COMPARISON OF COD-LIVER OIL AND ULTRAVIOLET IRRADIATION AS SOURCES OF VITAMIN D FOR CONFINED LAYING HENS

By RALPH B. NESTLER

Junior biologist, Animal Nutrition Division, Bureau of Animal Industry, United States Department of Agriculture

INTRODUCTION

In recent years various problems in poultry management have caused the poultry industry to resort more and more to semiconfinement and close confinement for the rearing and maintaining of its poultry flocks. This change of procedure from the raising of chickens on free range has brought new problems to the poultryman and, consequently, to the research worker who is endeavoring to help the poultryman out of his difficulties.

Vitamin D, a nutrient supplied to animals through the action of sunshine, is essential to the proper development of growing chickens and the normal processes of mature birds. Since birds in strict confinement are deprived of the ultraviolet rays from sunshine, they must obtain vitamin D from some other source. The object of the study reported in this paper was to determine the relative value of cod-liver oil and ultraviolet irradiation for supplying vitamin D to laying hens held in strict confinement, when the composition of the diet is kept constant throughout the year.

In 1931 Hendricks, Lee, and Godfrey (4) reviewed previous investigations on the use of cod-liver oil and ultraviolet irradiation for supplying vitamin D to confined birds and reported an experiment similar to the one now described. In their work, however, the mineral supplement was modified several times during each year, and changes were made in the source of irradiation. They concluded (4, p. 533):

Feeding cod-liver oil or administering ultraviolet irradiation to laying hens confined without access to direct sunlight or green feed increased egg production and the thickness of the egg shells and improved the general condition of the birds.

They pointed out that both of these sources of vitamin D seemed to have a beneficial effect on egg weight and hatchability.

Later investigations, such as that reported by Branion and Smith (1) in 1932, confirmed the importance of vitamin D as a factor in egg production and hatchability. Edson (3), after a study of 3 years, concluded that hatchability is improved considerably when cod-liver oil is fed to confined pullets. Reid (6) in 1933 discussed the possibilities of using ultraviolet irradiation as a source of vitamin D for laying hens. Murphy, Hunter, and Knandel (5) used fortified cod-liver oil as the source of vitamin D and reported in 1934 that when an adequate quantity of vitamin D is supplied, egg size and the weight of eggshells are greater than when the supply of vitamin D is inadequate. In the same year Carver and his associates (2) showed that the lack of sufficient quantities of vitamin D from either cod-liver oil or sun-

1 Received for publication Dec. 16, 1936; issued May 1937.
2 Reference is made by number (italic) to Literature Cited, p. 582.
shine seriously retards normal egg production, egg weight, and good hatchability. Titus and Nestler (9) in 1935 studied the effect on laying hens of cod-liver oil and viosterol at various dietary levels, and concluded that the optimum level of cod-liver oil in the diet of strictly confined laying stock is between 1 and 2 percent.

**EXPERIMENTAL METHODS AND MATERIALS**

The experiment reported in this paper was carried on for nearly 2 years at the National Agricultural Research Center, Beltsville, Md. The six pens used in this study were located on the second floor of a frame building, and each was approximately 8 by 11 feet in size. The only sunlight reaching them was filtered through ordinary window glass.

On September 6, 1929, 90 Rhode Island Red pullets were selected from those on the growing range and distributed at random, 15 to a pen. One cockerel was placed in each of the pens, and twice a week these cockerels were transferred from one pen to the next. All the females alive and in good condition at the end of the first year were retained for the second year's work.

On September 6, 1930, the number of birds per pen was brought to 15 again by the addition of Rhode Island Red yearlings that had been fed the same diet in another experiment. These birds were added in order to maintain the same area of floor space and hopper space per bird in each pen. No data for these birds, except their feed consumption, are included in the paper.

Two all-mash diets differing only in mineral content were fed throughout the experiment. Diet 1 was used in all pens from the beginning of the experiment to September 6, 1930, a period of 52 weeks, and diet 2 was fed during the remaining 48 weeks of the experiment. The change in the mineral content was made on the supposition that yearling hens require less phosphorus and more calcium in their feed than pullets. The essential differences between the diets were that diet 2 contained one and one-half times as much ash as diet 1 and that the former diet had 0.8 percent of phosphorus and 3.2 percent of calcium, whereas the latter had 1.0 percent of phosphorus and 2.1 percent of calcium. These diets were compounded as shown in table 1. The proximate chemical analyses of these diets was as shown in table 2.

<table>
<thead>
<tr>
<th>Diet no.</th>
<th>Ground yellow corn</th>
<th>Pure wheat bran</th>
<th>Rolled oats</th>
<th>Alfalfa meal</th>
<th>Desiccated meat meal</th>
<th>North Atlantic fish meal</th>
<th>Dried buttermilk</th>
<th>Ground limestone</th>
<th>Special steamed bone meal</th>
<th>Anhydrous sodium sulphate</th>
<th>Sodium chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39.5</td>
<td>19.3</td>
<td>11.9</td>
<td>4.3</td>
<td>8.0</td>
<td>7.0</td>
<td>5.0</td>
<td>2.5</td>
<td>1.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>38.3</td>
<td>18.7</td>
<td>11.5</td>
<td>4.2</td>
<td>7.7</td>
<td>6.8</td>
<td>4.9</td>
<td>6.9</td>
<td>1.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diet no.</th>
<th>Moisture</th>
<th>Crude protein</th>
<th>Ash</th>
<th>Ether extract</th>
<th>Crude fiber</th>
<th>Nitrogen-free extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.0</td>
<td>21.0</td>
<td>7.9</td>
<td>4.8</td>
<td>4.1</td>
<td>51.2</td>
</tr>
<tr>
<td>2</td>
<td>9.4</td>
<td>21.0</td>
<td>11.7</td>
<td>4.0</td>
<td>3.7</td>
<td>50.2</td>
</tr>
</tbody>
</table>

The estimated vitamin A potency of each of these diets was about 4,000 International units per kilogram of feed. Sherwood and Fraps
(8), in their most recent publication on the vitamin A requirements of hens, give a tentative estimate of 3 Sherman-Munsell units of vitamin A potency per gram of total feed as a sufficient quantity for keeping laying hens in good health and production. This estimate is equivalent to approximately 4,200 International units per kilogram of feed. Russell, Taylor, and Chichester (7) worked with diets containing 880 to 16,000 International units per kilogram of feed. The records they obtained on seven pens of pullets—revealed that the largest quantity of the factor ingested did not increase production, decreased mortality only slightly, and did not improve hatchability as compared with the smallest quantity fed.

Therefore, it is reasonably safe to assume that the diets used in the experiment herein reported had a vitamin A content sufficient to meet at least the minimum requirements of laying hens.

During both years of the experiment the birds in two pens received no vitamin D supplement, those in two other pens received 2 percent, by weight, of cod-liver oil added to the diet, and those in the two remaining pens received ultraviolet irradiation 15 minutes daily, except Sundays, at a distance of 3 feet from the source. A carbon arc, burning special carbons, was used for this irradiation. These carbons contained a quantity of silicon and had iron, aluminum, and nickel in the core. They were designed to produce a high intensity of radiation between 3,400 and 4,000 angstrom units and to give a more even distribution of radiation throughout the entire ultraviolet range than any other type of carbons then available.

The weights of the birds were obtained at the beginning of the experiment and at the end of every 4-week period thereafter. A record was kept of the weight of the feed given to the birds and the weight of the residue left at the end of each 4-week period. Four times a day throughout the experiment the birds in the trap nests were removed and the eggs were collected. The eggs obtained during the last 2 weeks of each of 16 consecutive 6-week periods were weighed. Their contents were removed, and the shells were rinsed with tap water to wash away all adhering albumen. After the shells and membranes had dried thoroughly, they were weighed, and composite samples were prepared for chemical analysis. In order to obtain data on the hatchability of the eggs produced by the birds on the different diets, eggs saved for 10 days were set in the incubator every 6 weeks.

**EXPERIMENTAL RESULTS**

In general, the results obtained for each pair of pens receiving vitamin D from the same source agreed very closely. Accordingly only the average results of each pair of pens are presented. In the case of the birds receiving ultraviolet irradiation, the agreement was not so good as in the other two cases, but this lack of good agreement is considered in no way to invalidate the conclusions drawn from the data.

A summary of the data is presented in table 3, and the significance of the differences shown in table 3 is given in table 4. The data on live weights of the birds, feed consumption, egg weights, weights of the eggshells, and hatchability of the fertile eggs set were analyzed by appropriate methods of variance analysis. The data on egg production and the total weight of eggs produced per bird were adjusted by covariance analysis for the number of days each bird lived.
Table 3.—Influence of cod-liver oil and ultraviolet irradiations as sources of vitamin D on the egg production, weight of eggs, weight of egg shells, hatchability of eggs, feed consumption, and live weight of Rhode Island Red hens 1

<table>
<thead>
<tr>
<th>Year and source of vitamin D</th>
<th>Birds</th>
<th>Feed consumption per bird per period of 4 weeks 2</th>
<th>Eggs produced per bird 4</th>
<th>Feed consumption per dozen eggs</th>
<th>Egg weight 5</th>
<th>Total weight of eggs per bird 4</th>
<th>Weight of eggshells with shell membranes 8</th>
<th>Hatchability of fertile eggs 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Live weight of birds 3</td>
<td>Number</td>
<td>Grams</td>
<td>Grams</td>
<td>Number</td>
<td>Grams</td>
<td>Grams</td>
</tr>
<tr>
<td>First year (52 weeks):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cod-liver oil</td>
<td>30</td>
<td>2,490±18.0</td>
<td>153.9±8.3</td>
<td>3,711</td>
<td>57.2±0.8</td>
<td>8,864±486</td>
<td>4.97±0.08</td>
<td>61.6±2.5</td>
</tr>
<tr>
<td>Ultraviolet irradiation</td>
<td>30</td>
<td>2,366±18.0</td>
<td>108.5±8.3</td>
<td>4,964</td>
<td>57.0±0.9</td>
<td>6,183±486</td>
<td>4.69±0.09</td>
<td>48.3±3.3</td>
</tr>
<tr>
<td>None (control group)</td>
<td>30</td>
<td>2,210±18.0</td>
<td>36.1±8.3</td>
<td>12,626</td>
<td>52.9±0.8</td>
<td>2,004±486</td>
<td>3.73±0.09</td>
<td>44.0±6.1</td>
</tr>
<tr>
<td>Second year (48 weeks):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cod-liver oil</td>
<td>25</td>
<td>2,675±27.0</td>
<td>108.6±6.6</td>
<td>4,823</td>
<td>59.3±0.9</td>
<td>6,477±405</td>
<td>5.28±0.13</td>
<td>61.8±3.5</td>
</tr>
<tr>
<td>Ultraviolet irradiation</td>
<td>24</td>
<td>2,444±27.0</td>
<td>75.4±6.7</td>
<td>7,187</td>
<td>58.8±1.0</td>
<td>4,514±422</td>
<td>4.93±0.15</td>
<td>53.6±4.8</td>
</tr>
<tr>
<td>None (control group)</td>
<td>20</td>
<td>2,285±27.0</td>
<td>6.9±7.3</td>
<td>97,546</td>
<td>54.4±1.0</td>
<td>319±403</td>
<td>3.09±0.17</td>
<td>8.3±16.5</td>
</tr>
</tbody>
</table>

1 Standard errors are used.
2 Average of the average live weights, per bird, at the beginning of the experiment and at the end of each 4-week period of the year.
3 Average of the average weights of feed consumed per bird during each 4-week period of the year.
4 Adjusted by covariance for the number of days each bird lived. The average number of days each bird lived during the first year was 338.7 out of a possible 364, and during the second year was 314.4 out of a possible 336.
5 Average of the average weights in the case of individual birds.
6 Weighted average of the percentage hatchability of the eggs of the individual birds.
<table>
<thead>
<tr>
<th>Year and source of vitamin D compared</th>
<th>Degree of significance (^1) between differences in—</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live weight of birds</td>
</tr>
<tr>
<td>First year (52 weeks):</td>
<td></td>
</tr>
<tr>
<td>Cod-liver oil and ultraviolet irradiation</td>
<td>H</td>
</tr>
<tr>
<td>Cod-liver oil and none (control)</td>
<td>H</td>
</tr>
<tr>
<td>Ultraviolet irradiation and none (control)</td>
<td>H</td>
</tr>
<tr>
<td>Second year (48 weeks):</td>
<td></td>
</tr>
<tr>
<td>Cod-liver oil and ultraviolet irradiation</td>
<td>H</td>
</tr>
<tr>
<td>Cod-liver oil and none (control)</td>
<td>H</td>
</tr>
<tr>
<td>Ultraviolet irradiation and none (control)</td>
<td>H</td>
</tr>
</tbody>
</table>

\(^1\) Differences are in favor of the first-mentioned source of vitamin D of each comparison.

\(^2\) H = highly significant (odds of at least 99 to 1); S = significant (odds of at least 19 to 1); N = not significant.

\(^3\) Difference is in the favor of ultraviolet irradiation.

For both years of the experiment, the average live weight of the birds receiving cod-liver oil was significantly greater than that of the birds receiving ultraviolet irradiation. Both of these groups had significantly better live weights than did the group receiving no vitamin D supplement.

During the first year the average weight of the feed consumed per bird in the group receiving cod-liver oil was significantly greater than that in the group receiving ultraviolet irradiation, whereas during the second year the reverse was true. Throughout both years the average weight of the feed consumed per bird in the latter group was significantly greater than that in the group receiving no vitamin D.

During the first year the quantity of feed consumed per dozen eggs by the group receiving cod-liver oil was 74.3 percent of that consumed by the group receiving ultraviolet irradiation, and 29.4 percent of that by the group receiving no vitamin D. During the second year the quantity consumed by the first-mentioned group was 67.1 percent of that consumed by the group receiving ultraviolet irradiation and 71.1 percent of that for the group receiving no vitamin D.

The average number of eggs per bird in the group receiving cod-liver oil was significantly greater than that in the group receiving ultraviolet irradiation. The egg production of either group receiving vitamin D was significantly greater than that of the group receiving none.

For both years the eggs from the hens receiving ultraviolet irradiation had about the same average weight as those from the hens receiving cod-liver oil. However, the eggs from the birds receiving no vitamin D averaged approximately 4 to 5 g lighter than those from the other two groups.

Although there was no significant difference between the average weights of the eggs from the birds receiving vitamin D from either of the two sources used in this experiment, nevertheless a highly significant difference existed between the total weights of the eggs produced.
per hen from these two groups. During the entire experiment the total weight of the eggs produced per bird in the group receiving ultraviolet irradiation was 69.7 percent of the total weight of the eggs per bird in the group receiving cod-liver oil.

During the first year the eggshells from the birds receiving cod-liver oil were significantly heavier than those from the birds receiving ultraviolet irradiation but during the second year the difference was not significant. The eggshells from the birds receiving no vitamin D were much lighter than those from birds receiving this vitamin.

The agreement between the hatchability results of the first year and those of the second is not good. During the first year there was no significant difference in the hatchability of the eggs from the hens receiving ultraviolet irradiation and those from hens receiving no vitamin D. On the other hand, the hatchability of eggs from the birds receiving cod-liver oil was significantly greater than that of the eggs from the other two groups. The second year's data show a marked decrease from that of the first year in the hatchability of the eggs from the hens receiving no vitamin D, whereas there was a slight increase in that of the eggs from the hens receiving ultraviolet irradiation.

Data are presented graphically in figures 1 to 6 to show the seasonal fluctuations and the differences among the three groups throughout the experiment. As shown in figure 1, the average live weight per bird in the group receiving ultraviolet irradiation and in the group receiving cod-liver oil were approximately the same during the first 8 weeks of the experiment, but from the eighth week to the end of the experiment the latter group maintained the highest body weight. The seasonal fluctuations were similar in the two groups receiving vitamin D. However, the weight of the birds receiving ultraviolet irradiation dropped more rapidly from February to November than
did that of the birds receiving cod-liver oil and failed to rise any higher the second year than it did the first.

Figure 2 shows that the cumulative feed consumption of the three groups was practically the same for about 16 weeks from the beginning of the experiment. After that the feed consumption of the birds receiving cod-liver oil gradually increased over that of the birds receiving ultraviolet irradiation until there was a difference of 2½ to 3 kg in the middle of the first spring. Thereafter the consumption of the former group was parallel to that of the latter until the following spring, when the difference tended to disappear. On the other hand, the feed consumption of the birds receiving no vitamin D supplement decreased to about 4½ kg below that of the birds receiving ultraviolet irradiation and was parallel to the latter until March of the second year, when the difference became greater.

Figure 3 shows that the percentage of egg production of the birds receiving cod-liver oil was consistently greater than that of the birds receiving ultraviolet irradiation except during the first 10 weeks of the experiment. The egg production of the hens receiving no vitamin D supplement was much lower than that of the hens receiving either cod-liver oil or ultraviolet irradiation. However, for the first 12 weeks, ended November 30, the former birds maintained as good production as the latter. A sharp decrease in the egg production of the birds receiving ultraviolet irradiation occurred at the same time as that of the birds receiving no vitamin D. However, in the former group, this drop was checked during January, and a gradual upward trend began again. In the latter group, the production decreased to
FIGURE 3.—Comparison of the egg production of birds receiving either cod-liver oil or ultraviolet irradiation as a source of vitamin D and that of birds receiving no vitamin D supplement.

FIGURE 4.—Comparison of the weights of eggs from birds receiving either cod-liver oil or ultraviolet irradiation as a source of vitamin D with those from birds receiving no vitamin D supplement.
2.8 percent in May and, except for the slight increase in July and August, it was below 10 percent for the remainder of the experiment. The egg production of the birds receiving cod-liver oil was not decreased in December of the first year as was that of the other two groups, but its rapid upward trend was checked to a slight extent.

It is surprising to note in figure 4 that from early in August to early in December of the second year, the weight of the eggs from the birds receiving no source of vitamin D rose rapidly until it was nearly as high as that of the eggs from the birds receiving cod-liver oil. The eggs from the birds receiving either source of vitamin D were heavier the second year than the first year. Those from the birds receiving ultraviolet irradiation were of greater weight than those from the

birds receiving cod-liver oil. However, the difference is not statistically significant.

A phenomenon similar to the one in figure 4 also occurs in figure 5. During the early part of December of the second year, the average weight of the eggshells from birds receiving no vitamin D supplement was higher than at any other time, 4.81 g, which is 86.2 percent of the greatest average weight of the eggshells from the birds receiving ultraviolet irradiation and 86.8 percent of those from the birds receiving cod-liver oil. By May, however, the average weight of the eggshells from the hens receiving no vitamin D had dropped to 2.94 g.

Figure 6 shows the ratios of the weight of eggshell to the weight of the whole egg. These ratios, in the case of the birds receiving no vitamin D supplement, show great fluctuations. Like the egg weights and the shell weights plotted in figures 4 and 5, respectively, the ratios

![Figure 6](image-url)
decreased to a low point in the spring of each year and increased to a high level in the late fall. For the other two groups of birds the fluctuations are less. The curve showing the ratios for the birds receiving ultraviolet irradiation are less variable than that for the birds receiving cod-liver oil.

So far as the author knows, nothing has been published heretofore on the effect of vitamin D, from different sources, on the percentage of ash, calcium, and phosphorus in eggshells. The percentage of ash in the shells of eggs from each of the three groups of birds in this ex-

![Figure 6](image-url)

**Figure 6.**—Comparison of the ratios of the weight of eggshell to the weight of the whole egg for birds receiving either cod-liver oil or ultraviolet irradiation as a source of vitamin D with the ratios for the birds receiving no vitamin D supplement. Data are not available for the interval between the eleventh and fifteenth periods, as indicated by light dotted lines.

periment showed minor fluctuations throughout the year, but there was no marked seasonal trend. In the eggshells from the birds receiving no vitamin D supplement the ash was slightly, but not significantly, less than in those from the birds receiving either cod-liver oil or ultraviolet irradiation. The average ash content of all shells, on a dry basis, was 53.33 percent. The percentage of calcium in the eggshells from the birds receiving cod-liver oil and those from the birds receiving ultraviolet irradiation were both 36.63 percent as compared with 36.38 percent in the eggshells from the birds receiving no vitamin D. However, this difference is not statistically significant. The percentage of phosphorus in the eggshells from the birds receiving ultraviolet irradiation and those from the birds receiving no vitamin
D were both 0.158, whereas in the eggshells from the birds receiving cod-liver oil it was only 0.149. In a previous 2-year experiment a similar phenomenon was noted in which there was a difference of the same magnitude.\(^3\)

**DISCUSSION**

The work herein reported substantiates the conclusion of Hendricks, Lee, and Godfrey that the inclusion of cod-liver oil as a source of vitamin D in the diet of confined laying hens is superior to the administration of ultraviolet irradiation for 15 minutes daily.

The remarkable increase in egg production of the birds receiving no vitamin D supplement during the first 12 weeks of the experiment (fig. 3) indicates that there may have been enough vitamin D stored in the bodies of the birds at the beginning of the experiment to meet their requirements for that length of time. Apparently as a result of this initial increase in egg production at a time when the supply of vitamin D was inadequate, the weight of the eggshells was abruptly reduced from the beginning. The writer is at a loss to explain why the weights of the eggs and of the eggshells fell to their lowest point in the spring of each year, and reached their highest point in the late fall. This phenomenon occurred to a slight extent in the experiment reported by Hendricks and his associates, but not in so marked a manner as in the present experiment.

**SUMMARY AND CONCLUSION**

Data on live weight, feed consumption, egg production, egg weight, hatchability of fertile eggs, weight of eggshells, and the chemical composition of eggshells were obtained on three groups of Rhode Island Red chickens kept in confinement for 2 years without access to direct sunlight. One group received cod-liver oil fed at a 2-percent level, another received ultraviolet irradiation administered for 15 minutes daily with a carbon arc, and a third received no vitamin D supplement. A definite level of phosphorus and a definite calcium-phosphorus ratio were maintained throughout each year. The same diet was fed for the duration of the experiment, except for a change in the mineral content at the end of the first year. Its vitamin A content was sufficient to meet the minimum requirements of a laying hen.

Cod-liver oil as a source of vitamin D gave better results in egg production, live weight of the hens, total weight of eggs produced per hen, weight of eggshells, and hatchability of fertile eggs, than did ultraviolet irradiation for 15 minutes daily. However, the differences in the results obtained from the two sources of vitamin D on the weight of eggshells and on the hatchability of eggs during the second year were not statistically significant. For maintenance of good egg weight, ultraviolet irradiation was nearly as efficacious as cod-liver oil. More feed was consumed per bird with cod-liver oil than with ultraviolet irradiation, but less feed was required for each dozen eggs produced.

The percentage of ash and calcium in the eggshells was practically the same for both sources of vitamin D. However, the percentage of phosphorus in the eggshells from the birds receiving cod-liver oil

\(^3\) Unpublished data.
was somewhat lower than that in the eggshells from either the birds receiving ultraviolet irradiation or those receiving no vitamin D supplement.

The results thus show conclusively that 2 percent of cod-liver oil added to a good laying diet for strictly confined birds is superior, as a source of vitamin D, to ultraviolet irradiation for 15 minutes daily with a carbon arc. Either source of vitamin D yields better results than an inadequate supply of the vitamin.

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