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CONCLUSIONS

1. Turkey eggs which are incubated under chicken hens lose from 11 to 13 per cent of their original weight during the first 24 days of incubation. Small turkey eggs lose relatively more weight than large eggs incubated under the same conditions.

2. Considerable variation was observed in the weight loss during the first 24 days of incubation of eggs of approximately the same size when incubated in the same environment. The range was from 7 to 24 per cent of the original weight. Differences in shell texture may account for these variations, although care was taken to select only apparently normal eggs with good texture for these experiments.

3. Variations in the weight loss during incubation within the limits of our observations as herein reported apparently have no significant correlation with the growth rate during the first eight weeks of the life of the poult.

4. Rate of air movement and humidity as environmental factors apparently influence hatchability more during the last four days than during the first twenty-four days of the incubation period.

5. It is probable that for turkey eggs cabinet incubators require conditions during the last four days of the hatch that are somewhat different from those which have proved satisfactory for hatching chicken eggs.

Some Observations on Humidity and Weight Loss in the Incubation of Turkey Eggs

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Four environmental factors are known to affect the development of the turkey embryo: temperature, exercise, air quality, and humidity. Knowledge of optimum conditions for the first two has been obtained with some definiteness, but less is known about the optimum conditions of humidity and air quality for normal pre-hatch development. This bulletin reports some observations on the effect of varying the humidity and rate of air movement during incubation.

The anatomy of the turkey egg is similar to that of the chicken egg. The yolk of the turkey egg is surrounded with the vitelline membrane, and is held suspended in the two layers of albumen with the chalaziferous layer knotted at each pole to serve as an anchor. The inner and outer shell membranes enclose the albumen and yolk, and the shell proper is composed of two layers of calcareous material. A cuticle layer consisting of viscous albuminous material is added last to seal the shell and prevent excessive evaporation.

Turkey eggs are similar to chicken eggs in that they contain about 66 per cent of moisture at the time they are laid. Some of this moisture is used in the pre-hatch metabolic activities, and some of it is lost through evaporation. The humidity of the environment in which embryonic development is occurring affects the amount of moisture lost during the incubation period. Just what the optimum is with respect to this factor has not been determined. Since turkeys are hatched successfully under widely varying climatic conditions, we can suspect that nature has endowed the embryo with rather wide powers of adaptation to the humidity factor. A search for the optimum should nevertheless be made.

Dunn [1] made a study of the weight loss factor in chicken eggs during incubation. His first significant conclusion was that "loss of weight may be added to the already long list of individual differences in the characteristics of eggs which include weight, length, breadth, shell weight, yolk weight, etc." Dunn also observed that with chicken eggs the larger eggs of a representative group lost relatively less weight than the smaller eggs. Recognizing the possibility of this influence, we have in our experiments selected eggs of uniform weight with the exception of the first group of 32 eggs,

[1] L. C. Dunn, The Variation of Eggs in the Rate at which They Lose Weight. Poultry Sci., 2:45-58; 166-171; and 199-204. 1923.

which were incubated naturally and later classified to observe whether in this instance weight loss varied with the groups. Twenty-four of the eggs in this group produced apparently normal and vigorous poults which were all alive at the end of four weeks, indicating that pre-hatch development must have been satisfactory. Data on the weight loss of these eggs during the first 24 days of incubation are given in Table 1.

TABLE 1.—*Average weights of large and small eggs and percentage of weight loss at 24th day of incubation—incubated under chicken hens*

Group	Average at start	8 days incubation	16 days incubation	24 days incubation	Weight loss
	Gms.	*Gms.*	*Gms.*	*Gms.*	*P. ct.*
69-79 grams (16 eggs).....	75.0	72.2	68.8	65.2	13.0±0.6
80-92 grams (16 eggs).....	85.5	82.7	79.2	75.6	11.5±0.4

With natural incubation the eggs are regularly moved about in the nest and the environmental conditions as to air movement and humidity may be expected to be rather uniform for all eggs. Even under these conditions a marked difference in the weight loss of individual eggs was observed. The range in weight loss of the 24 eggs from which vigorous poults hatched was 6.7 to 15.3 per cent. The fact that all poults were alive and apparently normal at the end of four weeks indicates a considerable adaptation to this condition. This conclusion is supported by later observations with larger numbers of eggs artificially incubated under the same environmental conditions.

A second observation to determine if the variation in weight loss affected the growth rate of the poults which hatched was made the following season. For this experiment 150 eggs of apparently normal shape and texture were selected from a group weighing 80 to 90 grams. These were all weighed individually and numbered so that the poult which hatched from each egg could be identified with the weight lost by the egg during the first 24 days of incubation. All eggs were incubated in a cabinet-type incubator with an excellent device for mixing air in the cabinet, so that uniform temperature and humidity were maintained in all parts of the cabinet. The trays holding the experimental eggs were shifted and rotated daily as a further precaution to insure similar environmental conditions. The cabinet was maintained at a relative humidity of 40 per cent during the 24-day period. On the twenty-fourth day the fertile eggs were transferred

to gravity-ventilated, sectional hatching units, each egg being placed in a wire pedigree basket so that the identity of the poult could be established. Ninety-nine normal poults hatched, and these were banded and placed together in a colony house under the same environmental conditions. They were weighed at four and eight weeks, and comparisons were made with the weight loss of the eggs during the first 24 days of incubation.

TABLE 2.—*Weights of poults grouped according to loss in weight of eggs during the first 24 days of incubation*

Group	Poults	Wt. at hatch	Wt. at 28 days	Wt. at 56 days
	No.	*Gms.*	*Gms.*	*Gms.*
A (weight loss 7.0 to 12.5%)	22	61	219	800±19
B (weight loss 12.6 to 15.0%)	43	58	217	797±15
C (weight loss 15.1 to 24.0%)	28	57	214	829±16

The uniformity of the group weights indicates that the wide variation in the weight loss during the first 24 days of incubation had no significant effect on the growth rate during the first eight weeks.

This experiment was repeated the following year with 150 eggs again selected for uniformity of weight (80 to 90 grams), shape, and shell texture. The same cabinet incubator was used, but the humidity was purposely adjusted to a lower level (30±5%). It was thought that with this condition the variation in weight loss would perhaps result in an advantage for one group or another. The eggs were again incubated in the cabinet for 24 days and then transferred to a gravity-ventilated sectional machine for the rest of the incubation period. Each egg was hatched in a separate basket, and each poult was again identified with the egg weight lost during incubation. Ninety-five poults were hatched, of which 80 were still alive at eight weeks. The poults were brooded together and were provided with the same ration and environmental conditions. The average weight of three groups of poults classified according to weight loss of eggs during the first 24 days of incubation is given in Table 3.

An inspection of these data again indicates considerable adaptation to the weight-loss factor during the first 24 days of incubation, since no significant differences are observed in the weight of the poults at eight weeks.

The following season two small cabinet incubators with a capacity of 350 turkey eggs each were obtained for the

TABLE 3.—*Weight of poults grouped as to loss of egg weight during the first 24 days of incubation*

Group	Poults	Wt. at hatch	Wt. at 28 days	Wt. at 56 days
	No.	*Gms.*	*Gms.*	*Gms.*
A-2 (weight loss 8.0 to 13.5%)	32	60	219	806±14.3
B-2 (weight loss 13.5 to 15.0%)	23	58	214	788±19.5
C-2 (weight loss 15.0 to 20.0%)	25	56	215	830±17.1

development of another phase of these experiments. These incubators are 24 inches deep, 24 inches wide, and 30 inches high and have a content of approximately 10 cubic feet. A motor-driven fan placed in the bottom of the cabinet draws air through an eight-inch opening over a circular electric heating coil and along the back of a case which lines the rear and side walls of the cabinet proper. Small openings above each tray permit some air movement, but it appears that most of the air in the cabinet moves over the top of the duct, through the center of the machine, and back to the fan. Figure 1 shows the system of air distribution in these incubators and also shows where moisture pans were placed for humidity control.

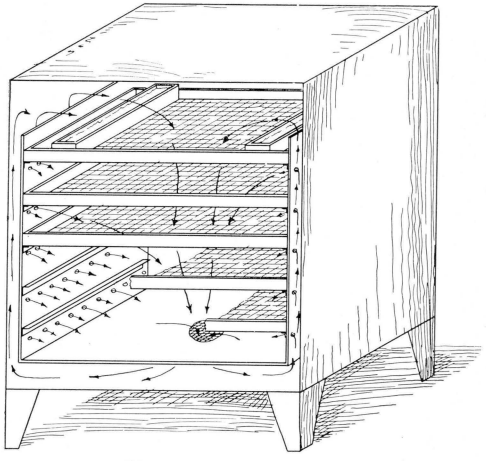

FIG. 1.—Sketch showing air movement in small cabinet incubators.

The rate of air movement in different parts of the cabinet was studied by placing an anemometer in different parts of the egg chamber. These determinations were made when the incubators were not being used for regular hatching, but temperature, humidity, and other conditions were provided exactly as for the regular experiment.[1]

A special door of beaver board was made for one of the machines, and an extension arm was attached to the anemometer so that it could be started and stopped from outside the cabinet as desired. Small holes were cut through the

[1] The coöperation of Mr. Chester C. Charles in this phase of the experimental work is acknowledged.

beaver board door so that the extension arm could be operated at the level of each egg tray. These holes were plugged with corks when not in use, so that the openings would not alter the rate or direction of air movement in the cabinet.

The air velocity directly over the fan opening in the bottom of each cabinet was 612 feet per minute. With eggs in the trays under the same conditions as prevailed when the experiments were in progress, the air movement on the first (top), second, and third trays was 75 to 95 feet per minute. Slight variations were observed in the air movement in different parts of the same tray, but on the whole the rate of movement was uniform. For the experiments covering the period from the 24th day to the finish of the hatch the top three trays of the cabinet machines were always used.

Each incubator has an electric heating unit connected with a thermostat which can be adjusted from outside the cabinet. Some refinements were made in the original temperature control equipment so that this factor was controlled at 100±0.25° F.

Preliminary trials indicated that humidity ranges of from 30 to 80 per cent relative could be secured through adjustment of the water surface in moisture pans placed in the top tray of the cabinet. Humidity readings were taken from three to five times daily by inserting a wet-bulb thermometer in a small opening in the top of each cabinet. The regular incubator thermometer was used as the dry bulb, and relative humidity interpretations were made through use of Table 4.

A search of the literature failed to show that the carbon-dioxide toleration of the turkey embryo has been determined, but numerous studies of this factor have been made with

TABLE 4.—*Relative humidity at dry-bulb temperature 100° F., pressure 29.0*

Depression	Relative humidity	Depression	Relative humidity	Depression	Relative humidity	Depression	Relative humidity
	P. ct.		*P. ct.*		*P. ct.*		*P. ct.*
5°	83	12°	62	19°	44	26°	29
6°	80	13°	59	20°	42	27°	27
7°	77	14°	57	21°	40	28°	25
8°	74	15°	54	22°	37	29°	23
9°	71	16°	52	23°	35	30°	21
10°	68	17°	49	24°	33	31°	19
11°	65	18°	47	25°	31	32°	18

chicken embryos. Lamson and Edmond [3] conclude, after extensive experiments carried on over a period of five years, "that if the carbon dioxide in the air of the incubator goes above 150 parts in 10,000, there will be a high mortality of the chick embryos, and that this dying will be greatly increased when the carbon dioxide rises above 200 parts in 10,000 (or 2 per cent)". These investigators worked entirely with gravity-ventilated incubators, and it is possible that higher levels of carbon dioxide are tolerated in cabinet machines with forced air movement. A determination of the carbon-dioxide content of samples of air taken from the experimental cabinet incubators showed less than 100 parts in 10,000 of air. This factor was not, therefore, limiting normal development.

TABLE 5.—*Showing effect of humidity of egg cabinet on weight loss and hatchability*

Lot	R. H. of cabinet	Wt. loss to 24th day	Range in wt. loss of individual eggs	Eggs in lot	Healthy poults	Hatch	Wt. at 56 days
	P. ct.	*P. ct.*	*P. ct.*	*No.*	*No.*	*P. ct.*	*Gms.*
A-1-33	70±2	6.7	5.0 to 9.1	60	28	46.7	1046±24
B-1-33	40±2	12.2	9.0 to 16.4	60	30	50.0	1028±23
A-2-33	70±2	5.0	3.1 to 15.4	100	51	51.0	.....
B-2-33	50±2	9.9	3.7 to 22.2	100	52	52.0	.....
Experimental discards hatched in gravity-ventilated sections 24th to 28th days				155	105	68.0	.....

For the first experiment with the small cabinet incubators 120 eggs of normal shape and shell texture and weighing from 80 to 95 grams each at the time they were placed in the incubators were divided into two lots of 60 eggs each. For the second experiment 200 eggs of the same size range and shell quality were divided into two lots of 100 eggs each. The hatches were carried through to completion in the experimental incubators, the eggs being transferred to hatching trays on the 24th day after incubation started. The large, small, and odd-shaped eggs which remained after the selection of the 80-to-95-gram group were incubated in the cabinet incubators for 24 days and were then transferred to a gravity-ventilated unit for the rest of the incubation period. The fact that these eggs were not uniform in size and shell texture precluded their use as a perfectly comparable control group, but a comparison of the hatching percentage with the

[3] G. H. Lamson, Jr., and H. D. Edmond, Carbon Dioxide in Incubation. Storrs Agr. Exp. Sta. Bul. No. 76. 1914.

experimental lots A-2 and B-2 was made. The hatching percentage of the discarded eggs was 68 per cent of all eggs in the group, which is appreciably higher than for either lot A-2 or B-2. Table 5 presents data on four lots incubated in the small cabinet incubators with the variable indicated in the second column. Lots A-1 and B-1 were incubated concurrently, as were lots A-2 and B-2.

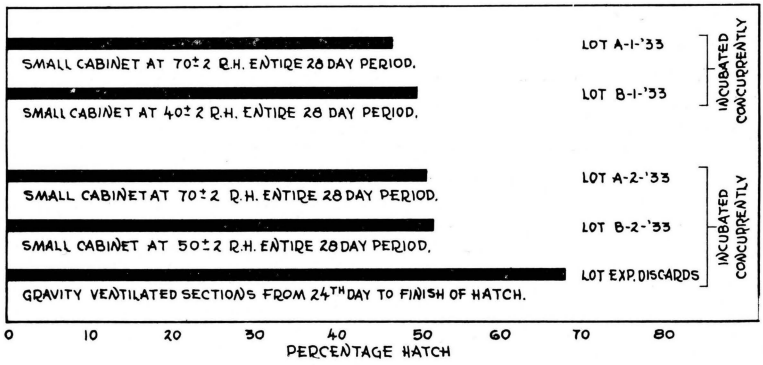

Fig. 2.—Graphic representation of data in Table 5.

The fact that the 155 eggs which were classified as experimental discards hatched better than either lot A-2 or B-2 suggested that conditions from the 24th day on through the finish of the hatch might have a much more significant influence than did the humidity of the cabinet to the 24th day. It was noted that poults required a longer rest or lag period after the shell was pipped than do baby chicks, and the rather rapid air movement in the cabinet incubators may have resulted in considerable energy loss during this lag period. With poults endowed with an extraordinary amount of vitality, the loss of moisture and energy may not have been significant, but with those less well endowed with vitality this factor may have been quite detrimental.

To obtain more detailed information on optimum conditions for the last four days of the incubation period two more series of experiments were planned. For the first of these, which will be referred to as Experiment 3-33, 800 Bronze turkey eggs were incubated in one unit of a cabinet incubator with excellent temperature control and with relative humidity adjusted to 42±3 per cent. The eggs were tested on the 24th day, and 561 fertile eggs were obtained. These were divided into three groups of 187 eggs each and were incubated for the remainder of the hatch under three different sets of conditions as follows:

Lot A-3 in a small cabinet incubator with humidity adjusted to 71±2 per cent relative and temperature 100±0.25° F.

Lot B-3 in a small cabinet incubator with humidity adjusted to 52±2 per cent relative and temperature 100±0.25° F.

Lot C-3 in two units of a sectional, gravity-ventilated incubator which, having been operated in experimentation for several years, appeared desirable for best results. Each section was provided with a moisture pan and temperatures were adjusted to 103 to 104 at the top of the egg.

Table 6 presents the results of two experiments which were repeated under as nearly comparable conditions as could be provided.

TABLE 6.—*Showing effect on hatchability of different environmental conditions from the 24th day to the finish of the hatch*

Lot	Eggs	Variable	Healthy poults	Hatched weak	Dead in shell
	No.		*P. ct.*	*P. ct.*	*P. ct.*
A-3	187	Cabinet at 71±2 R. H.	56.1	3.2	40.6
B-3	187	Cabinet at 52±2 R. H.	54.5	8.0	37.5
C-3	187	Gravity-ventilated egg chamber	64.2	2.6	33.2
A-4	185	Cabinet at 71±2 R. H.	49.7	3.2	47.0
B-4	185	Cabinet at 52±2 R. H.	59.4	3.2	37.3
C-4	185	Gravity-ventilated egg chamber	70.8	1.6	27.5

It is apparent that in both experiments the advantage was definitely in favor of the gravity-ventilated hatching units for finishing the hatching period. The eggs for both series

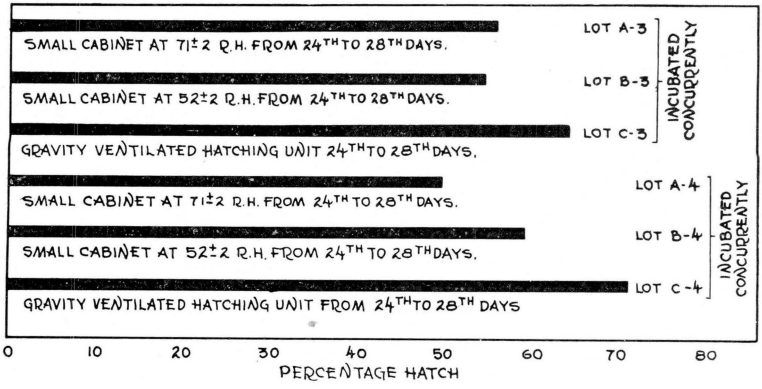

Fig. 3.—Graphic representation of data in Table 6.

of experiments were produced during the latter part of June after the peak of hatching power had been reached, but the hatches from lots C-3 and C-4 were still quite satisfactory. The eggs for all lots in each series came from the same flocks, and were fairly distributed as to age, so that this factor did not affect hatchability. Since the hatches from lots C-3 and C-4 were quite satisfactory for late-season hatches, one may reason that the conditions under which the eggs were incubated during the first 24 days were favorable, and that the differences in hatchability were due to the variations introduced after the 24th day of incubation.