial calcite
All mash ration consumed per bird, hen-day basis	75.63 lbs.	75.14 lbs.	71.46 lbs.	74.85 lbs.
Mineral consumed per bird, hen-day basis	2.01	2.09	2.70	2.59
Production per bird, hen-day basis	149	154	161	148
Production per bird of those living through experiment	149	147	154	146

Part V

1932-33 Experimental Work

Due to the low mineral supplement consumption in both previous years' experiments it was considered advisable to reduce the mineral content of the all-mash ration. The high mineral content of the meat and bone scraps used (50-55 per cent protein) together with the one per cent of steamed bonemeal used in the ration undoubtedly reduced the amounts of lime needed from the supplements fed. While the practice of changing the basal ration annually can be questioned, when a change is made to improve the experimental procedure, we regard this as justifiable. For the experiment of 1932-33, while it was thought advisable to reduce the mineral content of the ration as much as possible, due to the effect this had previously of masking the true value of the supplements, a semi-purified ration was not used. However, high protein meat scraps with the analysis given below were used, to reduce as much as practically possible the mineral fed in this part of the ration, and the one per cent of steamed bonemeal was omitted.

High protein meat scraps

	Moisture	Fat	B. P. L.	Protein
(Av. of 4 representative samples) %	4.16	7.98	7.45	68.75

Such a high protein meat scrap would not contain more than approximately 12 per cent of mineral as compared to 20-25 per cent in the more generally used 50-55 per cent protein meat and bone scraps. The use of such a product reduced the mineral content of all-mash ration approximately 1.5 per cent.

The all-mash ration used throughout the experiment was as follows:

Percent or lbs.	
35	ground yellow corn
10	wheat bran
15	wheat middlings
10	pulverized oats
10	pulverized barley
8	meat scrap (68% protein)
5	dried buttermilk
5	alfalfa meal
1	fine salt
1	cod liver oil
100	Total

This was fed ad libitum in hoppers, arranged with receptacles underneath so that no feed wasting could occur.

The lime supplements used in each of the four pens, each of 25 S. C. Rhode Island Red pullets, were the same as in the previous year's trial, similarly fed so not wasting could occur. No granite or other insoluble grit was fed at any time. Apart from the basal ration changes to induce greater lime supplement consumption, this was a repetition of last year's experiment.

This trial started November 18, 1932, and was continued through six four-weekly periods until June 8, 1933.

A second outbreak of infectious bronchitis in March killed 33 pullets in less than a month and, of course, resulted in a severe set-back in production. However, apart from this the experimental results were not affected in any way as the disease was equally severe in all pens and all figures were computed on a hen-day basis.

Table 6 shows detailed results of the feed consumption, mineral or lime supplements used, and egg production.

TABLE 6.—Summary of experiment from November 18, 1932 to June 8, 1933

	Pen I Oyster shell	Pen II Black Hills limestone	Pen III Commercial limestone	Pen IV Commercial calcite
	lbs.	lbs.	lbs.	lbs.
All mash ration used per bird, hen-day basis	42.8	42.53	45.5	45.2
Mineral consumed per bird, hen-day basis	1.74	2.07	2,09	2.51
Production per pullet, hen-day basis (eggs)	83.2	85.7	84.1	91

Part VI

Chemical Analysis of Calcareous Material*

The chemical analyses of the minerals used in the foregoing feeding experiments were considered necessary in order to see whether or not there was any correlation between their composition and their effect on egg production and egg shell strength. Analyses of two lots of egg shells were also considered of interest as the only reference to an analysis of egg shell was that of B. Wieke (1) who reported the percentage of calcium, magnesium, carbonate, calcium phosphate, and organic matter.

Although a great number of feeding trials on various types of calcareous materials have been carried out, only a few give some idea of the composition of the materials used. It must also be recognized that the physical structure or composition may influence the results obtained by the various types of calcareous materials used. Some experiments in this field have been carried out in connection with these experiments; although only a few of a preliminary nature, they indicate a tool which may lead to very interesting information..

Procedure

Composite samples of egg shells produced and representative samples of the mineral fed were ground in a ball mill to pass through a 100 mesh sieve and each thoroughly mixed..

Moisture was determined on a two gram sample by heating to constant weight at 105° C. The sample was then tranferred to a beaker and covered with 200 cc warm water. HCl (1 part conc. acid to one part H_2O) was added until the carbonates were dissolved and 10 cc of the acid in excess was then added. After standing, covered, on the steam bath for five hours, it was filtered through a tared filter paper and the residue washed with H_2O. The residue was dried to constant weight and the gain in weight recorded as HCl insoluble matter, and was saved for further separation.

* The work herein reported was carried out by John T. Tripp, graduate student.

The filtrate was made up to 500 cc with water and 50 cc portions used for analysis. These aliquots were evaporated to dryness; dissolved in 5 cc concentrated HCl and 100 cc H_2O and again evaporated to precipitate SiO_2. Five cc HNO_3 and 50 cc H_2O were then added and evaporated a third time to oxidize organic matter. Four additions of HNO_3 were necessary in the case of the egg shells to secure clear solutions.

The SiO_2 was filtered and burned to constant weight in a platinum crucible. The silica was then covered with hydrofluoric acid; 1 drop H_2SO_4 added and heated. The loss of weight was recorded as SiO_2.

Ten cc saturated NH_4Cl and 1 cc bromine water were added to the filtrate and boiled gently until the odor of bromine could no longer be detected in the vapors. While hot, it was made just basic to litmus with dilute NH_4OH. The precipitate so obtained was ignited, weighed and recorded as Al_2O_3 and Fe_2O_3.

The oxides were dissolved in hot HCl and separated by the basic ammonium tartrate method (2). The $Fe(OH)_3$ when separted was dissolved in hot H_2SO_4, reduced with zinc and titrated, hot, with $KMnO_4$. Aluminum was calculated by difference.

The filtrate from the $Fe(OH)_3$ and $Al(OH)_3$ was heated to boiling, made barely basic to methyl orange; and 10 cc saturated, hot $(NH_4)_2C_2O_4$ added slowly with constant stirring. It was boiled gently for 1 minute and filtered at the end of 2 hours. The precipitate was dissolved in HCl and reprecipitated as before. The Ca was then determined by titrating with $KMnO_4$ at 65° C.

The combined filtrates from the first and second precipitations of calcium were evaporated to 75 cc and 15 cc saturated $NaNH_4HPO_4$ added to the cold solution. The solution was made alkaline and 5 cc NH_4OH in excess were added. In 12 hours it was filtered. The precipitate was then dissolved in HCl and reprecipitated as before. It was ignited and weighed as the pyrophosphate.

The HCl insoluble residue was fused with Na_2CO_3 in a platinum crucible and dissolved in water and HCl. It was then given the same treatment as the acid soluble portion of the sample.

Sulphates were determined in four 50 cc portions of the acid soluble part of the sample by precipitating with $BaCl_2$. The filtrate was made alkaline with NH_4OH and 10 cc $(NH_4)_2CO_3$ was added to precipitate the heavy metals. It was then filtered and concentrated on a steam bath. More $(NH_4)_2CO_3$ was added and the precipitate removed. When no more precipitate would form, the solution was acidified with HCl and evaporated. By careful heating ammonium chloride was expelled. The residue was dissolved and evaporated in platinum crucibles. It was dried and the weight recorded as sodium and potassium chlorides.

Sodium was determined on two portions with uranyl zinc acetate.

Potassium was determined in the other 2 portions of the mixed chlorides as K_2PtCl_6 and the factor .3067 was used in converting to KCl, as advised by Hillebrand and Lundell (4).

Phosphorus was determined on new samples dissolved in HNO_3. It was necessary to evaporate three or four times to oxidize organic matter in the case of the egg shells.

The phosphorus was then precipitated and reprecipitated as ammoni-

TABLE 7

	Clam shells		Chalkstone		Limestone (Black Hills)		Oyster shells		Limestone (Dolomite)		Egg shells Oyster shell-fed		Egg shells No added Ca but in food	
	HCl soluble	Total	HCl soluble	Total	HCl soluble	Total	HCl soluble	Total	HCl soluble	Total	HCl soluble	Total	HCl soluble	Total
H_2O	.55	.55	.84	.84	.49	.49	.30	.30	.24	.24	.85	.85	1.53	1.53
SiO_2	.12	.65	1.02	8.31	.46	11.03	.27	.54	.35	.46	.07	.37	.06	.30
CaO	53.98	54.11	48.56	48.73	47.71	47.85	54.22	54.42	31.20	31.33	51.24	51.36	51.38	51.52
MgO	1.03	1.09	.80	.90	.51	.73	.78	.81	20.24	20.26	1.08	1.09	.72	.74
Fe_2O_3	.69	.70	1.67	1.69	.63	.66	.38	.41	.10	.11	trace		trace	
Al_2O_3	.31	.41	2.02	2.94	.94	1.76	.80	.88	1.24	1.35	1.66	1.78	1.68	1.86
Na_2O	.73	.73	.19	.19	.07	.07	.28	.28						
K_2O					.11	.11	.12	.12	.36	.36	.24	.24	.29	.29
CO_2	42.36	42.36	36.38	36.38	37.45	37.45	42.55	42.55	45.07	45.07	40.02	40.02	37.99	37.99
SO_3			.47	.47							1.05	1.05	.47	.47
P_2O_5	.10	.10	.24	.24	.15	.15	.27	.27	.10	.10	.55	.55	.63	.63
Cl	.02	.02			.03	.03	.01	.01	.12	.12	.06	.06	.04	.04
	HCl insoluble		HCl insoluble		HCl insoluble		HCl insoluble		HCl insoluble		HCl insoluble		HCl insoluble	
SiO_2	.53		7.29		10.57		.27		.11		.30		.24	
CaO	.13		.17		.14		.20		.13		.12		.14	
MgO	.06		.10		.22		.03		.02		.01		.02	
Fe_2O_3	.01		.02		.03		.03		.01					
Al_2O_3	.10		.92		.82		.08		.11		.12		.18	
Organic											2.60		5.30	

um phosphomolybdate. The precipitate was then dissolved in NH_2OH and precipitated as $MgMH_4PO_4$. It was ignited and weighed as $Mg_2P_2O_7$.

Chorides were determined by dissolving samples in HNO_3 and precipitating with $AgNO_3$.

CO_2 was determined by decomposition with HCl and absorbing the evolved gas in NaOH and weighing. It was also determined by using standard NaOH as an absorbent and titrating. The most satisfactory results were obtained by absorbing the CO_2 in ascarite.

Spectrographs were taken of all the precipitates to insure their purity.

In addition to the chemical separation and determination of the elements, spectroscopic examinations were made of all the minerals and of the composite samples of the egg shells.

The results of the spectroscopic examination did not reveal any traces of elements other than those reported. This, however, does not necessarily mean that other elements are not present because after the work was completed it was found that the technique used would not reveal minute traces. The time of exposure was too long and the range of the spectroscope used was too narrow to make certain the presence of any elements that might be present.

Table 7 gives the results of the analyses of the mineral fed and the egg shells produced.

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Summary

1. The results of five years' experimental work in comparing several calcareous materials as sources of calcium for laying hens are reported.

2. A lack of calcium fed as a supplement to the ordinary complete ration, either all-mash or mash and grain, markedly decreases egg production and causes a loss of egg shell strength.

3. Added calcium is absolutely necessary for maximum egg production.

4. Added calcareous materials can stimulate the calcium secreting part of the oviduct in twenty-four hours after feeding, when such materials had been previously denied the hens.

5. Over a five year experimental period no significant difference was found in favor of any of the supplements used, namely oyster shell, clam shell, chalkstone, Black Hills limestone, dolomitic limestone, calcite, or commercial limestone, when results were judged by egg production, egg weight, and egg breaking strength.

6. When compared with any of the other tested supplements dolomitic limestone was not economically satisfactory because of excessive consumption.

7. A simple and very satisfactory apparatus for testing egg shell breaking strength is described.

8. A complete analysis of five of the calcareous materials tested is given together with that of egg shells.

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