THE EFFECT OF DIET
ON THE INTERIOR QUALITY OF EGGS

THESIS FOR THE DEGREE OF M. S.

GRACENT EIDT
1938

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THESIS

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INTRODUCTION

From a relatively obscure position in agriculture less than a century ago, the poultry industry, according to the 1926 census, has risen to third place in the United States. As late as the middle of the nineteenth century, there was very little scientific or general information available concerning the keeping of poultry, as compared to today, when practically every state college is teaching the science of poultry husbandry, as well as conducting extensive research in this field.

Many factors have been influential in bringing about this change. Among the more important of these are standardization of breeds, improvement of cold storage, refrigeration of cars, mechanical incubation, scientific grading methods, and a more complete understanding of the principles of feeding. This last-mentioned factor is, without a doubt, one of the most important in the science of poultry husbandry, and must be thoroughly understood if a product of acceptable quality is to be put on the market.

Investigations have shown that a high correlation exists between the methods of feeding the flock and the quality of the product obtained, both in eggs and meat. A generation ago, little attention was given the matter of feeding. Flocks often were left to forage for themselves during the summer months. It is not surprising that eggs from such flocks frequently failed to reach the consumer in good condition.

Once the close relationship between feeding and the other factors in the care of the flock was realized as effecting the quality of the egg, investigational work gradually was undertaken in an effort to determine which dietary constituents are essential to produce a product that approximates the requirements of the consumer.

Dietary factors which influence egg quality naturally fall into two groups; those concerned with the formation of the shell, and those effecting the interior parts of the egg. It is the purpose of the present work to determine which of a number of ingredients used in different rations tended to produce an egg of greater desirability insofar as shell strength and the quality of the various interior parts of the egg are concerned.

HISTORICAL

In the last decade a great deal of experimental work has been done regarding dietary factors effecting the interior quality of eggs. In reviewing this work, one finds that it naturally falls into somewhat distinct divisions, depending upon the part of the egg effected. The scope of this thesis does not include any material on the influence of dietary differences effecting the vitamin content of the egg. It is known, however, that vitamin influencing factors in the feeding and care of the flock have an important effect on both the fresh and the stored egg. For this reason a brief review of recent work, is given here.

Bethke and his associates (1) have shown that the vitamin A potency of egg yolks can, by feeding cod liver oil and green feeds, be increased to five times the amount found in yolks produced by hens not receiving these supplements. Similar results were reported by the New York Experiment Station (2).

Sherwood and Fraps (3) found that a ration containing yellow corn and alfalfa as vitamin sources, did not contain sufficient vitamin A to maintain high egg production as well as a high vitamin A potency in the eggs. Holmes (4) showed that cod liver oil increased the vitamin A potency of eggs produced by hens that were fed a diet deficient in this vitamin. Wilcke, Nelson, and Henderson (5) found that rats fed egg yolks from hens whose ration included yellow corn and cod liver oil showed a more rapid growth rate than rats fed yolks from eggs produced by birds lacking these ingredients in their diet.

Much work has been done in determining the result of various dietary factors on the interior parts of the egg. This work can be classified according to the part of the egg these various dietary factors affect. Those affecting the yolk follow:

Neel (6) states that egg quality is the result of a combination of stock, feeding, cleanliness and marketing. The direct association between feed and yolk color was early recognized, and, since yolk color is one of the first qualities of the egg to be noticed by the consumer, a great amount of work has been done to determine the effect of specific dietary rational factors on this part of the egg.

Parker (7) found no definite seasonal trend in yolk color, but believed it to be closely correlated with the amount of green feed the bird receives. This statement is substantiated by Parker, Gossman and Lippincott (8) who found the depth of yolk color depended upon the amount of greens fed rather than upon the kind. They also discovered that birds fed white corn produced light yolks in contrast to the production of dark yolks when fed yellow corn. That the depth of yolk color was directly proportional to the amount of greens consumed by the bird was further shown by Parker (9), and by Bisbey, Appleby, Weis, and Cover (10).

Kent (11) shows that the quantity of production, as well as the kind of feed, determines the depth of yolk color, hens laying fewer eggs having more pigment to distribute among them.

As a desirable yolk color can be produced by careful choice of ingredients in the diet, so yolks of objectionable color result from the excessive use of green feed, or by giving access, in any amounts, to certain green plants. That yolks of undesirable color were produced by feeding cheeseweed was shown by Almquist and Lorenz (12). This was especially true of eggs coming from storage. The same authors later showed that cheeseweed will produce off-colored whites (13).

Regarding the influence of dietary factors on the white of the egg, work paralleling that on the yolk has been done. As with the yolk, excessive feeding of green feed has been found to produce a lower quality albumin, as well as one often of inferior color.

Since the relationship of various feeds to yolk color is based upon certain complex coloring substances found in both the feed and the egg, it may be well to consider this work briefly. Almquist (15) found that the pigments in the yolk were composed largely of xanthophyll, which is a group of complex organic substances of the same general constitution and very closely related in their physical and chemical behavior. Their color ranges from red to yellow, and they are found not only in the yolks of eggs, but in green leaves and the tissues of many animals.

In the same work, Almquist states that a second group of pigments in the yolks are the carotenes. These are similar to the xanthophylls, but neither can be converted into the other. Of the two, the yolk color is controlled much more by the amount of xanthophyll in the feed.

Kline, Schultze, and Hart (16) state that carotenes are precursors of vitamin A, and that hens and chicks can convert carotenes into vitamin A. They found that xanthophylls had no vitamin A value.

Palmer and Kempster (17) showed that chicks could be raised to maturity on a carotene-free diet and be normal except for the lack of color in the egg yolk, body fat, and skin.

Kempster (18) showed that the yellow yolk color was due mainly to xanthophyll, the sources of which were the green leafy plants and yellow corn, and that the yellow yolk color can be controlled by the amount of xanthophyll in the feed.

Almquist and Lorenz (12) also showed that it was possible to produce nearly white yolks by withholding feeds containing yolk coloring pigments.

While perhaps not of equal importance with the condition of the yolk or white, the flavor of the broken egg is a factor concerning the quality of the egg as a whole, which can by no means be ignored. A brief discussion of the more important work done in this line should, therefore, be considered.

That a desirable flavor is dependent mainly upon the feeding of clean, wholesome grains and mashes, properly balanced, is shown by Schroeder (19), who also points out that strong feeds such as onions, turnips, excessive amounts of cabbage, etc. impart an undesirable flavor to the egg. Jones (14) also points out that rape or turnip tips are apt to taint the egg flavor. Work done at Kansas (2) showed that the addition of meat and bone scraps to the ration apparently gave to the eggs an undesirable odor which disappeared when they were a week old. That a fishy flavor to newly laid eggs may be due to inheritance rather than environment is shown by Vondell (21).

EXPERIMENTAL

To conduct this experiment ten pens containing fifteen birds each, of single comb White Leghorns were selected. An effort was made in selecting the individuals to have each flock of comparatively uniform breeding for egg number, and size. Excepting the diet and range factors, the flocks were cared for under uniform conditions. Each group was housed in a 10 x 12 foot pen in a straw loft house at the Michigan State College Poultry Department. Mash was kept before the birds constantly. Grain, consisting of equal amounts of cracked yellow corn and whole wheat, was fed in troughs once a day. Fresh water, kept warm with a 25 watt bulb during the months of November, December, January, February and March, was furnished daily. Each pen was lighted by a 50 watt bulb during early morning in order to provide a thirteen hour day for the birds. Ample straw litter was kept on the floors and changed whenever necessary.

The birds were trapnested, the eggs being marked and gathered three times daily. Immediately upon gathering, the eggs were stored in refrigeration at 36° F. until the measurements of shell strength and interior parts were taken. At no time were the eggs allowed to stand for more than forty-eight hours.

With the exception of two pens, as indicated in the accompanying table, the birds were given no range. One pen was given limited range in a run 10 x 10 feet, which was completely enclosed, while another group was given free range, which provided this flock access to a manure pile and conditions otherwise typical of an average farm yard.

The following table gives the ration for each of the ten pens and also indicates where range was excluded, limited, or free.

TABLE I

	Pen 1	Pen 2	Pen 3	Pen 4	Pen 5	Pen 6	Pen 7	Pen 8	Pen 9	Pen 10
Gr. Barley	20	20	17.5	20	17	20	20	20	20	20
Gr. Oats	20	20	20	20	20	20	20	20	20	20
F. Midds	20	20	20	20	20	20	20	20	20	20
Bran	20	20	20	20	20	20	20	20	20	20
Alf. Meal	5	5	5	5	5	5	5	5	5	5
Salt	1	1	1	1	1	1	1	1	1	1
S. O. M.	1	2.5	5.5	1.3	4	8.5	2.5	5	5	2.5
Meat Scraps	1	2.5	5.5	1.3	4	8.5	2.5			2.5
Fish Meal	1	2.5	5.5				2.5			2.5
Corn Meal	11	6.5		11.4	6		6.5	4	4	6.5
Corn Gluten								5	5	
*Molasses								No	Yes	
Crude Prot.	15.15	16.99	20.3	14.9	16.92	19.92	16.99	17.14	17.14	16.99
Range			No	No	No	No	Lim.	No	No	Free

*Molasses was included in the laying mash of Pen 9 at the rate of 7%. This was to determine if this ingredient has any effect on the interior quality of the eggs produced in that pen.

Before the actual measurements of the interior parts of the egg, or of comparative shell strength could be made, certain apparatus had to be constructed. For determining the pounds pressure necessary to crush the shell of the egg, a machine was devised which gave this information on a comparative basis to tenths of a pound. The device consisted first of a movable yoke, or "egg breaker", mounted on four ball bearing steel showcase door rollers. In the center of the yoke, an upright steel plate was fixed to the base board. A spring milk scale, lying horizontally, was attached to a hook inserted in the end of the yoke. The pressure necessary to break the egg was supplied through the lever which was attached to the scale by a rope passing through a two inch pulley. An adjustable cam was set to allow for one-sixteenth to one-eighth inch crushing of the shell. A small metal angle iron was placed on the scale dial ahead of the hand, to record the pressure exerted to crush the shell. In operating, the egg was placed in the opening within the yoke, with the large end against the stationary plate. Pressure, through the lever, was then applied until the egg was held in position, when the cam was set to allow the proper amount of break. With the metal angle iron in place ahead of the scale hand, additional pressure was applied to the handle until the shell broke. Breaking of the shell permitted the yoke to follow the scale lead until the space allowed by the cam set was taken up. In doing this, the pressure was partially relieved from the scale, which resulted in the scale's hand dropping back a few pounds. The angle iron, however, remained at the figure in the scale dial marking the pressure required to break the shell.

As a means of securing a color standard with which the yolks were compared, the formula adopted by C. H. Schroeder, Associate Director of Research for the Larrome Milling Company of Detroit, Michigan, from work carried on by Dr. Sharp of Cornell University, was used. This consisted of the proper amounts of New Type Duco in red, orange, Chinese yellow, and white colors to mix in securing a uniform gradation of colors ranging from a pure white to a deep red.

In mixing the various colors, the following technique was used. Twenty-five C.C. pipettes, one for each of the four colors, were used to measure the exact amounts of the component colors. In trying various means of doing this, it was found most successful to first fill the pipette to slightly above the level indicating the exact amount of duco desired. After filling to this excess of the amount desired, the duco was allowed to escape until slightly less than the desired amount remained.

After stopping at this point, the duco adhering to the inside of the glass from the previous excess filling slowly drained into the main volume, increasing it to the exact amount desired. When this was reached, the duco was released into the mixing vessel. No draining of the pipette was allowed after the main volume was removed. By holding an electric light immediately behind the pipette, the level of the duco could be seen through the film lining the inside of the glass.

By the above means, the exact amounts of each color desired were transferred to the mixing vessell. After thoroughly mixing these, the whole was applied in a thick layer to the inside of a 25 c.c. test tube. A quarter inch round camel hair brush was used. Twenty-four test tubes were required in making the complete set, the range comprising a complete gradation from pure white, through yellows and oranges, to deep red. Starting with the white, each gradation was numbered by fives, beginning with 00, 0, 5, 10, etc. to 110. The glass imparted a gloss to the color, which most successrully duplicated that of the yolk.

When comparing the color of a yolk to the scale, comparisons were made until two adjoining scale colors were found that were immediately darker and lighter than the yolk. The color of the yolk was then designated by the number of the color it most nearly matched.

In mixing the different Ducos for each test tube color, a total of about 3 c.c. of the colors was compounded. The accompanying table shows the amounts of each of the four Ducos used to give the desired scale color, the latter being indicated by numbers from 00 to 110.

TABLE II

Tube No.	White	Chinese yellow	Orange	Red
00	3 c.c.			
0	2.75	.25 c.c.		
5	2.62	.37		
10	2.4	.6		
15	2.25	.75		
20	2.	1.		
25	1.5	1.5		
30	1.	2.		
35		3.		
40		2.9	.09	
45		2.8	.18	
50		2.25	.75	

TABLE II (continued)

Tube No.	White	Chinese yellow	Orange	Red
55		2.	1.	
60		1.75	1.25	
65		1.5	1.5	
70		1.25	1.75	
75		1.	2.	
80		1.	2.	.1
85			3.	.
90		1.	2.	.13
95		.33	2.33	.33
100			2.62	.37
105			2.5	.5
110			2.25	.75

In gathering the various data desired, the system of measurement developed by Dr. P. J. Schaible was used. The egg was first weighed, the weight being recorded as ounces per dozen. The shell strength was then found by the method already described under the construction and operation of the apparatus for that purpose. The egg was then broken into a petri dish for the measurements of the interior parts. To collect the outside liquid white, a strip of window screen No.10, about five eighths inches high by four long was bent to approximately the same curvature as the side of the petri dish, and placed inside the dish near its edge. By then tipping the dish slightly, the outer liquid white separated from the remainder of the egg by passing through the screen.

From this position it was collected by a 25 c.c. pipette and transferred to a c.c. graduate, where the amount was measured.

The solid white was then incised in four places around its diameter and, with a fine glass hook, was removed from around the yolk. This procedure freed the inner liquid white, which was then separated from the remaining parts, removed, and measured as was the outer white.

With the remaining solid white already removed from around the yolk, it was easily transferred to a third c.c. graduate for measurement.

The pipettes used for transferring both liquid whites were 25 c.c. size with one eighth inch tip openings. A 50 c.c. size was necessary for removing the solid white, with a three sixteenth inch opening to permit handling the more dense material.

After removal of all parts of the white from the petri dish, the yolk was first measured for diameter. In doing this the yolk was first shifted to approximately the center of the dish, where its diameter in millimeters was found. The measurement was made by placing the rule under the dish, reading the figures through the glass. It was recorded to the nearest half unit.

In finding the height of the yolk, a micrometer was used which was first inverted and fixed in a perpendicular position in a retort stand for convenience in using. The petri dish was placed in the stand in a position analogous to that of resting upon the anvil of the micrometer. The adjustment screw was then lowered until the tip of the spindel touched the top of the yolk. The measurement then read included the thickness of the glass besides the height of the yolk. Previous measurements had shown the thickness of the glass to be two millimeters, which was substracted from the micrometer reading to give the actual height of the yolk.

To find the index of the yolk the height was divided by the width. This reduced the two dimensions to a single term, thereby making its subsequent interpretation in relation to other data easier.

RESULTS AND DISCUSSION

Throughout the project separate records were kept for each bird in each pen, giving the information collected concerning the shell strength and measurements of the interior parts of the egg. Since the observations and conclusions are taken entirely from the averages of the individuals, it is obviously unnecessary to reproduce here the record for each hen throughout the experiment. As an illustration, however, the record of one bird is included, showing the data collected, method of tabulation, and averages, as shown in Table III. From such individual records, the averages for each pen were determined. These pen averages are shown in Table IV. From this latter data, the pen averages, the observations and conclusions are drawn when such data is interpreted in view of the rations fed.

As previously stated, the purpose of this project was to determine the effect, if any, of certain ingredients in the ration upon the interior quality of the egg. "Interior quality" here refers chiefly to the way the yolk stands up and to the proportion of firm white to total liquid white. Such information must be essential to the production of high quality eggs, since the public demands certain qualities in the white and yolk in both fresh and stored conditions.

Since any stabilization of the poultry industry depends largely upon successful storage of surplus eggs from periods of high production to those of low, with the resultant higher prices, it is of no small importance to the poultry man to know what qualities must be present in

TABLE III

Pen 21, Bird No. 58

Date	Egg wt.	Shell str.	Outside white	Inside white	Firm white	Total white	Yolk color	Yolk width	Yolk height	Yolk index
6-8-32	23.	8.8	9.5	4.5	15.	29.	70.	43.5	16.	.367
6-9	24.	6.8	8.	5.5	18.	31.5	75.	50.5	16.	.395
6-13	22.	6.4	6.	5.5	19.	30.5	90.	42.5	16.	.376
6-14	23.	5.6	5.	4.5	21.	30.5	90.	40.	17.	.425
6-20	23.	6.7	5.5	6.	17.	28.5	70.	40.	16.	.40
6-22	23.	7.3	7.	5.	17.	29.	70.	42.	16.	.38
6-23	22.	7.6	6.	5.	16.	27.	70.	40.	15.5	.388
6-24	22.	7.6	4.5	5.	18.	27.5	75.	42.	15.	.356
6-26	22.	6.4	4.5	4.5	17.	26.	75.	41.	16.	.39
6-27	23.	6.2	5.5	3.	20.	28.5	80.	40.	17.	.425
6-30	24.	7.1	6.	4.	19.	29.	70.	40.	16.5	.413
7-3	22.	6.4	5.	6.	17.	28.	70.	42.	16.5	.393
Av.	22.7	6.9	6.	4.8	17.8	28.7	75.1	41.	16.	.392

the egg to insure its coming from storage in a condition that will be acceptable to the public.

Observations have shown that the rate of deterioration of firm white is largely constant, that is, a certain rate of break-down progresses during a given period, quite irrespective of the proportion of firm to liquid white at the beginning of the storage period. This break-down of firm white is the factor most accountable for the difference between the fresh and stored egg.

Eggs held even in ideal storage conditions undergo deterioration to some extent. This is evidenced, when the stored egg is broken, by a greater extent of flattening out of the firm white as it surrounds the yolk. As already noted, this is due to a transformation of the consistency of the firm white from one characteristic of a high quality egg in which the firm white "stands up" well around the yolk, to that of a watery consistency found normally in the outside white. When stored at higher temperatures, the degree of deterioration of thick white is roughly proportional to the amount of temperature increase. Since the rate of deterioration is largely constant, it follows that an egg with a firm white high in percentage to the total white, when placed in storage, will, after being held, have a correspondingly higher percentage of firm white than the egg that goes in storage with a low percentage of firm white. Therefore, it becomes the concern of the poultry man to produce eggs, both for immediate use and for storage, that have this high percentage of firm white (22).

In attempting to isolate any factors that could be associated with the production of the desirable interior qualities mentioned, it becomes obvious that, in view of the number of ingredients used in any standard laying mash, any single project of this nature must necessarily be limited in its scope to the influence of a small part of the total feed on the qualities concerned. With this in mind, the rations used were purposely compounded in such a manner that only certain of their ingredients were varied. By this means, any essential variations in the egg quality could, assuming all other factors equal, be associated with the variance in diet.

Analysis of egg white shows that it is composed largely of protein. Since the quality of the egg is determined mostly by the relative amounts of the various parts of the white, one of the objectives of this project was to determine what influence the sources and different levels of protein in the ration had upon this part of the egg. To do this, three of the pens were fed rations that varied essentially only in the level of the protein, the two sources of which were Soy Bean Oil Meal and meat scraps. For convenience in reference the rations having the three levels of protein are repeated here in Table IV.

As shown in the table the percentages of crude proteins for pens four, five, and six are 14.90, 16.92, and 19.92 respectively.

Table IV is also a compilation of the measurements of the eggs taken from these three pens. In comparing the measurements of these eggs, the highest egg weight per dozen was obtained from the pen receiving the lowest protein level. This weight (24 ounces per dozen) is also the highest weight from the entire ten pens, while the ration yielding this egg weight also received the lowest level of protein of the ten pens. The shell strength of Pen 5, which received a protein level near the average of not only the three pens compared here, but of

TABLE IV

	Pen 4	Pen 5	Pen 6
Gr. Barley	20.	17.	20.
Gr. Oats	20.	20.	20.
F. Midd's	20.	20.	20.
Bran	20.	20.	20.
Alf. Meal	5.	5.	5.
Salt	1.	1.	1.
Soy Bean O. M.	1.3	4.	8.5
Meat Scraps	1.3	4.	8.5
Corn Meal	11.4	6.	0
Crude Protein	14.90	16.92	19.92

	Av. wt. of egg	Shell str.	Outside thin white	Inside thin white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 4	24.0	7.0	4.8	5.2	21.7	31.8	45.5	39.0	17.5	.448
Pen 5	23.2	7.1	5.	5.3	19.3	30.2	46.5	38.5	17.0	.441
Pen 6	23.8	6.3	5.0	5.0	21.1	31.0	46.4	39.8	17.1	.429

the entire group of pens, is the highest. Pen 6, receiving the highest protein level of the three pens, produced the lowest amount of outside white, but since the pen receiving the lowest protein level did not produce the highest amount, the relationship between the high protein level and low outside white cannot be reliable. The lowest amount of inside thin white was produced by the high protein level pen. Here again, the order of differences in the part of white in question is irregular as compared to the order of protein levels. However, since the differences in the measurements are small, it is probable that the protein level had little influence upon this part of the white.

Regarding the amount of firm white, the lowest protein level produced the highest amount of this part. This amount of firm white was also the second highest of the entire ten pens. In comparing the range of protein levels of the three pens in consideration, or pens from one through six, all of which differed only in levels and sources of protein, no reliable relation is found between the levels of protein and amount of firm white obtained. The greatest total amount of white from the ten pens was produced by the low protein level of this group.

Pen 5 produced the deepest color yolk. However, depth of yolk color is known to be associated with the xanthophyll content of mash ingredients such as yellow corn, green feeds, etc., and cannot, therefore, be linked to protein level of the feed. The highest, and hence the most desirable yolk index, came from the low protein ration. This ration also produced the yolk of greatest height measurement of the ten pens. A notable comparison between these three rations is the fact that the low protein ration yielded the lowest per cent of production, but in doing this produced eggs with the greatest number of desirable qualities, including greatest weight, greatest amount of firm white, yolk with greatest height and with the greatest index.

A second comparison (Table V) of three levels of protein from three sources instead of two, as in the first comparison, was run. The protein was supplied through Meat Scrap, Fish Meal and Soy Bean Oil Meal.

In this comparison the pen receiving the highest protein level yielded the greatest egg weight per dozen, the greatest amount of firm white, and the least amount of inside thin white; whereas, the pen receiving the lowest protein level of the three produced eggs with the greatest shell strength, greatest yolk height, and largest yolk index. In each of these six comparisons, however, the remaining two figures in the same measurement are the reverse of those expected in view of the comparison already made. Therefore, the value of the associations pointed out here is seriously questioned.

It must be mentioned that the reliability of any of the apparent associations made from these three pens is still further weakened by the fact that the numbers of individuals in the first two pens were very small as shown in Table XI. This was due to an outbreak of Colibacillosis in these flocks, causing a high mortality in these pens during the course of the experiment.

A point of comparison can be made between the three pens receiving protein from two sources as compared to those receiving their protein from three sources. In both groups, the pens receiving the low protein level produced eggs with the greatest number of desirable yolk qualities. Regarding measurements of the parts of white, however, the most desirable amounts of these were produced by the high protein level.

TABLE V

	Pen 1	Pen 2	Pen 3
Gr. Barley	20.	20.	17.5
Gr. Oats	20.	20.	20.
F. Midd's	20.	20.	20.
Bran	20.	20.	20.
Alf. Meal	5.	5.	5.
Salt	1.	1.	1.
Soy Bean O. M.	1.	2.5	5.5
Meat Scraps	1.	2.5	5.5
Fish Meal	1.	2.5	5.5
Corn Meal	11.	6.	0
Crude Protein	15.5	16.99	20.3

	Av. wt. of egg	Shell str.	Outside thin white	Inside thin white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 1	22.4	6.7	5.6	5.4	17.4	28.6	51.5	38.7	17.3	.447
Pen 2	21.2	4.9	5.4	5.5	16.9	27.6	49.9	39.8	16.5	.414
Pen 3	23.8	6.3	4.2	5.0	22.0	31.2	47.6	40.1	16.8	.418

In the comparison of Pen 3 with Pen 6, differing only in the number of sources of protein, it is seen immediately that there is very little difference between these pens in any of the measurements taken. The firm white varied only .9 c.c., being in favor of the flock having three sources of protein.

Pen 3, having three sources of protein, produced eggs having about one half c.c. less outside white, and one c.c. more firm white.

As a whole, the pens receiving protein from three sources produced eggs of slightly higher quality than the pens receiving protein from two sources.

A study of Pens 2 and 8 (Table VI) was made for a comparison of sources of protein, the levels being practically identical. Pen 2 received protein from the three sources, Soy Bean Oil Meal, Meat Scrap, and Fish Meal while Pen 8 received only one vegetable protein supplement, Soy Bean Oil Meal. Pen 8 produced eggs weighing 1.2 ounces heavier per dozen than Pen 2. Shell strength was greater by 1.9 pounds; 1.8 c.c. more thick white came from Pen 8. Regarding the yolk measurements, Pen 2 produced yolks slightly less in height and greater in width than Pen 8, giving the latter pen a higher yolk index. The amount of inside white was practically the same for both pens. Only in the amount of inside white was Pen 2 more favorable. Summing up these comparisons, the flock receiving only the vegetable protein produced eggs of considerably greater desirability, both in weight, shell strength, and interior quality.

A comparison was also made between high and low protein levels. Pens 3 and 7 were used for this purpose with Pen 3 receiving a total of sixteen and one half pounds of protein supplement as compared to the total of seven and one half pounds in Pen 7. The sources of protein

TABLE VI

	Pen 2	Pen 8
Gr. Barley	20.	20.
Gr. Oats	20.	20.
F. Midd's	20.	20.
Bran	20.	20.
Alf. Meal	5.	5.
Salt	1.	1.
Soy Bean O. M.	2.5	5.
Meat Scraps	2.5	0
Fish Meal	2.5	0
Corn Meal	6.5	4.
Corn Glutin		5.
Crude Protein	16.99	17.14

	Av. wt. of egg	Shell str.	Outside thin white	Inside thin white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 2	21.2	4.9	5.4	5.4	16.9	27.6	49.9	39.8	16.5	.414
Pen 8	22.4	6.8	4.9	5.6	18.7	29.2	49.	38.8	16.6	.428

TABLE VII

	Pen 3	Pen 7
Gr. Barley	17.5	20.
Gr. Oats	20.	20.
F. Midd's	20.	20.
Bran	20.	20.
Alf. Meal	5.	5.
Salt	1.	1.
Soy Bean O. M.	5.5	2.5
Meat Scraps	5.5	2.5
Fish Meal	5.5	2.5
Corn Meal	0	6.5
Crude Protein	20.30	16.99

	Av. wt. of egg	Shell str.	Outside thin white	Inside thin white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 3	23.8	6.3	4.2	5.0	22.	31.2	47.6	40.	16.8	.418
Pen 7	23.8	6.3	6.0	4.9	19.5	29.5	49.2	40.6	17.0	.419

for the two pens were similar, each ration including Soy Bean Oil Meal, Meat Scraps, and Fish Meal.

The egg weight per dozen and shell strength were identical for the two pens. Pen 3 produced eggs that were distinctly more favorable in outside white and firm white, while measurements of the inside white were practically the same for both pens. The yolk width, height, and index were practically identical for the two pens. Only in yolk color was Pen 7 more desirable. The yolk color of this latter pen was nearly two points deeper, as calculated by the Lorro Color Scale. This difference may be attributed to the fact that Pen 7 received six and one half pounds of yellow corn meal, while Pen 3 received none.

Considering these comparisons, the flock receiving the high protein level produced eggs that were slightly superior in quality as compared to those from flocks receiving a low protein level.

An attempt was made to determine whether the addition of molasses would improve the palatability of the ration and whether its addition would affect the interior quality of the egg. To do this, two flocks, Pens 8 and 9, were fed identical rations excepting the addition of seven pounds of molasses per hundred pounds of mash for Pen 9.

A comparison of the measurements taken showed that the egg weight and shell strength for the two pens were practically the same, as was the amount of inside white. Check of the outside white and firm white, however, showed that the flock not receiving the molasses produced eggs slightly superior in quality in these two factors. Yolk measurements indicated that the flock not receiving the molasses produced eggs of higher quality, regarding yolk width, although the yolk index for the two was practically the same.

TABLE VIII

	Pen 8	Pen 9
Gr. Barley	20.	20.
Gr. Oats	20.	20.
F. Midd's	20.	20.
Bran	20.	20.
Alf. Meal	5.	5.
Salt	1.	1.
Soy Bean O. M.	5.	5.
Corn Meal	4.	4.
Corn Glutin	5.	5.
Molasses	No	Yes
Crude Protein	17.14	17.14

	Av. wt. of egg	Shell str.	Outside thin white	Inside thin white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 8	22.4	6.8	4.9	5.6	18.7	29.2	49.	38.8	16.6	.428
Pen 9	22.3	6.6	6.2	5.4	17.6	29.4	49.	39.1	16.6	.425

The percentage of production for the two pens was nearly identical. Since the ration without the molasses produced both a better quality white and higher yolk index, it is evident that the addition of this ingredient to the ration is not advisable from the standpoint of improving interior egg quality.

One of the many problems in the minds of the commercial poultry man is the quality of eggs from flocks given little or no range, as compared with those from flocks given free range. An attempt to answer this question, therefore, becomes one of the chief objectives of this project. For this purpose three flocks were used. Pens 2, 7, and 10 each received the same mash ration but differed in range conditions. Pen 2 was allowed no range; Pen 7 was given a limited range as previously described; Pen 10 was given free range. This last pen, therefore, received care comparable to that of the average small farm flock in which birds have access to litter piles, insects, green feed, etc. as found about the farmyard.

Comparing the egg weights of these three flocks, the pens given limited range and free range produced eggs weighing approximately two and one half ounces more per dozen than those from the flock given no range. There was very little difference between the egg weight of the flocks receiving limited and free range. Comparing shell strength, the flock receiving no range produced eggs definitely inferior to the two receiving range, while the flock given limited range produced the strongest shelled eggs. The amounts of inside white from the three pens were nearly identical. For firm white, the pen with free range produced the most desirable eggs. The least amount of outside white, of considerable importance in egg quality was, however, produced by the pen given no range.

TABLE IX

	Pen 2	Pen 7	Pen 10
Gr. Barley	20.	20.	20.
Gr. Oats	20.	20.	20.
F. Midd's	20.	20.	20.
Bran	20.	20.	20.
Alf. Meal	5.	5.	5.
Salt	1.	1.	1.
Soy Bean O. M.	2.5	2.5	2.5
Meat Scraps	2.5	2.5	2.5
Fish Meal	2.5	2.5	2.5
Corn Meal	6.5	6.5	6.5
Crude Protein	16.99	16.99	16.99

	Av. wt. of egg	Shell st.r	Outside thin white	Inside thick white	Thick white	Total white	Yolk color	Width of yolk	Height of yolk	Yolk index
Pen 2	21.2	4.9	5.4	5.5	16.9	27.6	49.9	39.8	16.5	.414
Pen 7	23.8	6.3	6.0	4.9	19.5	29.5	49.2	40.6	17.0	.419
P3n 10	23.5	5.8	5.6	5.1	20.6	31.3	76.8	39.5	16.4	.415

The yolk color from the flock given free range was the most notable factor in the comparisons. The average color from this flock was almost twice as dark as that from the flock given no range, whereas the difference between it and the flock given limited range was almost as great. The yolk color from this flock was by a wide margin the darkest of the entire ten pens. This was doubtlessly due to these birds' having access to abundant green feed, which was denied the other pens. The yolk index for the flock given limited range was the highest. The lowest yolk index came from the flock having no range.

These comparisons indicate that the flock receiving no range produced eggs inferior in quality to those from flocks receiving limited range. Comparing the two flocks receiving limited and free range, as already noted, the factors of most favorable egg weight, shell strength, inside thin white, yolk height and yolk index were produced by the flock receiving limited range. Also the moderate yolk color of this pen is probably preferable to the extremely dark yolk of the pen receiving free range. Relative to outside thin white, firm white, and width of yolk, the pens receiving free range were the more favorable. However, there was no marked difference in the comparisons between these two pens.

Of the three flocks, therefore, the pen receiving no range produced the lowest quality eggs. Of the remaining two, the flock receiving limited range produced better quality eggs than did the flock receiving free range, although the differences between these two pens are much smaller than those in comparing either to the flock given no range.

Undoubtedly the difference noted between the quality of eggs from these three pens can be associated with the amount of sunshine received. Pen 2, given no range, produced eggs of lower quality than Pens 7 and 10 given limited and free range,respectively.

TABLE X

Individual Averages

	Individual	Egg wt.	Shell str.	Outside white	Inside white	Firm white	Total white	Yolk color	Yolk width	Yolk height	Yolk index
Pen 1	12	22.3	6.5	6.5	5.9	16.1	28.7	54.5	38.	17.4	.455
	16	22.5	6.9	4.8	5.	18.7	28.5	48.5	39.4	17.2	.437
	Av.	22.4	6.7	5.6	5.4	17.4	28.6	51.5	38.7	17.3	.447
Pen 2	18	20.	4.	4.8	4.8	17.3	26.6	43.6	39.	15.9	.408
	22	22.5	5.87	6.12	6.25	16.5	28.6	56.2	40.7	17.2	.428
	Av.	21.2	4.9	5.4	5.5	16.9	27.6	49.9	39.8	16.5	.414
Pen 3	42	25.	6.3	4.2	4.9	23.	32.	46.1	39.9	17.9	.446
	39	23.4	8.4	4.5	6.4	19.4	30.4	48.2	40.5	16.9	.42
	46	23.2	6.4	3.7	4.4	22.4	30.5	50.	40.2	16.5	.408
	36	23.3	5.3	4.4	4.9	21.6	30.9	48.5	41.1	16.6	.404
	37	23.2	5.2	2.4	5.5	21.	29.	45.8	38.6	16.5	.428
	40	25.	5.5	3.7	3.9	25.5	33.	50.	39.9	16.9	.433
	43	24.8	5.4	3.9	4.5	23.8	32.4	45.	40.3	16.7	.415
	45	25.	8.	6.6	5.5	20.	32.4	47.5	41.	16.9	.41
	Av.	23.8	6.3	4.2	5.	22.	31.2	47.6	40.1	16.8	.418
Pen 4	61	21.6	7.6	3.9	4.	20.	28.	44.	39.2	17.5	.445
	55	24.	6.9	4.8	4.6	20.1	29.5	42.	40.8	18.9	.461
	53	26.1	7.5	6.	6.3	22.8	35.2	46.5	40.5	16.6	.409
	57	24.5	5.9	4.5	6.1	24.1	34.8	50.	36.	17.7	.472
	Av.	24.	7.	4.8	5.2	21.7	31.8	45.5	39.	17.5	.448

TABLE X (Continued)

Individual Averages

Pen	Individual	Egg wt.	Shell str.	Outside white	Inside white	Firm white	Total white	Yolk color	Yolk width	Yolk height	Yolk index
Pen 5	75	26.2	7.9	5.1	6.9	22.7	34.8	45.6	39.1	17.6	.45
	65	23.2	6.5	2.5	4.6	22.4	29.6	45.7	39.7	16.4	.411
	66	23.2	7.2	5.5	4.6	20.2	30.5	45.3	40.1	17.	.421
	77	21.3	7.8	7.6	4.8	15.7	28.1	46.6	37.9	16.6	.436
	63	21.2	7.7	7.	4.7	14.9	26.7	44.5	39.8	16.9	.425
	76	23.6	6.6	4.8	4.3	20.8	30.	50.	40.6	17.5	.43
	78	24.	6.9	5.6	6.9	18.6	31.4	47.5	40.5	17.2	.425
	Av.	23.2	7.1	5.4	5.3	19.3	30.2	46.5	38.5	17.0	.441
Pen 6	88	23.4	7.	4.3	5.	20.9	30.3	42.5	39.8	17.2	.43
	84	24.	7.	4.2	5.4	21.2	30.8	49.	40.5	16.9	.418
	87	23.4	5.9	6.3	6.5	18.8	31.7	45.	39.2	16.8	.428
	93	27.2	7.3	3.7	5.3	25.	34.	46.2	40.5	17.9	.443
	86	21.9	5.2	4.2	3.6	20.	27.8	48.3	39.4	17.	.43
	80	24.6	6.8	4.9	5.	21.9	32.	45.8	40.5	16.8	.415
	82	24.	6.8	4.3	4.9	22.8	32.	45.4	39.3	17.2	.437
	89	23.2	5.5	4.6	4.7	20.4	29.8	47.8	40.6	18.2	.445
	91	22.5	5.6	4.7	5.1	20.7	30.5	47.8	39.2	16.4	.418
	81	24.	6.	6.2	5.2	19.7	31.2	46.2	39.5	17.	.429
	Av.	23.8	6.3	4.7	5.0	21.1	31.	46.4	39.8	17.1	.429

TABLE X (Continued)

Individual Averages

	Individual	Egg wt.	Shell str.	Outside white	Inside white	Firm white	Total white	Yolk color	Yolk width	Yolk height	Yolk index
Pen 7	5	21.7	6.1	7.5	3.7	16.5	27.8	55.8	40.	16.2	.405
	9	23.4	6.7	6.3	6.5	18.7	31.5	50.	40.5	15.5	.384
	8	28.7	7.6	7.5	5.3	22.6	35.5	48.6	44.4	18.8	.426
	13	22.	5.4	4.7	4.6	20.	29.5	49.5	37.8	17.5	.463
	14	24.3	5.3	5.9	5.	21.5	32.4	50.	40.5	16.7	.413
	7	23.2	5.9	6.2	4.5	17.5	27.9	45.	42.6	16.6	.386
	1	22.6	7.3	5.2	4.4	18.6	28.2	46.2	39.4	16.6	.42
	11	24.5	6.1	5.1	5.7	20.7	31.5	48.6	39.4	17.6	.446
	Av.	23.8	6.3	6.	4.9	19.5	29.5	49.2	40.6	17.0	.417
Pen 8	22	22.4	6.7	4.1	5.7	20.	29.8	49.4	38.1	16.4	.429
	27	22.8	7.5	5.	5.6	18.8	29.4	51.5	39.2	16.5	.42
	16	22.	5.6	5.5	5.4	15.6	26.5	46.5	41.3	17.2	.415
	28	23.3	7.2	4.8	5.6	20.2	30.6	46.5	40.2	16.4	.406
	29	21.6	6.9	5.2	5.5	19.	29.8	52.	35.6	16.6	.463
	Av.	22.4	6.8	4.9	5.6	18.7	29.2	49.	38.8	16.6	.428
Pen 9	35	20.6	5.	3.5	4.8	17.6	31.3	46.	39.	16.6	.425
	31	22.5	6.8	6.9	5.	16.5	26.	48.6	39.6	17.	.426
	41	22.8	6.4	7.2	7.2	17.2	28.4	50.	39.	16.4	.424
	33	21.3	7.9	8.6	4.6	14.6	31.6	50.6	38.8	16.	.415
	36	24.9	6.7	7.9	6.4	20.1	27.9	49.	38.8	17.4	.448
	41	22.	7.1	7.4	6.6	16.	34.5	50.	39.1	16.5	.421
	45	22.3	6.3	1.9	3.2	21.5	30.1	50.	40.4	16.5	.406
	Av.	22.3	6.6	6.2	5.4	17.6	29.4	49.	39.1	16.6	.425

TABLE X (Continued)

Individual Averages

Individual	Egg wt.	Shell str.	Outside white	Inside white	Firm white	Total white	Yolk color	Yolk width	Yolk height	Yolk index
58	22.7	6.9	6.	4.8	17.8	28.7	75.1	41.	16.	.392
52	25.	7.1	5.4	5.9	21.6	32.9	69.6	40.	16.5	.412
50	22.7	5.3	7.	6.2	17.6	30.9	75.	39.7	17.	.445
46	23.8	6.	5.5	4.5	21.8	31.8	82.	40.	16.6	.41
55	25.2	4.9	3.	5.3	25.5	33.8	91.6	38.2	17.	.445
48	21.8	5.6	2.6	3.8	22.4	28.8	69.	37.6	16.3	.435
54	23.8	5.1	10.	5.2	17.6	32.8	75.8	39.8	16.5	.415
Av.	23.5	5.8	5.6	5.1	20.6	31.3	76.8	39.5	16.4	.415

TABLE XI

Table shows pen averages for each quality factor measured.

Underlined figures indicate most desirable qualities.

Pen	No. of indiv.	Av. wt. of egg	Shell str.	Out. thin white	In. thin white	Firm white	Total white	Yolk color	Wd. of yolk	Ht. of yolk	Yolk index
1	2	22.4	6.7	5.6	5.4	17.4	28.6	51.5	38.7	17.3	.447
2	2	21.2	4.9	5.4	5.5	16.9	27.6	49.9	39.8	16.5	.414
3	8	23.8	6.3	4.2	5.0	22.	31.2	47.6	40.1	16.8	.418
4	4	24.	7.0	4.8	5.2	21.7	31.8	45.5	39.	17.5	.448
5	7	23.2	7.1	5.4	5.3	19.3	30.2	46.5	38.5	17.0	.441
6	10	23.8	6.3	4.7	5.0	21.1	31.0	46.4	39.8	17.1	.429
7	8	23.8	6.3	6.0	4.9	19.5	29.5	49.2	40.6	17.0	.419
8	5	22.4	6.8	4.9	5.6	18.7	29.2	49.	38.8	16.6	.428
9	7	22.3	6.6	6.2	5.4	17.6	29.4	49.	39.1	16.6	.425
10	7	23.5	5.8	5.6	5.1	20.6	31.3	76.8*	39.5	16.4	.415

*While indicated as most desirable, probably a yolk color of about 55 would be most acceptable by the average consumer.

CONCLUSIONS

1. There is little, if any evidence of difference between protein levels or sources and egg weight.

2. There is evidently no association between either the number of sources or the level of protein and shell strength.

3. Rations high in protein produce eggs with high quality white.

4. Rations low in protein produce eggs with high quality yolk.

5. It is improbable that the number of sources of protein has any influence on the interior quality of the egg.

6. The addition of molasses to the ration has a slightly detrimental, although not significant effect on the quality of the egg.

7. Flocks given limited range produced higher quality eggs than those given free range.

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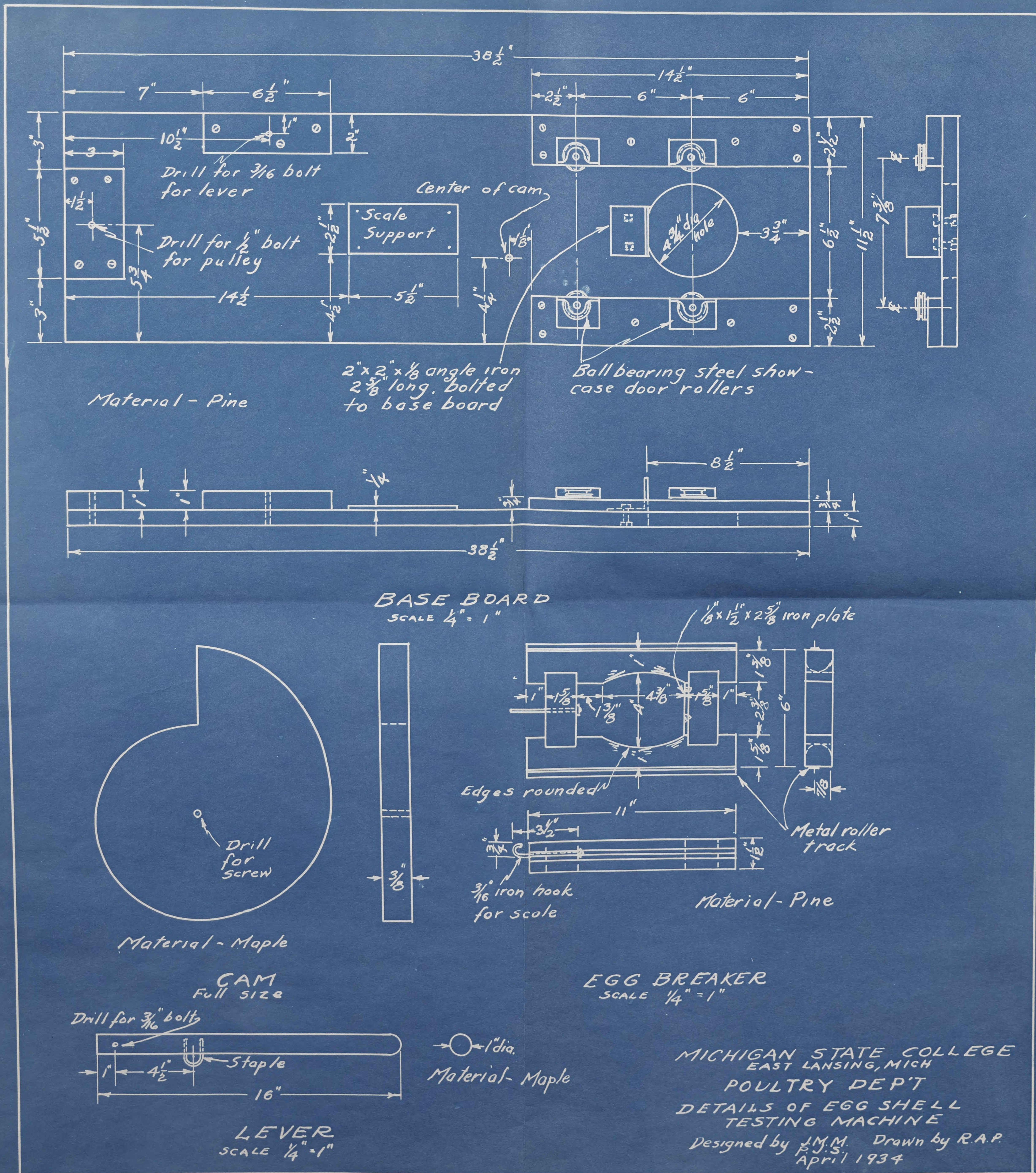
Device used in determining shell strength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7"
6 1/2"
14 1/2"
2 1/2"
6"
6"
1"
2"
10 1/2"
3"
3
Drill for 3/16 bolt for lever
1/2
Drill for 1/2" bolt for pulley
5 3/4
5 1/2"
3"
Scale Support
2 5/8"
Center of cam
1/8"
4 3/4" dia hole
3 3/4"
2 1/2"
6 1/2"
11 1/2"
7 3/8"
2 1/2"
14 1/2
4 1/2"
5 1/2"
4 1/4"
2"x2"x1/8 angle iron 2 5/8" long, bolted to base board
Ball bearing steel show-case door rollers
Material - Pine
8 1/2"
1"
1"
1/4"
3/4"
3/4"
1"
38 1/2"
BASE BOARD
SCALE 1/4" = 1"
1/8"x1 1/2"x2 5/8" iron plate
1"
1 5/8"
1 3/8"
4 3/8"
1 5/8"
1"
1 5/8
2 3/8
1 5/8
6"
7/8
Edges rounded
11"
3 1/2"
3/4"
1/2"
3/16" iron hook for scale
Metal roller track
Material - Pine
Drill for screw
3/8"
Material - Maple
CAM
Full size
EGG BREAKER
SCALE 1/4" = 1"
Drill for 3/16" bolt
Staple
1"
4 1/2"
16"
1" dia.
Material - Maple
LEVER
SCALE 1/4" = 1"
MICHIGAN STATE COLLEGE
EAST LANSING, MICH
POULTRY DEP'T
DETAILS OF EGG SHELL TESTING MACHINE
Designed by J.M.M. P.J.S. Drawn by R.A.P.
April 1934