SOME FACTORS AFFECTING EGG SIZE IN THE DOMESTIC FOWL

by

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INTRODUCTION

Although egg size is an inherited and fixed characteristic of the individual bird, there remains a certain amount of variation among the eggs produced by a single female. Some of these variations are due to environmental and others to physiological factors. Investigators have shown that there are seasonal fluctuations in egg size; that eggs of pullets increase in size during the first year of production; that intensity of production, sexual maturity, feed, and body weight each has some effect on egg size.

The manner in which these different factors react on the bird to influence the size of egg, the components of the egg most susceptible to change, and the length of time required for the various factors to influence the size of the egg have not been fully determined. Jull (1924) has shown that increase in size of yolk is directly proportional to the increase in the size of the body. Asmundson (1931) reports that the amount of albumen secreted by the oviduct is to some extent dependent on the size of the bird and also the size of the oviduct. Atwood (1923) has shown that the position of the egg within the clutch affects egg size, there being a gradual decrease with each succeeding egg. Most birds lay in clutches, producing from one to five or more eggs on consecutive days. There is usually a one-day interval between clutches. In as much as hens lay larger eggs at the beginning of each clutch this may be an indication that the reproductive organs function better after a day's rest. Accepting the above as a fact, what effect do longer pauses in production and broodiness have on egg size.

There seems to be a divergence of opinion among investigators as to the manner in which pullets increase in egg weight during their first year of production. Maw and Maw (1932) and Atwood (1928) report that there is a gradual increase in the weight of eggs of pullets during their entire first year of production. Hays (1930) has shown that pullets reach their maximum egg weight in February and decrease during the spring and summer. This may indicate that temperature or climatic conditions have some effect on egg size.

Another problem connected with egg size is that of determining the minimum number that may be weighed for securing a dependable measure of a female's maximum egg size. In order to do this, a time of year must be selected when birds are laying their maximum size eggs, with a minimum amount of variation.

PURPOSE

The purpose of this study was to determine what effect the following factors had on egg size: Position of the egg in the clutch, annual production, pause in production, sexual maturity, extremes in temperature, and feed. The study also included the effect temperature had on production, and the determination of the minimum number of eggs that needed to be weighed to obtain a reliable measure of a bird's egg size.

MATERIAL AND METHOD

Most of the material used in this study was obtained from the records of the Department of Poultry Husbandry of the Kansas State College. During the years 1921-22 all eggs at the Poultry Farm were weighed daily on the day following production to .5 of a gram. The records of 125 Single Comb White Leghorns and 50 Single Comb Rhode Island Reds were chosen for this study. Birds that had produced 100 eggs or more and that had at least 10 months' record were used. This included their entire first year of production in practically all cases.

In determining what effect the various factors named have on egg size, all the data were put on a weekly basis and some on a daily basis. The study made from the records dated from October 1, 1921 to September 30, 1922. The mean weekly egg size was obtained for each bird during the fifty-two weeks, and from this the mean weekly egg size was secured for each breed.

The birds in each breed were classified according to sexual maturity and the Leghorns were also grouped as to total number of eggs produced during the first year of production. The mean weekly egg size during the year for each group was secured in the same manner as for each breed. The weekly per cent of flock production was obtained during the fifty-two weeks for each breed and the different groups within each breed. The record of the daily maximum and minimum temperatures for the period studied was obtained from the Department of Physics of the Kansas State College. These temperatures were separately arranged on a mean weekly basis.

To make further check on some of the information secured from the above records, 38 White Leghorn females were kept and observed in individual batteries during the spring of 1932 in a temperature controlled room to determine effects of temperature upon egg size. In addition, the eggs from 300 pullets were weighed daily from March 10 to July 1, 1932 to check on egg size in relation to temperature.

To determine what effect feed consumption has on egg size, an additional eight birds were selected that were in good production. Each hen's eggs were weighed for seven days while the birds were with the rest of the flock under the same conditions they had been all year. At the end of seven days, the birds were put in individual batteries in a basement room and fed varying amounts of feed.

To ascertain the effect of temperature on feed and water consumption, the daily intake of each was weighed in grams for six of the 38 birds kept in individual batteries for a period of seven days under normal temperature and then for the same length of time under high temperature. In determining what part of the egg is most affected under high temperature, the yolk, shell, albumen, and total egg weights were taken on 3 eggs for each of 15 birds that were in the batteries under both high and normal temperatures. The method used in separating the parts of the egg was that given by Curtis (1911).

A statistical study was made to determine the minimum number of eggs that need to be weighed to determine a female's maximum egg size.

POSITION OF THE EGG IN THE CLUTCH IN RELATION TO EGG SIZE

A bird's intensity is determined by the number of eggs she lays on consecutive days without pausing or missing a day, as calculated by Hays (1930). A bird with low intensity will lay every other day or lay two days and miss one. Birds with high intensity will lay from four to eight eggs on successive days and then miss a day and start a new clutch. Some hens will lay every day over a long period but they are the exception rather than the general rule.

To determine what effect intensity or the position of the egg within the clutch has on egg size, 529 clutches were used. They ranged from two to eight days in length. From the records, ten hens were selected that had a fairly uniform two-egg clutch; of these ten were taken from each bird's record, making 100 two-egg clutches. As far as possible the first clutch in each month was chosen to avoid a biased selection. The clutches with 3-4-5 and 6 eggs were obtained in the same manner. Since seven and eight-egg clutches were few in number, they were chosen at random among the various hens. In this way 50 seven-egg and 45 eight-egg clutches were obtained.

Table 1 gives the mean egg size of each respective clutch and the decrease or increase of each egg compared with the egg laid the preceding day. It also shows the decrease from the first to last egg of each clutch, and the average decrease per egg within the clutch.

It was evident that in most cases there was a gradual decrease in the size of eggs throughout the clutch. It will be observed that the decrease from the first to the last egg increased with the number of eggs laid on consecutive days,

Table 1. Relation of Egg to Position within Clutch

	Mean egg size for different positions in clutch								Decrease of 1st to last egg in clutch	Mean decrease per egg
	1	2	3	4	5	6	7	8		
2-egg clutch (100 samples)	51.23	50.08							1.15	1.15
Diff. of eggs in clutch		- 1.15								
3-egg clutch (100 samples)	53.65	52.66	52.31						1.34	.67
Diff. of eggs in clutch		-.99	-.35							
4-egg clutch (100 samples)	54.53	53.53	52.88	53.04					1.49	.49
Diff. of eggs in clutch		-1.00	-.65	+.16						
5-egg clutch (78 samples)	53.24	52.27	51.49	51.45	51.63				1.61	.40
Diff. of eggs in clutch		-.97	-.78	-.04	+.18					
6-egg clutch (56 samples)	54.84	53.72	52.82	52.70	52.62	53.10			1.74	.34
Diff. of eggs in clutch		-1.12	-.90	-.12	-.08	+.48				
7-egg clutch (50 samples)	55.42	55.08	53.99	53.97	54.31	54.10	53.80		1.62	.27
Diff. of eggs in clutch		-.34	-1.09	-.02	+.34	-.21	-.30			
8-egg clutch (45 samples)	53.96	53.70	53.36	53.15	52.83	52.34	52.25	52.10	1.86	.26
Diff. of eggs in clutch		-.26	-.34	-.21	-.32	-.49	-.09	-.15		

but that the mean decrease per egg was smaller the larger the clutch. There was considerable variation in the clutches of different hens, and the same hen was not always consistent in the manner in which the decrease in egg size occurred within the clutch. Nevertheless, when a fairly large number of clutches was considered, it clearly demonstrated that in most cases there was a gradual decrease in size with each successive egg in the clutch, and likewise revealed that the larger the clutch, the smaller was the average decrease per egg.

This information is in agreement with that reported by Atwood (1926) and Hays (1930). The former concluded that as a rule, the greater the productive capacity of a bird, the smaller the average decrease in the weight of the eggs which were laid on consecutive days. He further stated that during the period of maximum production, the decrease in the weight of the eggs laid on consecutive days was at a minimum.

Hays has shown that there is a negative correlation coefficient of $.3157 \pm .0164$ between intensity of production and clutch size, which indicates that small egg size is associated with high intensity.

EFFECT OF PAUSE IN PRODUCTION ON EGG SIZE

A pause in production is a period during which a bird ceases to lay. It may be due to various causes. Goodale (1918) and Hays (1924) have shown that winter pause is inherited. Broodiness naturally makes a break in the egg record, and as a rule when a bird is molting she will go out of production. In determining what effect a pause in production has on egg size, an elapse of seven days or more without laying was considered a pause in this study.

The records were gone over and 50 pauses were selected from the Leghorns, and 40 from the Rhode Island Reds. They varied from 8 to 30 days in length. The pauses were all chosen from February 1 to June 1 to avoid as much as possible variation in egg size, due to factors other than pauses in production. As will be shown later in this paper there is a minimum amount of variation in the size of eggs during this period. The first egg in each of the three clutches before and after the pause was considered, and in addition, the first three eggs in the first clutch on each side of the pause. The mean egg size was also obtained for each position in the clutch.

Table 2 shows a decrease in the size of the first egg laid after a pause. This was much more pronounced in the Rhode Island Reds than in the Leghorns. The mean size of

Table 2 . Effect of Pause in Production on Egg Size

Mean size in grams of first egg in clutch		
	Rhode Island Red	White Leghorn
	Before Pause	
1st clutch	57.48 ± .422	54.59 ± .373
2nd clutch	57.11 ± .368	54.17 ± .477
3rd clutch	56.61 ± .354	53.20 ± .464
Mean	57.06 ± .222	53.98 ± .253
	After Pause	
1st clutch	52.92 ± .410	51.66 ± .391
2nd clutch	56.41 ± .451	54.48 ± .422
3rd clutch	57.62 ± .070	55.33 ± .420

the first egg after a pause in the Rhode Island Reds was 4.14 ± .466 grams smaller than the mean size of the first egg in the three clutches preceding the pause. This was 8.88 times its probable error. In the Leghorns the first egg after a pause was 2.32 ± .465 grams smaller than the mean of the first egg in the three clutches preceding the pause. In this case the difference was 4.99 times its probable error.

It will be observed that the mean size of the first egg in the second and third clutches after a pause were back to normal size in both breeds, indicating that after the first clutch there was no decrease in egg size due to a pause in production. In comparing the size of the eggs in the first clutch after a pause with those before the pause, it was found that on the average a hen recovered her normal egg size from two to three eggs after a pause.

Broodiness was the cause of many pauses in production in the Rhode Island Reds; most of the pauses were also longer than in the Leghorns. Payne and Steup (1929) have shown that when a bird goes broody and is out of production for some time, her oviduct contracts and her ovaries have a tendency to become smaller. This may account for the larger decrease in the Rhode Island Reds in the first egg after a pause than in the Leghorns.

ANNUAL PRODUCTION AND EGG SIZE

It has been a rather popular opinion that small egg size is associated with high annual production. Hays (1930) reports that high intensity is associated with small egg size, but this does not necessarily mean that high annual production and small egg size are closely correlated. It is true that high intensity is one of the major factors which contributes to high annual production, but Hays has also shown that persistency in production, sexual maturity, lack of winter pause, and broodiness all have an influence on total production in the Rhode Island Red breed with which he worked. Jull (1924), Atwood (1928), and Parkhurst (1926) have reported that there was not a significant correlation between total production and egg weight. Marble (1930) has shown that the extremes in high and low production are associated with small egg size. He concluded that low egg production is accompanied by smaller egg size due to the lack of a general factor for vigor which affects both characteristics, and high egg production is accompanied by decreased egg size, probably due to increased length of the clutch. Lippincott, Parker, and Schaumburg (1924) found a correlation coefficient of .330 $\pm$.078 between total production and small egg size.

In this study to determine the association between annual production and egg size 125 White Leghorns were divided into three groups according to the total number of eggs produced. All birds producing over 210 eggs were placed in one group, those producing from 160 to 209 in another, and those producing less than 160 eggs were placed in a third group. The birds were divided so that each lot contained practically the same number. The mean annual egg size was 52.26 grams for the birds producing over 210 eggs; 50.29 grams for the group producing from 160 to 209 eggs; and 51.40 grams for the birds producing less than 160 eggs. The mean weekly egg size was obtained for each group and is represented in figure 1. It will be observed that the

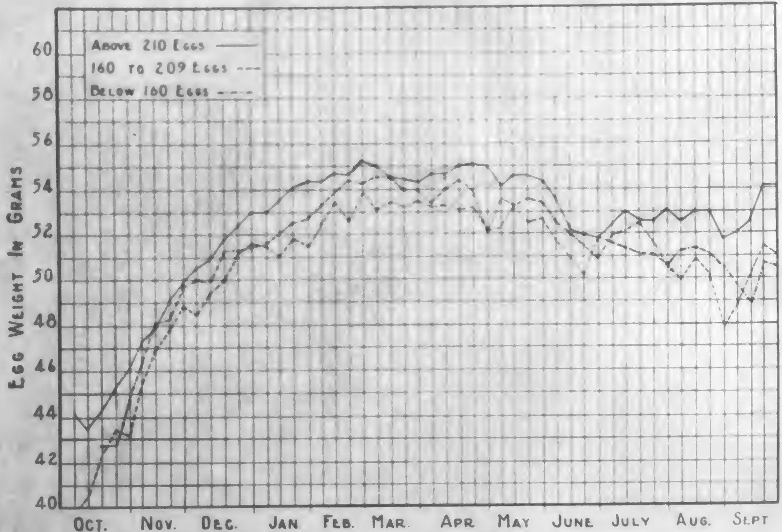

Fig. 1. Mean Weekly Egg Weight Of 125 White Leghorns Grouped According To Annual Production

highest producing birds maintained a slightly higher mean weekly egg weight during the entire year; the birds producing from 160 to 209 eggs had the lowest mean weekly egg weight; and the lowest producing lot was intermediate between the other two groups.

These results indicate that small egg size was not associated with high annual production in as much as the highest producing birds had a higher mean weekly egg size throughout the year. In flocks that were bred for high production and large egg size, both characteristics were found within the same bird. This indicated that small egg size was not necessarily correlated with high annual production, and that egg size may be inherited independently from the factors that contribute to high annual production. The fact that small egg size was correlated with high intensity may be due to the decrease of the egg size in the clutch, as shown by Hays (1930).

AGE AT SEXUAL MATURITY AND EGG SIZE

Several investigators have worked with the problem of sexual maturity and its relation to egg size and production. The results indicate that both are influenced to a certain extent by the age at which a pullet starts to lay. If the earlier maturing pullet lays from 10 to 20 eggs before the late maturing bird starts, it is to be expected that she has a better chance of making a higher annual record. The fact that egg size is correlated with body weight and that as a rule the earlier maturing birds are smaller, probably accounts for the fact that small egg size is associated with early maturity.

In checking the effect of sexual maturity on egg size 125 Leghorns and 50 Rhode Island Reds were used. Each breed was divided in groups according to age at first egg. The Leghorns were placed in three groups: those above 210 days of age at sexual maturity, and those below 190 days constituted the high and low groups; the intermediate group ranged from 191 to 209. The Rhode Island Reds were divided into two groups: those above and those below 230 days ago at sexual maturity. Figure 2 shows the mean weekly egg weight for the White Leghorns. The earlier maturing birds continued to lay smaller eggs during the entire year. These results are in agreement with those of Jull (1924), Lippincott (1925), Hays (1930), and others who reported that small egg size is associated with early sexual maturity.

Figure 3 shows the mean weekly egg weight for the late and early maturing Rhode Island Reds. These results are not in agreement with those of the White Leghorns -- the late maturing birds lay smaller eggs throughout the year. No explanation of this divergence can be offered unless it

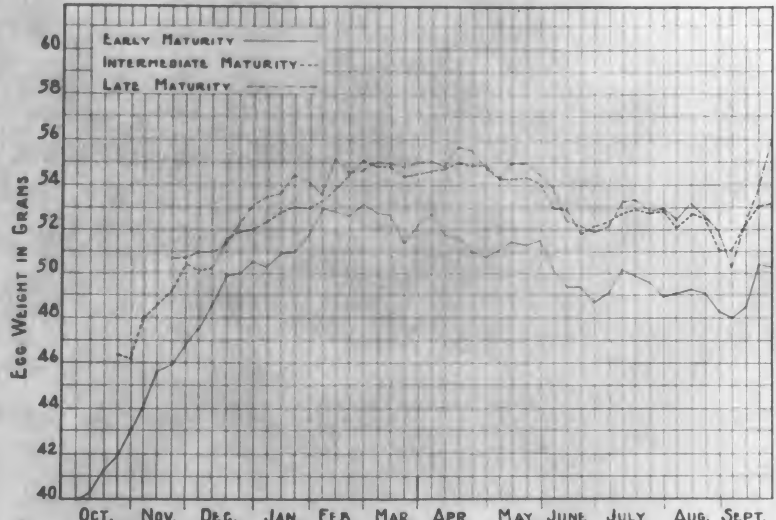

Fig. 2. Mean Weekly Egg Weight Of 125 White Leghorns Grouped According To Age At Sexual Maturity

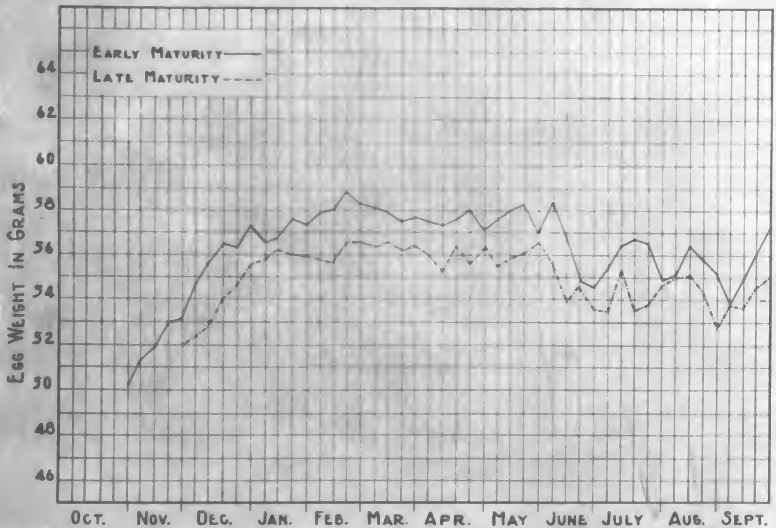

Fig. 3, Mean Weekly Egg Weight of 50 Rhode Island Reds Grouped According to Age at Sexual Maturity is due to smallness of numbers, there being only 25 birds in each group.

The weekly percentage of flock production was obtained for each lot within the breed, and very little difference was found in the production after the later maturing birds started to lay.

TEMPERATURE AND ITS EFFECT ON EGG SIZE

Among the various factors affecting egg size, the writer was unable to obtain any information from the literature concerning temperature and its effect on egg size. The fact that egg size fluctuates during the year and that the variation differs in various parts of the country indicates that temperature or climatic conditions may have some effect on egg size.

In determining the effect of temperature on egg size, the mean weekly egg weight was obtained from the records for 125 Single Comb White Leghorns and 50 Rhode Island Reds, for a period of 52 weeks, starting October 1, and ending September 30. The mean weekly maximum temperatures were secured for the same period.

Figures 4 and 5 show the mean weekly egg weight for the White Leghorns and Rhode Island Reds respectively in relation to the mean weekly maximum temperature. It will be observed that the two curves representing the mean weekly egg

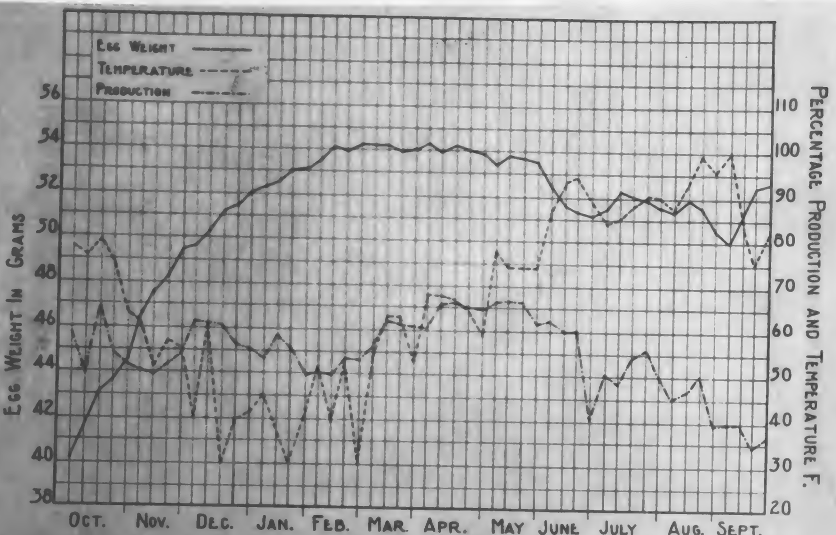

Fig. 4. Mean Maximum Weekly Temperature In Relation To Mean Weekly Egg Weight And Weekly Percentage Of Flock Production For 125 White Leghorns

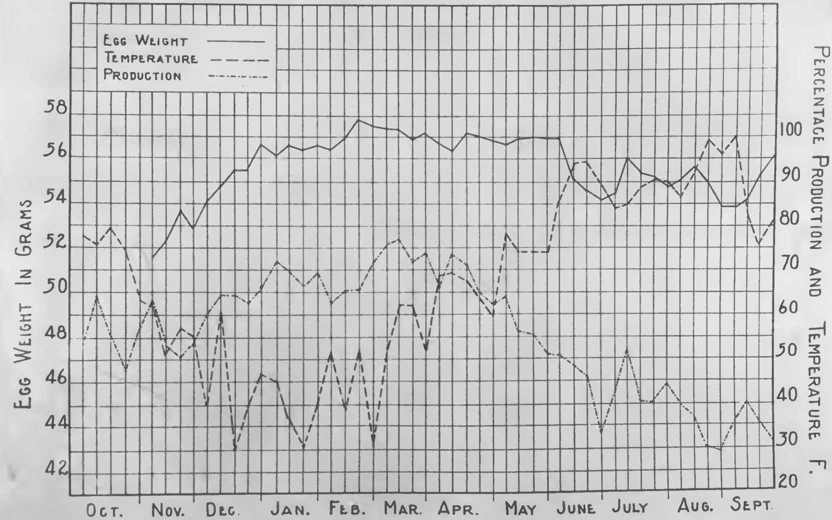

Fig. 5. Mean Maximum Weekly Temperature In Relation To The Mean Weekly Egg Weight And Weekly Percentage Of Flock Production In 50 Rhode Island Reds

weight of the two breeds are very similar. The Leghorns started in production six weeks earlier than the Rhode Island Reds but both breeds reached their maximum egg size in the early part of February. From February to the latter part of May there was very little variation in the mean weekly egg size. In the early part of June when the temperature went up to 95 degrees F. there was a rather sharp decline in the egg size of both breeds. When the temperature went down in the latter part of June the egg size had a slight increase. During this period the temperature was still up to 85 degrees. From the second week in July the temperature gradually rose and the egg size declined. On the 47 and 49 weeks when the temperature was up to 100 degrees F. the egg size took another sharp decline. At this period the average egg size for the Leghorns was 4.34 grams smaller than it was in the last week of February. The mean egg size for the Rhode Island Reds was 4.03 grams smaller during this period than it was the third week in February. On the 50 week when the temperature started down again, the egg size immediately increased in both breeds.

To check the results obtained from the records, the eggs from 300 pullets were weighed each evening from March 10 to July 1, 1932. The eggs were weighed in groups on gram scales, and the daily mean egg size was obtained from the total weights. The average egg size for these pullets followed a similar trend as for the White Leghorns and the Rhode Island Reds shown in figures 4 and 5, only the decline in June was not so pronounced. The mean egg size for this group during March, April, and May was between 54.5 and 55.5 grams, and the latter part of June it was down to 52.2 grams. During June there were no periods of unusually high temperature to cause a sharp decline in egg size.

Controlled Temperature and Egg Size

To make a more critical study of temperature and its effect on egg size, 38 females were selected from a group of 45 and placed in individual batteries in a brooding room where artificial heat could be applied. The experiment was carried on from April 30 to July 3, 1932.

The birds were fed a regular laying mash with one per cent cod liver oil and scratch grain in the evening, the same as they had been receiving all year. The lights were turned on at 6:30 a.m. and off at 7:30 p.m., giving the birds a thirteen-hour day. On May 9 six birds were culled out, three of which were laying soft shelled eggs, and the other three went out of production, leaving 32 birds in the experiment. Most of the birds laid very well; the average production during most of the experiment was above 60 per cent. During the periods of high temperature, production was decreased to 45-55 per cent. The eggs were gathered four times a day and kept in an adjoining room to avoid evaporation due to high temperature. Each bird's eggs were weighed every evening to .5 of a gram. A Tycos bi-record recording thermometer was used to keep a record of the temperature and the relative humidity in the room in which the birds were kept. During this discussion, normal temperature will be considered as that period in which heat was not applied; it ranged from 70 to 80 degrees F.

From March 13 to 17 the eggs were weighed from these same birds and the average egg size for the group during the five days was 54.56 grams. The day the birds were put in the batteries their average egg size was 55.44 grams, and the maximum temperature was 68 degrees.

Figure 6 shows the mean daily egg size and the daily maximum temperature from May 2 to July 3. The beginning of the continuous line represents the mean egg size and the dash line the maximum temperature for the day the birds were put in the batteries. The temperature in the battery room was 82 to 84 degrees F., which was 14 to 16 degrees warmer than it was out doors. Within three days the average egg size dropped to 47.6 grams, which is a decrease of over seven grams. It is difficult to determine if temperature was responsible for all of this first decrease in egg size, since the sudden change to confinement in the batteries may have had some effect on egg size. From May 4 to the 19 the

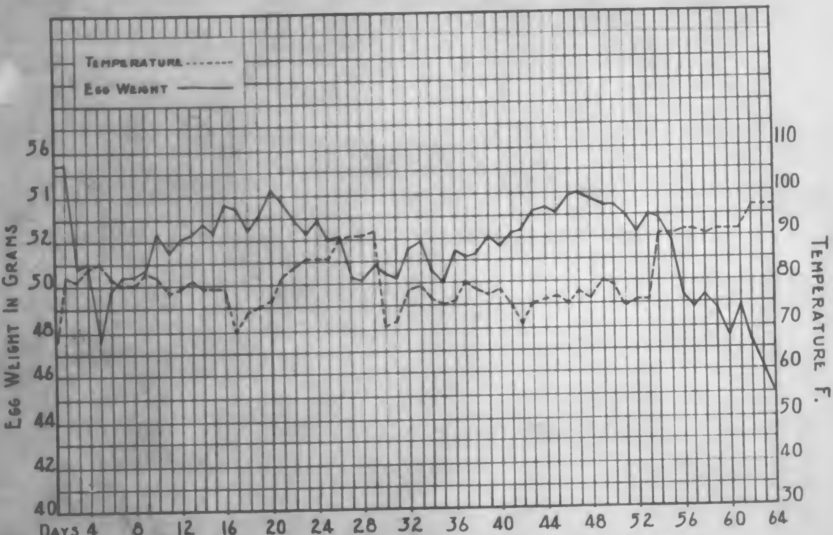

Fig. 6. Mean Daily Egg Size In Relation To Daily Temperature Under Controlled Temperatures

temperatures were gradually reduced to a range of 70 to 80 degrees F.; the room could not be cooled off entirely because chicks were being brooded in the adjoining room. The average egg size gradually increased until it reached 54.27 grams on May 19. At this time the heat was turned on and was gradually increased until it reached 92 degrees on May 28. The egg size immediately declined as the temperature increased, and when the temperature was turned off the egg size started to increase gradually again. From May 28 to June 21 the heat was turned off and the egg size again increased until it reached 54 grams. To ascertain what effect a more sudden rise in temperature had on egg size, the heat was applied on the night of June 21 and the temperature increased from 76 to 92 degrees in a few hours. The following day two birds died apparently due to the heat; the change in temperature was probably too sudden. For the next two nights the heat was turned off to give the birds a chance to become adjusted to the change. From then on the heat was applied continuously day and night. It will be observed from figure 6 that the mean egg size takes a sharp decline the day following the rise in temperature.

The temperature was held at 92 degrees for a period of eight days. During this time the mean egg size was down to 47 to 49 grams. This is five to seven grams smaller than it was when under normal temperature. On the evening of June

29 more heat was applied which brought the temperature from 92 to 97 degrees. It was held at this temperature for the next three days. The mean daily egg size still continued to decrease under the higher temperature, going down to 47.11 and 45.06 grams. While the temperature was at 92 degrees the production still stayed above 50 per cent, but when the temperature was raised to 97 degrees it dropped to 30 per cent. The mean egg size for the last day the temperature was at 97 degrees F. was 9.24 grams smaller than the mean egg size on May 19, which was before the second application of heat. This was a 17 per cent decrease in egg size. At this period the mean egg size was 10.39 grams smaller than the day the birds were put in the batteries. This was practically a 20 per cent decrease in the size.

This decrease was much greater than the decrease obtained from the records as shown in figures 4 and 5. There were days when the maximum temperature reached 100 degrees F. during the summer when these data were taken, but the decrease in egg size was not nearly so great as shown in figure 6. The fact that the heat was applied continuously day and night and that the relative humidity was much higher than out doors, ranging from 70 to 80 per cent, may account for the greater decrease of the egg size where artificial heat was applied.

The birds seemed to vary as to how soon the egg size was affected after heat was applied from 36 to 72 hours. None of the eggs laid within 24 hours showed a marked decrease. When heat was applied, the egg size decreased much faster than it increased when the temperature was lowered. Figure 6 shows that when the temperature goes down, the egg size increases very gradually.

Distribution of Decrease in the Egg Size under High Temperature

It has been shown previously in this paper that egg size can be reduced 10 to 17 per cent by high temperatures. In order to determine which components of the egg are most susceptible to change under temperatures 15 females were selected and the various parts of three eggs from each bird were weighed under normal and high temperatures. Only two eggs were obtained from two of the hens, making a total of 86 eggs in the experiment. The eggs were gathered four times a day and kept in a basement, and weighed the following morning. To obtain a comparison of the evaporation of the eggs laid under high temperature with those produced under normal temperature, an equal number of eggs were secured from the laying houses as were gathered from the batteries, and weighed at the same time. The eggs were weighed again the following morning and it was found that those laid under high temperature evaporated .06 of a gram more per egg, which is not a significant difference.

The method used in separating the different parts of the egg for weighing is that described by Curtis (1911). First the whole egg was weighed, then broken and the albumen drained off. The yolk was freed of albumen by rolling on a piece of filter paper and then weighed. The shell was dried with filter paper and then weighed. To obtain the weight of the albumen, the yolk and shell were added together and the total subtracted from the whole egg weight. All weighings were made on a chainamatic balance of .001 of a gram.

Table 3 shows the mean egg weight and its various parts for each bird under normal and high temperature. It will be observed that there is a decrease in all parts of the egg under high temperature. The mean egg weight after heat was applied was 4.592 grams smaller than it was under normal temperature. The weights were made during the last period of application of heat but before the eggs had reached their minimum weight. Of this decrease 2.924 grams were in albumen, .948 gram was in the yolk, and .721 gram in the shell. The percentage distribution of the loss, considering the loss in the whole egg 100 per cent, was 63.67 per cent in the albumen, 20.64 per cent in the yolk, and 15.70 per cent in the shell. In order to interpret these figures correctly the mean percentages of the different

Table 3. Decrease in Size of the Different Parts of the Egg Under High Temperature

	Mean Egg Weight in Grams							
	Whole Egg		Albumen		Yolk		Shell	
Bird No.	Under Normal Temp.	Under High Temp.	Under Normal Temp.	Under High Temp.	Under Normal Temp.	Under High Temp.	Under Normal Temp.	Under High Temp.
4417	58.955	53.429	34.026	30.575	19.334	18.340	5.594	4.514
7592	58.608	50.388	34.760	30.728	17.768	15.613	6.081	4.046
7601	52.252	48.075	30.221	27.332	16.193	15.428	5.838	5.315
7603	51.117	48.353	30.264	28.189	16.274	16.028	4.579	4.136
7616	53.230	47.789	31.893	28.364	15.784	15.028	5.553	4.397
7619	56.235	51.845	33.419	29.485	17.944	17.873	4.872	4.488
7620	54.802	49.929	31.694	28.580	17.484	16.533	5.624	4.817
7629	54.772	51.525	30.182	28.680	19.091	18.072	5.499	4.773
7633	50.293	46.212	29.732	27.096	15.645	14.614	4.917	4.502
7635	58.191	54.512	33.480	31.414	18.667	17.393	6.044	5.705
7640	54.388	47.618	31.647	27.404	17.603	15.834	5.138	4.381
7646	50.590	45.677	28.561	25.994	16.549	14.736	5.480	4.947
7649	59.742	55.147	36.077	32.338	18.181	17.976	5.484	4.833
7621	55.918	51.500	33.018	29.679	17.555	17.156	5.346	4.666
5135	58.897	57.111	36.037	35.302	16.830	16.052	6.030	5.758
Mean	55.199	50.607	32.334	29.410	17.393	16.445	5.472	4.751
De-crease		4.592		2.924		.948		.721

parts of the egg must be considered. Under normal temperature 58.57 per cent of the egg was albumen, 31.50 per cent yolk, and 9.91 per cent shell. If each part of the egg decreased in proportion to its size, the percentage distribution of the loss would be the same as the percentages of the different parts of the egg, as named above. In the eggs produced under high temperature there was 5.79 per cent less shell, 5.10 per cent less albumen, but 10.86 per cent more yolk. This shows that during high temperature the greater percentage of decrease takes place in the shell and albumen. Although the yolk showed some decrease under high temperature, the percentage decrease was not nearly so great as in the whole egg, shell, and albumen. It was very noticeable while weighing the eggs that the shells of the eggs produced under high temperature were thinner and more fragile than those produced under moderate temperature. In as much as the shell and albumen are secreted by the oviduct and that the yolk is formed in the ovary, these results indicate that the functioning of the oviduct is more affected by high temperature.

Table 4 shows the individual weights and various parts of all the eggs used in this experiment. It will be observed that there was considerable variation among the birds as to the amount of decrease in their egg size. Some females seem to be more sensitive to temperature changes than

Table 4. Individual Weights (in grams) of the Egg and Its Parts Under Normal and High Temperatures

	Whole Egg		Albumen		Yolk		Shell	
Bird No.	Normal Temp.	High Temp.	Normal Temp.	High Temp.	Normal Temp.	High Temp.	Normal Temp.	High Temp.
4417	61.739	54.659	35.353	31.430	20.510	19.310	5.875	3.920
	55.644	54.425	31.823	31.327	18.732	18.180	5.090	4.918
	59.481	51.204	34.901	28.969	18.761	17.530	5.818	4.705
7592	57.074	52.043	33.954	31.528	17.071	16.680	6.049	3.835
	59.646	49.245	34.872	28.931	18.546	15.275	6.228	5.039
	59.105	49.876	35.453	31.726	17.687	14.885	5.965	3.265
7601	52.928	46.895	30.332	26.622	16.935	15.271	5.660	5.002
	51.150	49.080	29.973	27.775	15.489	16.000	5.689	5.305
	52.678	59.250	30.359	27.599	16.154	15.014	6.165	5.637
7603	50.383	48.038	29.760	27.457	15.851	16.593	4.772	3.988
	52.368	48.985	31.451	29.391	16.484	15.435	4.433	4.159
	50.600	48.036	29.581	27.719	16.487	16.057	4.533	4.260
7616	53.650	50.077	31.900	29.635	16.321	15.822	5.429	4.620
	53.032	47.280	31.739	28.059	15.714	14.838	5.579	4.383
	53.007	46.010	32.040	27.399	15.317	14.423	5.650	4.188
7619	55.370	52.990	32.478	30.147	18.011	17.745	4.881	5.098
	57.100	50.700	34.361	28.822	17.876	15.000	4.863	3.878
7620	53.066	51.291	30.365	29.003	17.074	17.360	5.627	4.927
	55,910	49.750	32.629	28.985	17.632	15.850	5.649	4.915
	55.432	48.748	32.089	27.750	17.747	16.390	5.596	4.607

(table 4 continued)

Bird No.	Whole Egg Normal Temp.	Whole Egg High Temp.	Albumen Normal Temp.	Albumen High Temp.	Yolk Normal Temp.	Yolk High Temp.	Shell Normal Temp.	Shell High Temp.
7629	54.250	52.078	30.092	28.547	18.950	19.312	5.208	4.220
	54.104	49.622	29.732	27.242	18.774	17.150	5.598	5.230
	55.962	52.875	30.722	30.250	19.550	17.755	5.690	4.870
7633	50.908	46.380	29.762	27.234	16.000	14.918	5.146	4.228
	49.729	45.595	29.269	26.148	15.256	14.620	5.204	4.827
	50.243	46.660	30.164	27.905	15.679	14.305	4.400	4.450
7635	59.122	55.870	34.638	32.323	18.629	17.687	5.855	5.860
	57.260	53.154	32.321	30.505	18.705	17.099	6.233	5.550
7640	54.939	48.023	32.404	27.233	17.388	16.478	5.147	4.312
	54.341	47.597	31.788	26.627	17.367	16.225	5.186	4.745
	53.885	47.235	30.750	28.350	18.052	14.800	5.083	4.085
7646	51.781	44.965	29.989	24.677	16.474	15.213	5.319	5.075
	49.773	45.005	26.608	25.775	17.688	14.430	5.478	4.800
	50.216	47.062	29.087	27.529	15.485	14.568	5.644	4.965
7649	59.387	56.202	36.190	32.849	17.570	18.460	5.627	4.893
	56.826	54.845	34.364	31.951	17.780	17.887	4.682	5.007
	63.012	54.395	37.677	32.215	19.193	17.580	6.142	4.600
7621	56.371	51.280	33.170	29.103	17.773	17.677	5.428	4.500
	56.706	50.335	33.154	28.465	17.952	17.015	5.600	4.855
	54.677	52.885	32.729	31.468	16.940	16.775	5.009	4.642
5135	60.839	56.178	37.860	33.860	17.402	16.300	5.971	6.018
	55.854	56.885	33.728	35.675	15.889	15.445	6.237	5.765
	59.999	58.270	36.918	36.370	17.200	16.410	5.881	5.490

others. One female, 7610, showed no decline in egg size under high temperature, while others decreased over 10 grams per egg. The egg size for some of these birds decreased considerably more than is shown in this table. After the eggs in table 4 were obtained, the temperature was raised from 92 to 97 degrees and the egg size continued to decline.

Each bird was weighed at the time she was put in the batteries; the average weight for the group was 1647 grams (3.65 pounds) per bird. At the end of the experiment each individual was weighed and the average weight was 1817 grams (4.01 pounds) per bird. This was an increase of .36 of a pound per bird during the period they were in the batteries. The body temperature of each bird was taken under high and normal temperatures. They were taken the same time of day, from 3 to 5 p.m. on both occasions. The average body temperature under high temperature was 108.6 degrees F., and for the same birds under moderate temperature it was 106.4 degrees F. This was an increase of 2.2 degrees in body temperature under high temperature. It may be that this is connected in some way with the decrease in egg size under high temperature.

Feed and Water Consumption under Normal and High Temperatures

In as much as egg size was reduced during high temperature, tests were made to determine the amount of feed and water consumed under normal and high temperature, and to ascertain what effect the amount of feed consumed has on egg size. In the former test the feed and water were weighed in grams to 6 birds for seven days under normal temperature and for the same period under high temperature. Each bird was in an individual battery, and was fed an all mash ration in a can which was constructed to avoid waste. Every evening just before the lights were turned off, the feed and water not consumed were weighed back and the next day's ration weighed out. Each female was given 140 grams of mash and 500 grams of water daily during the entire experiment. To check the amount of evaporation of the water, two cans of the same size as were used by the birds and containing the same amount of water were placed in the room, and the loss was recorded and deducted from the amount of water used each day.

Table 5 shows the mean daily feed and water consumption under normal and high temperatures. The birds consumed 12 grams less feed per day under high temperature, which was a decrease of 12 per cent, and consumed 9 grams more water per day under high temperature, which was an increase of 3.8 per cent. It will be observed that there was considerable variation in the mean daily feed and water consumption. If a bird consumed a small amount of feed or water one day, as a rule, the following day the intake was materially increased.

Table 5. Feed and Water Consumption under Normal and High Temperatures

	Mean daily consumption weight in grams			
	Normal temperature		High temperature	
Days	Feed	Water	Feed	Water
1	105	255	78	229
2	119	299	89	253
3	98	265	76	235
4	82	167	106	284
5	85	181	79	231
6	72	160	84	200
7	108	242	67	202
Mean	95	224	83	233

To ascertain what effect decreased feed consumption has on egg size, eight birds in good production were selected from one of the laying houses. Their eggs were weighed each evening to .5 gram for seven days while they were still in the laying house under the same conditions they had been all year. The birds were then put in individual batteries and all fed a full ration for three days. For the next 14 days four of the birds were reduced to 50 grams of feed per day which was approximately one-half ration, and the other four were allowed all that they would eat. The average egg size of the birds that were put on half ration for the seven days that they were in the laying house was 56.10 grams, and their average for the period they were on half ration was 56.45 grams. The average egg size for the other group was 52.58 grams while in the laying house, and 51.91 while in the batteries. The birds on half ration gradually decreased in production and went into a molt. These numbers were not large but the results showed that the reduced feed consumption did not decrease the egg size. The results also indicated that the reduced feed consumption of the birds under high temperature was not a factor in causing the decline in egg size since it was much less than was recorded here.

Temperature and Its Effect on Egg Production

Temperature undoubtedly has an effect on production, but it is difficult to determine to what extent because of the influence of other factors; such as, breeding, housing, and management. Some flocks and individuals within a flock continue to lay through extremes of high and low temperature, while others seem more sensitive to climatic changes.

Figures 4 and 5 show the weekly percentage of flock production of the White Leghorns and Rhode Island Reds respectively, in relation to the mean weekly maximum temperature. The production of both breeds seemed to react in about the same manner to temperature. In the second week of June when the temperature was up to 95 degrees F. the production took a sharp drop in both breeds. In the last two weeks of August when the temperature stayed at 100 degrees, the production continued to go down.

A sudden drop in temperature during the winter is usually followed by a decline in production, also. The mean minimum weekly temperature for the second and third weeks in January was 13 and 14 degrees above zero and the last week in February was 11 degrees above zero. These were the coldest weeks throughout the year. During these two months there was a decline in production. The reduction in the number of eggs during October and November was probably due to fall molt. In this study the birds decreased in production during high temperature more than they did in low temperatures during the winter. The low temperature was probably not cold enough to cause a sharp decline in production.

Graham (1930) reports a relationship between temperature and egg production, in both weekly intervals and longer trends. He also states that prolonged high production in the winter months appears to render the birds more sensitive to temperature changes.

Willham (1931) reports that long continued trends in temperature either upward or downward do not seem to affect egg production nearly so much as sudden changes either upward or downward. He found also that lower temperatures affect production more than higher temperatures.

MINIMUM NUMBER OF EGGS THAT MAY BE WEIGHED FOR SECURING A DEPENDABLE MEASURE OF A FEMALE'S EGG SIZE

With the growing interest in egg size, it is desirable to obtain a method of securing a bird's egg size without going to the expense of weighing a large number of eggs. Jull (1930) has shown that a dependable measure of a bird's mean egg size can be obtained by weighing one egg each week during the year. Maw and Maw (1931) report that the weighing of the first ten eggs laid in the fifth month gives a reliable estimate of the mean annual egg weight. It seems to the writer that it is unfair to many birds to include the entire period of pullet production for obtaining a record of a bird's egg size. It is well known that egg size is variable during the early stages of production, being dependent upon the age at which a pullet starts to produce. The inclusion of the eggs produced during the early stages of production handicaps the early maturing female in a comparison with her later maturing sister. When maximum egg size is reached, it may be the same for the two birds.

The results of this study have also shown that the size of the eggs produced during the summer period in some regions may be variable, depending upon the maximum temperatures encountered. A fluctuation of as much as 20 per cent on egg size dependent upon temperature is a very important factor when attempting to compare egg size of birds from different regions of the United States. It would, therefore, appear that the summer season should be avoided in choosing a period in which to obtain a measurement of a bird's egg size.

It will be observed from figures 4 and 5 that the mean maximum weekly egg size for 125 White Leghorns and 50 Rhode Island Reds was reached the second and third weeks in February, respectively. From here until the latter part of May there was very little fluctuation in egg size in either breed. This seems to be the most desirable period in which to obtain a measure of a bird's maximum egg size. The mean maximum egg size of 24 White Leghorns was obtained by averaging the weights from February 7 to May 15. In order to determine the minimum number of eggs that need to be weighed for securing a dependable measure of this maximum egg size, the mean weights of the eggs laid during the first week in April were obtained, and also the mean weights of the first ten eggs laid in April for the same 24 White Leghorns.

Table 6 shows the mean maximum egg weight for the 24 birds from February 7 to May 15, the mean egg weight for the first week in April, and the mean weight of the first ten eggs laid in April. The difference in mean weights of the

Table 6. Mean Egg Size from February 7 to May 15 Compared with the Mean Egg Weight of First Week in April and the First Ten Eggs Laid in April

No. of birds	Mean Maximum Weight	Mean Weight of first week in April	Deviation from mean Maximum	Mean Weight of first ten eggs in April	Deviation from mean Maximum
3895	54.18±.497	55.25±.437	1.07±.651	55.45±.306	1.27±.583
3925	57.36±.520	55.50±.426	1.86±.672	56.00±.343	1.36±.622
3986	49.91±.237	51.50±.595	1.59±.640	50.30±.405	0.39±.469
3701	50.35±.622	53.40±.451	3.05±.768	51.50±.541	1.15±.824
3705	50.74±.499	52.62±.089	1.88±.506	50.35±.820	0.39±.959
3708	50.20±.255	51.20±.256	1.00±.361	49.95±.510	0.25±.570
3991	50.00±.402	51.33±.476	1.33±.622	51.00±.295	1.00±.498
3995	51.53±.270	49.20±.432	2.33±.509	50.10±.365	1.43±.453
3997	56.50±.341	55.00±.953	1.50±.990	56.95±.578	0.45±.671
3606	57.54±.328	55.83±.540	1.71±.631	56.35±.256	1.19±.416
3690	59.55±.408	58.37±.715	1.18±.823	58.25±.396	1.30±.568
3866	58.61±.497	59.90±.965	1.29±.920	60.30±.548	1.69±.739
3648	59.61±.499	60.10±.276	0.49±.570	60.05±.135	0.44±.517
3662	52.97±.359	53.66±.497	0.69±.613	52.40±.322	0.57±.482
3924	56.56±.357	57.50±.413	0.94±.545	57.30±.270	0.74±.447
3926	52.51±.278	52.58±.518	0.07±.587	52.45±.379	0.06±.470
3957	49.70±.377	50.66±.549	0.96±.665	50.85±.425	1.15±.568
3979	52.15±.189	53.08±.333	0.93±.382	52.55±.230	0.40±.297
3728	51.51±.215	52.00±.356	0.49±.415	51.80±.302	0.29±.370
3730	51.29±.226	51.83±.411	0.54±.468	51.15±.312	0.14±.385
3739	48.07±.591	46.50±.100	1.57±.599	47.90±.339	0.17±.517
3962	51.69±.227	53.12±.680	1.43±.716	50.90±.534	0.79±.580
3702	50.67±.310	47.83±.983	2.84±.103	48.90±.517	1.77±.602
3703	53.33±.618	54.10±.335	0.77±.702	54.45±.331	1.12±.700

periods in April compared with the mean maximum egg weight is shown. In comparing the mean egg weight of the first week in April with the mean maximum egg size, in three cases, the difference was found to be statistically significant. A few of the birds laid only two or three eggs during the week, which is a rather small number to depend upon for securing an accurate measure of a bird's egg size. To obtain a more dependable measure, the mean size of the first ten eggs laid in April were obtained and compared with the mean maximum egg size. Table 6 shows that in no case was the difference statistically significant. Thirteen of the birds showed a variation of less than a gram between the mean size of the first ten eggs laid in April, and the rest showed a variation of less than 1.80 grams. If the birds averaged one gram variation, that would be only three-fourths of an ounce to the dozen. In as much as the mean egg size of the 125 White Leghorns and the 50 Rhode Island Reds showed very little fluctuation from February until the latter part of May, it seems that 10 eggs from a female any time during this period should give a fairly dependable measure of her mean maximum egg size. The mean egg size for the first 10 eggs in March was secured and compared with the mean maximum egg size and the results were practically the same as for the first 10 eggs in April.

If it is desired to compare egg size of birds from different regions of the United States, as is true in the Record of Performance program, some consideration of the effects of temperature on egg size must be given. The taking of egg weights should be limited to the period immediately following the attainment of the maximum size but avoiding periods in which excessively high temperatures may be encountered.

SUMMARY

1. Records which were studied showed that on the average there was a gradual decrease in size with each successive egg in the clutch, and the longer the clutch the greater was the decrease from first to last egg, but the smaller was the decrease of each egg within the clutch.

2. The first egg after a pause in production of seven days or more in Rhode Island Reds showed a decrease of 4.14 grams; in White Leghorns the decrease was 2.32 grams. Results showed that the egg size was recovered within two or three eggs after production was renewed.

3. Small egg size was not associated with high annual production. The higher producing birds maintained a higher mean weekly egg size throughout the year.

4. In the White Leghorns the earlier maturing birds laid smaller eggs during the entire year, but in the Rhode Island Reds studied, the reverse was true.

5. The mean weekly egg weight when compared with the mean maximum weekly temperature showed a sharp decline when the temperature was above 85 degrees F.

6. The mean daily egg size of birds placed under controlled temperature was reduced from 15 to 20 per cent by application of high temperature. The egg size declined much more rapidly under high temperature than it increased when the temperature was lowered.

7. All components of the egg decreased under high temperature; the shell and albumen decreased considerably more than the yolk in proportion to their weight, which indicates that the oviduct is more sensitive to high temperatures.

8. Extremely high or low temperatures were followed by a decline in production; birds were more sensitive to sudden changes in temperature than to gradual changes upward or downward.

9. The birds consumed 12 per cent less feed under high than under moderate temperatures, but experimental results showed this factor was not responsible for the decrease in egg size under high temperature.

10. In the White Leghorns and Rhode Island Reds studied, both breeds reached their maximum egg size in the early part of February; from here until the latter part of May when summer temperatures begin to have their effect,

there was very little flustuation in egg size.

11. Results indicated that a dependable measure of a female's maximum egg size can be obtained by weighing the first ten eggs in April.

12. In comparing egg size of birds for different parts of the United States, temperature and its effects on egg size should be taken into consideration.

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REFERENCES

Atwood, H.
1923. Certain correlations in the weight and number of eggs and the weight of the fowls. W. Va. Agr. Sta. Bul. 182:1-16.

1926. Some factors affecting the weight of eggs. W. Va. Agr. Exp. Sta. Bul. 201:1-30.

1928. The variation in the weight and number of eggs and the weight of White Leghorn fowls during two years of production. Poul. Sci. 8:50-55.

1929. A study of the time factor in egg production. W. Va. Agr. Exp. Sta. Bul. 223:1-15.

Atwood, H., and Thomas Clark
1929. Further studies on factors influencing the weight of eggs. Poul. Sci. 8:193-197.

1930. The relationship between annual egg production and mean egg weight in White Leghorn fowls. Proc. 22nd Poul. Sci. pp. 52-54.

Asmundson, V. S.
1931. The formation of the hen's egg. Sci. Agr. 11:10-11.

Curtis, M. R.
1911. Method for determining the weight of parts of eggs. Maine Agr. Exp. Sta. Bul. 191:93-112.

1914. Factors influencing the size, shape, and physical constitution of the egg of the domestic fowl. Maine Exp. Sta. Bul. 228:105-136.

Dudley, F. J.
1931. An analysis of egg weights. Poul. Sci. 9:207-219.

Graham, J. C.
1930. A relation of temperature to egg production. Proc. 22nd Poul. Sci. Assn., pp. 48-51.

1931. Correlation of body weight at first egg to average monthly egg weights. Proc. 23rd. Poul. Sci. (Not yet published).

Ginn, W. M.
1932. The accuracy of periodically weighing a few representative eggs to determine the total monthly and yearly points produced. Poul. Sci. 11:40-44.

Hays, Frank A.
1929. The inheritance of egg weight in the domestic fowl. Jour. Agr. Res. 38:511-519.

1930. Increase in egg weight during the pullet laying year. Proc. 22nd Poul. Sci. Assn. pp. 16-19.

Jull, M. A.
1924. Egg weight in relation to production. Part I. The relation of the weights of the parts of the egg to total egg weight. Poul. Sci. 3:77-88.

1924. Egg weight in relation to production. Part II. Poul. Sci. 3:152-172.

1930. Problems in egg weighing in relation to production. Poul. Sci. 9:207-219.

Lippincott, W. A.
1925. The correlation between age at the first egg and the weight of eggs during the first laying year in White Leghorns. Poul. Sci. 4:127-140.

Marble, Dean R.
1930. The non-linear relationship of egg weight and annual production. Poul. Sci. 9:257-265.

1930. The non-linear relationship of egg weight and mean annual body weight. Proc. 22nd Poul. Sci. Assn. pp. 55-59.

Marble, Dean R.
1931. A statistical study of factors affecting egg weight in the domestic fowl. Poul. Sci. 10: 84-92.

Maw, A. J. G., and W. A. Maw
1931. A method of estimating the mean annual egg weight. Sci. Agr. 12:281-286.

Parkhurst, Raymond T.
1926. Certain factors in relation to production and egg weight in White Leghorns. Poul. Sci. 5: 121-126.

Willham, O. S.
1931. The relation of temperature to egg production. Panhandle Agr. Exp. Sta. Bul. 28:1-16.