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F. B. MUMFORD, *Director*

The Cooling of Eggs

E. M. FUNK

COLUMBIA, MISSOURI

SUMMARY

Eggs must be held at relatively low temperatures to preserve their quality. Recent investigations at the Missouri Agricultural Experiment Station show the temperature changes which occur when eggs are held in various containers and at different temperatures.

Eggs in which the temperature varied from 92°F to 102°F when held in an egg room at 50°F and cooled to below 68°F required the following time: single egg in one hour (39.9°F), an egg in the center of three layers of eggs on a wire tray, 3 hours; an egg in the center of a wire basket, 5 hours, (32.5°F); an egg in the center of a galvanized pail, 10 hours (32.9°F); an egg in the center of a chilled case, 15.5 hours (29.2°F); and an egg in the center of a warm case in 15 hours (24.0°F).

Eggs held in a household refrigerator in containers similar to those used in cooling eggs in an egg room (50°F) cooled more rapidly than when they were cooled in the egg room because the difference in temperature between the egg and the surrounding air was greater.

Circulation of air in the refrigerator or egg room increased the rate of cooling particularly when the eggs were held on a wire tray or in a wire basket.

Eggs placed in cases which had been chilled cooled more rapidly than those placed in warm cases.

The general laws of cooling apply to the cooling of eggs and certain values can be used for estimating the decrease in temperature of eggs held in different containers and at various temperatures. There are many factors influencing the rate of heat flow from an egg and therefore values determined under one set of conditions will not apply to cooling under other conditions.

The problem of preventing an increase in temperature is as important as the problem of cooling eggs. The use of chilled cases, case liners, and insulation for the cases will reduce the rate at which the temperature of the egg increases when the eggs in their containers are exposed to high temperatures.

The Cooling of Eggs

E. M. Funk

One of the major problems of egg marketing agencies during the summer months is to assemble eggs which have been properly cooled and held at low temperatures on the farm, and to move those eggs through the regular marketing channels to the consumer without heat damage. Those eggs which go into the top grades in the principal city markets are eggs which show no effect of high temperatures. Serious damage to egg quality results if eggs are held at temperatures above 68°F, because germ development begins at that point. Much lower temperatures are desirable but if eggs can be held below 68°F damage from germ development will be prevented. Any information which contributes to a better knowledge of the subject of cooling eggs should be of value to the industry as a whole, and particularly to those interested in conducting an educational campaign on this subject.

METHODS USED IN STUDYING THE COOLING OF EGGS

The Missouri Agricultural Experiment Station has investigated the temperature changes which take place in eggs held in different containers and at various temperatures. Warm eggs were cooled by placing them in a cool basement and in a household refrigerator. Cooled eggs were subjected to warm temperatures. The effects of air circulation, insulation and types of containers were studied in the investigation. The thermocouple potentiometer shown in Figure 1 was used to determine the temperature of the contents of the egg. Figure 2 shows the thermocouple attached to an egg in a case and a single egg on a wire tray. It also shows the incubator and refrigerator used and the containers in which the eggs were held. Using this type of thermometer the temperature of the inside of the egg can be taken at any time and under any desired condition. This type of thermometer has the advantage of being small and therefore introducing a negligible amount of heat or cold into the egg. The electrical wires were confined in a small glass tube to prevent any possible chemical reaction between the metal wires and the contents of the egg. Several hundred temperature readings taken in this manner supplied the data for the charts and tables presented in this publication.

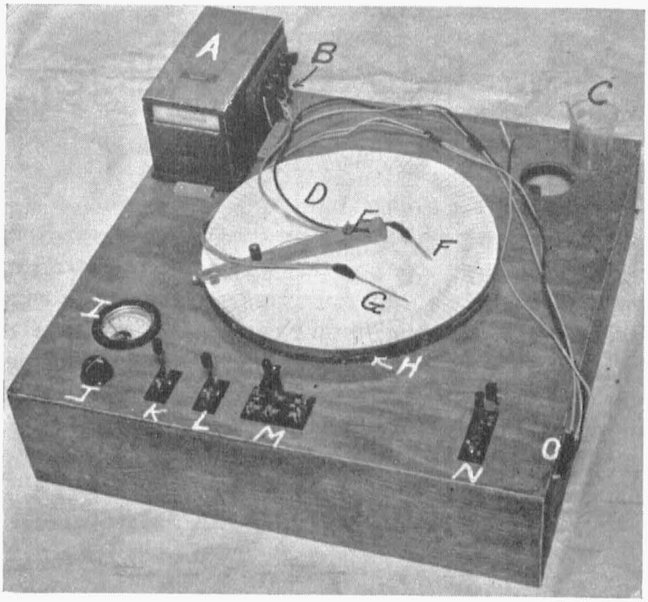

Figure 1.—Thermo-couple potentiometer used in this investigation. A, galvanometer; B, connections leading to galvanometer; C, beaker used for holding shaved ice at 32°F; D, graduated dial; E, potentiometer arm; F and G, thermo-couple junctions which were inserted in eggs; H, circle of manganin wire surrounding the dial; I, milliameter; J, rheostat adjustment; K, switch controlling galvanometer light; L, switch controlling the potentiometer current; M, switch used for reversing the current for readings below 32°F; N, switch used to select the thermo-couple F or G; O, copper-constantan wires connecting the thermo-couples. Three dry cell batteries which supplied the current are attached beneath the galvanometer.

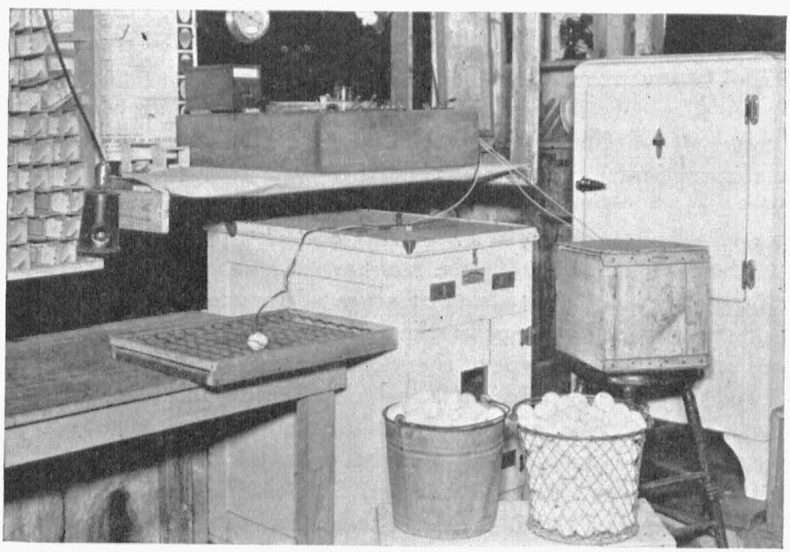

Figure 2.—Thermo-couple attached to a single egg on a wire tray and to an egg in the center of a case (one-half of a 30 dozen case). The containers and equipment shown were used in this investigation.

COOLING EGGS IN AN EGG ROOM

Table 1 and Figure 3 show the time required to cool eggs to different temperatures when the eggs were held in various containers in an egg room where the average temperature was 50°F. A single egg on a wire tray, three layers of eggs on a wire tray, and eggs in a wire basket, galvanized pail, chilled case, and warm case were cooled from high temperatures (92°F to 102°F) to temperatures below 60°F by holding

TABLE 1.—EFFECT OF CONTAINER ON COOLING EGGS IN AN EGG ROOM (50°F.)

Hour	Single egg	Wire tray	Wire basket	Galva-nized pail	Chilled case	Warm case
0	101.0	102.0	100.0	98.5	97.2	92.0
1	61.1	86.9	96.0	97.9	96.2	91.8
2	51.3	74.4	87.2	95.9	94.5	91.3
3	----	66.5	79.1	92.2	92.0	90.2
4	----	61.0	72.7	87.0	89.8	88.6
5	----	56.5	67.5	82.1	87.5	86.1
6	----	55.4	63.6	77.7	----	----
8	----	51.9	58.5	70.6	----	81.0
10	----	----	56.5	65.6	76.5	75.5
12	----	----	54.7	62.2	----	----
14	----	----	----	59.8	----	69.8
18	----	----	----	----	64.5	----
20	----	----	----	----	62.2	63.1
24	----	----	----	----	59.4	59.6
28	----	----	----	----	57.0	56.7

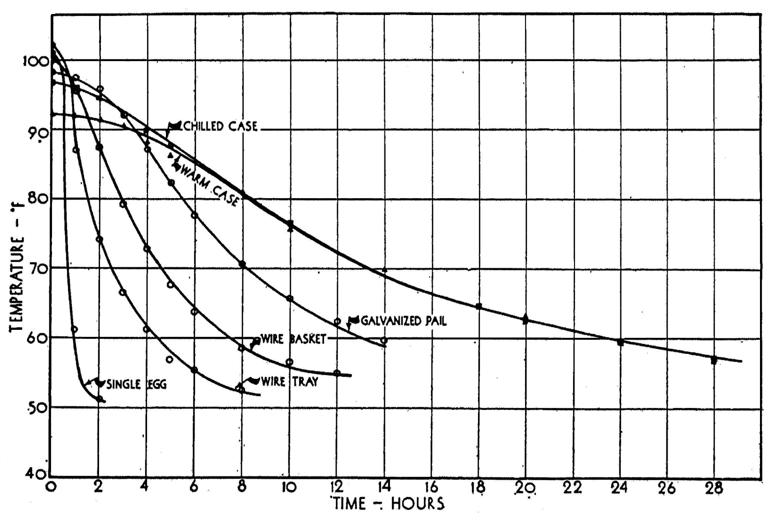

Figure 3.—Effect of Container on the Rate of Cooling in Eggs Held in an Egg Room (50°F).

them in an egg room (50°F). The temperature of the center of the egg which was located as near as possible in the center of the container was taken at regular intervals so that the rate of cooling in each instance could be determined. The results obtained do not give any new concepts of cooling but they do present data to support the logical assumptions which have been made on this subject. If we assume that the time required to cool eggs to below 68°F is a fair measure of efficiency in cooling, we find that eggs held in different containers cooled to below 68°F as follows: single egg on a wire tray, one hour; an egg in the center of three layers of eggs on a wire tray, 3 hours; an egg in the center of a wire basket containing 156 eggs, 5 hours; an egg in the center of a galvanized pail containing 156 eggs, 10 hours; an egg in the center of a chilled case, 18 hours (cooled from 97.2°F to 64.5°F); and an egg in the center of a warm case, 20 hours (cooled from 92.0°F to 63.1°F).

There are two apparent explanations for the longer time required to cool eggs in the cases, etc. First, the size of the mass to be cooled was increased and the insulation subsequently placed around the eggs was greatly increased so that the rate of cooling was reduced. Second, the curves plotted in Figure 3 show a very definite lag in cooling in the case. This was evidently due to the fact that several hours was required for the colder air to reach the center of the case.

COOLING EGGS IN A HOUSEHOLD REFRIGERATOR

The results of cooling eggs in a household refrigerator (30-38°) are shown in Figure 4 and Table 2. It will be observed by comparing Figures 3 and 4 that the eggs cooled more rapidly in the refrigerator than in the egg room. The more rapid decrease in temperature of the eggs held in

TABLE 2.—EFFECT OF CONTAINER ON COOLING EGGS IN A HOUSEHOLD REFRIGERATOR. (30-38°F)

Hours	Single egg	Wire basket	Galvanized pail	Warm case
0	97.7	101.0	98.0	101.9
1	55.0	96.5	----	----
2	35.5	85.9	90.5	98.2
3	----	74.0	----	----
4	----	63.5	73.5	95.9
5	----	56.0	----	----
6	----	53.2	62.0	91.0
8	----	43.1	----	82.0
10	----	39.0	53.0	74.0
12	----	36.0	----	----
13	----	----	42.2	----
14	----	----	----	63.0
18	----	----	----	54.0
20	----	----	36.5	50.9
23	----	----	----	47.8
27	----	----	----	44.6
31	----	----	----	40.3

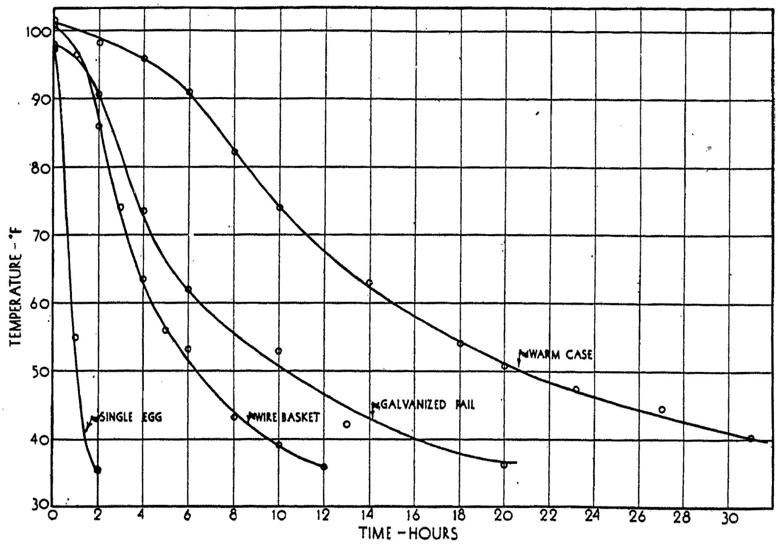

Figure 4.—Effect of Container on the Rate of Cooling in Eggs Held in a Household Refrigerator (30-38°F).

the refrigerator is, of course, due to the greater difference between the temperature of the egg and the air surrounding it. Eggs exposed in a wire basket in a refrigerator cooled from 101°F to 63.5°F (a decrease of 37.5 degrees) in 4 hours, while eggs placed in a warm case cooled from 101.9°F to 63°F (a decrease of 38.9°) in 14 hours. Similar decreases in temperature occurred when eggs were held in the egg room at 50°F in a wire basket for 6 hours and in a case for 20 hours. The rate of cooling was approximately 50 per cent greater in the refrigerator than in the egg room.

EFFECT OF THE CIRCULATION OF AIR ON COOLING

Air movement in the egg room or refrigerator was an important factor influencing the rate of cooling. As an illustration, Table 3 and Figure 5 show the results obtained by cooling a wire basket full of eggs in an egg room by still air, and by air blown through the eggs with an electric fan. During the first hour the temperature of an egg in the center of a wire basket exposed to circulating air (50°F) dropped from 95.2°F to 55.1°F or 40.1 degrees, while eggs in a similar position exposed to still air decreased only 4 degrees. Possibly producers and dealers would not want to use such a method for cooling eggs but some circulation of air in the cooling room seems desirable, particularly if the eggs are exposed in a wire basket or on a wire tray. An objection to the rapid circulation of air through eggs is, of course, that air movement hastens

TABLE 3.—EFFECT OF AIR CIRCULATION ON COOLING EGGS IN A WIRE BASKET (50°F)

Hour	Still Air	Circulating Air
	Temp. °F	*Temp. °F*
0	100	95.2
.25	----	81.8
.50	----	69.0
.75	----	60.8
1.00	96	55.1
1.25	----	53.1
1.50	----	51.5
1.75	----	50.8
2.00	87.2	50.2
3.00	79.1	----
4.00	72.7	----
5.00	67.5	----
6.00	63.6	----
7.00	60.5	----
8.00	58.5	----
9.00	57.2	----
10.00	56.5	----
11.00	55.2	----
12.00	54.7	----
13.00	54.2	----

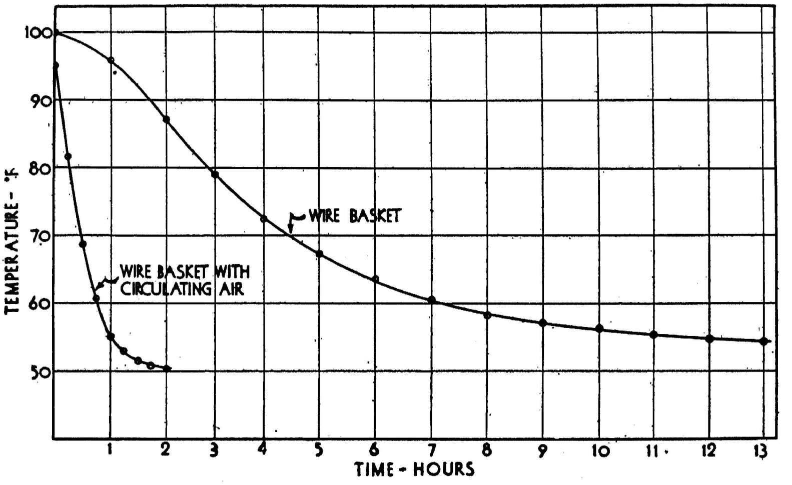

Figure 5.—Effect of Air Circulation on the Cooling of Eggs Held in a Wire Basket at 50°F.

evaporation and thereby increases the size of the air cell. The amount of evaporation would be influenced by the humidity of the air. A candling observation, and also weight determinations of eggs cooled with the circulation of air (one hour) and without the circulation of air through a wire basket, showed that there was no significant difference in the eggs subjected to the two methods of cooling.

RATE OF COOLING IN DIFFERENT PARTS OF THE EGG

The rate of cooling in the center of the egg and in the albumen just beneath the shell are shown in Figure 6 and Table 4. The outer albumen cools more rapidy than the center of the egg but the egg is apparently a fairly good conductor of heat and therefore the difference in cooling was not great. Heat is radiated from the surface of the egg and conduction inside the egg tends to equalize differences in temperature which may exist in different parts of the egg.

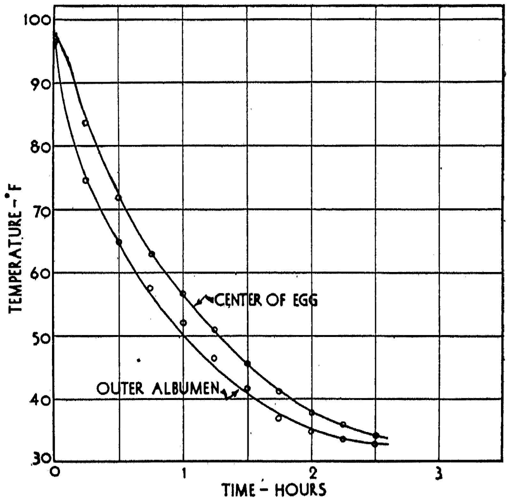

Figure 6.—Rate of Cooling in Different Parts of the Eggs When Held at 30-32°F.

TABLE 4.—RATE OF COOLING IN DIFFERENT PARTS OF THE EGG WHEN HELD AT 30-32°F.

Hour	Center of Egg	Outer Albumen
0	98.0	96.9
.25	83.5	74.5
.50	71.9	64.8
.75	62.5	57.2
1.00	56.2	51.9
1.25	50.8	46.5
1.50	45.3	41.5
1.75	41.0	36.9
2.00	37.5	34.5
2.25	35.8	33.5
2.50	34.0	32.8

THE USE OF COOLED CASES

A comparison of the results (see Table 1 and Figure 3) obtained in cooling eggs in a chilled case and a warm case indicates that it would be desirable to place eggs in cases which have been chilled instead of placing them in warm cases. It will be observed that during the first five hours the temperature of the eggs in the cooled case decreased 9.7 degrees while the eggs in the warm case decreased 5.9 degrees. The flats, fillers, and case when warm have considerable heat capacity which tends to reduce the rate of cooling. Figure 7 shows the difference in the rate of warming in eggs which were held in a chilled case and in a warm case. Eggs held in a warm case at 100°F for 14 hours increased 33.7 degrees while eggs held in a chilled case for the same length of time increased 25.3 degrees. It is evident from these results that cooling the

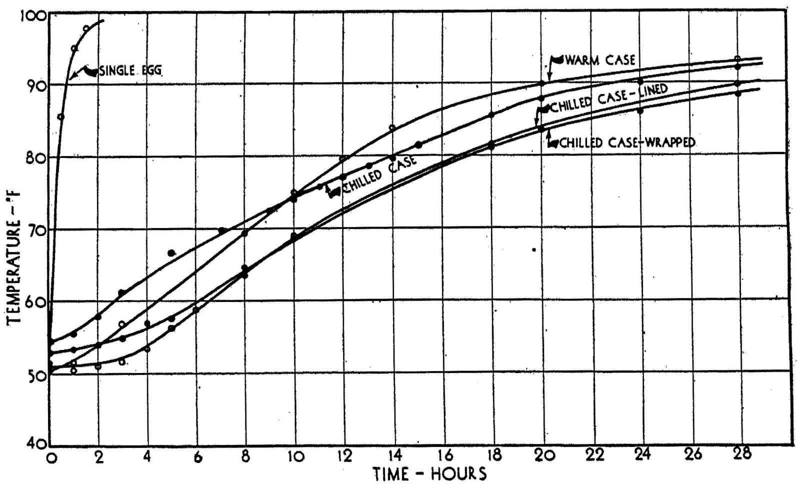

Figure 7.—Effect of Container on the Warming of Eggs Held at 100°F.

cases in hot weather before using them will reduce the temperature of the eggs more rapidly and will also help to prevent an increase of temperature in eggs which are exposed to high temperatures.

RATE OF WARMING EGGS

The problem of maintaining the proper temperature for eggs from production to consumption is not only a problem of reducing the temperature but of maintaining a low temperature in the egg after it has been cooled. The farmer or dealer may lower the temperature of the eggs to the desired level for holding but when they are transported to

TABLE 5.—EFFECT OF CONTAINER ON WARMING EGGS WHEN HELD AT 100°F.

Hour	Single egg	Chilled case	Chilled case lined	Chilled case wrapped	Warm case
0.	51.2	54.3	51.5	52.9	50.3
0.5	85.6	----	----	----	----
1.0	95.0	55.5	50.4	53.2	51.8
1.5	97.7	----	----	----	----
2.0	----	57.8	51.1	53.9	54.0
3.0	----	61.3	51.5	54.7	56.9
4.0	----	----	53.5	57.0	----
5.0	----	66.8	56.2	57.4	----
6.0	----	----	58.8	----	----
8.0	----	----	63.4	64.6	69.5
10.0	----	74.0	69.0	68.8	74.9
12.0	----	76.9	----	----	79.5
14.0	----	79.6	----	----	84.0
18.0	----	85.5	81.5	81.0	----
20.0	----	87.5	83.8	----	90.0
24.0	----	89.9	----	86.0	----
28.0	----	92.0	89.9	88.4	93.1

another point they are often subjected to high temperatures and therefore the eggs are again warmed. Table 5 and Figure 7 show the rate at which the temperature increased in eggs held under different conditions. The results show that when eggs which had been reduced to approximately 50°F were exposed to 100°F in a forced draft incubator the temperature in the center of a single egg was raised to above 68°F in 10 minutes and that the temperature of eggs exposed in containers in the forced draft incubators for 10 hours had increased as follows; eggs in the center of a warm case 24.6 degrees, chilled case 19.7 degrees, chilled and lined case 17.5 degrees, and a chilled case wrapped in a light blanket 15.9 degrees. These results show that it is highly desirable to case eggs which have been cooled and that the use of chilled cases, case liners or additional insulation will materially reduce the rate at which the temperature of the eggs increases.

RATE OF WARMING EGGS IN THE TOP AND MIDDLE FILLER OF THE CASE

That those eggs near the outside of a case should change temperature more rapidly than those in the center of the case is to be expected. Table 6 and Figure 8 show the differences which exist when eggs are warmed. The results show that during the early stages the eggs in the top layers warm more rapidly than those in the center of the case, and the 68°F point is reached about 5 hours sooner. After 48 hours, however, there is no appreciable difference between the temperature of the eggs in the top and middle layers of the case. Similar differences would be expected to prevail when eggs are cooled. Therefore the readings we have reported for eggs in the center of containers represent the slowest rate of cooling or warming in that particular container.

TABLE 6.—RATE OF WARMING OF EGGS IN TOP AND MIDDLE FILLERS OF A CASE. EGGS HELD AT 100°F.

Hour	Top Filler	Middle Filler
0	51.9	51.5
1	53.0	50.4
2	56.8	51.1
3	58.8	51.5
4	63.2	53.5
5	65.8	56.2
6	69.0	58.8
8	73.7	63.4
10	78.5	69.0
17	87.5	81.0
20	89.4	83.8
26	92.7	89.2
28	93.2	89.9
30	93.5	90.7
34	95.0	92.9
42	96.0	94.0

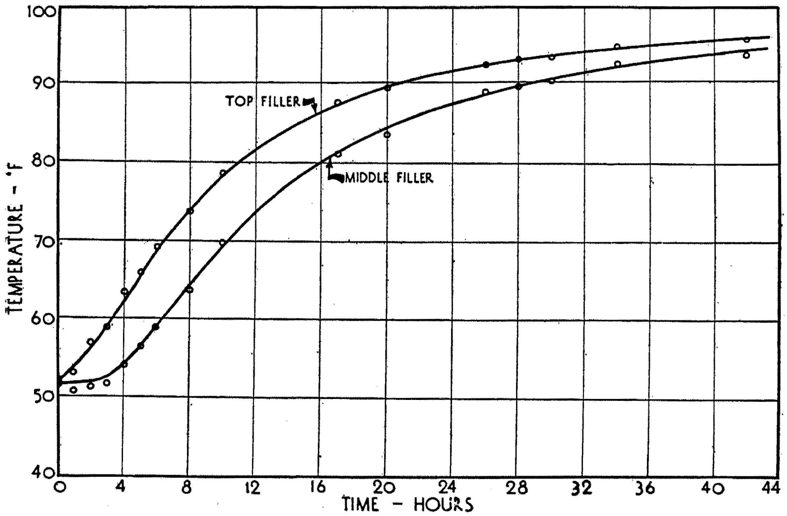

Figure 8.—Rate of Warming in the Top and Middle Fillers of a Case When Held at 100°F.

GENERAL LAWS OF COOLING AS APPLIED TO EGGS

Newton's law of cooling states that the rate of loss of heat by a surface is proportional to the difference between its temperature and that of the surroundings. Since we may reason that the principal loss of heat from an egg is by radiation from its surface, we may express for all practical purposes this law for the cooling of an egg as

$$D = K (Te - Ts)$$

where D is the decrease in temperature during any time interval, Te is the temperature of the egg and Ts is the temperature of the surroundings at the beginning of a time interval, and K is a constant to be determined for the material (egg) studied. It is evident that after the container and egg have been held at a relatively low temperature long enough for the maximum rate of cooling to be reached at the point (center of the egg) where the temperature is being taken, the temperature change should be uniform and therefore the above formula would give an equation for approximating the temperature change in the egg during any period of time in which a temperature difference existed. Calculating the values of K under the conditions investigated gives the values listed in Table 7.

TABLE 7.—RELATIVE RATES OF COOLING AND WARMING EGGS

Container, Temperature, Etc.	Value of K for time intervals of one hour
A. Refrigerator (30-38°)	
1. Single egg on wire tray	.650
2. Eggs in a wire basket	.210
3. Eggs in a wire basket with circulating air	.860
4. Eggs in a pre-heated bucket	.115
5. Eggs in a pre-heated case	.075
B. Egg Room (50°F)	
1. Single egg on wire tray	.750
2. Three layers on wire tray	.280
3. Eggs in a wire basket	.202
4. Eggs in a wire basket with circulating air	.910
5. Eggs in a pre-heated bucket	.130
6. Eggs in a case	.060
C. Forced draft incubator (100°F)	
1. Single egg on a wire tray	.900
2. Eggs in a chilled case	.065
3. Eggs in a warm case	.085
4. Eggs in a chilled case lined with case liner	.055
5. Eggs in a chilled case lined with two thicknesses of newspaper	.050
6. Eggs in a chilled case wrapped in a blanket	.052
7. Eggs in a wire basket	.370

It should be noted that for cooling in cases or other containers where some time is required for the cold air to reach the center of the container, the values of K only apply to that portion of the curve formed after the point of maximum cooling has been reached. It is also true that theoretical curves calculated for cooling in single eggs do not fit the readings made during the first few minutes because some time is required for the center of the egg to be affected.

An accurate determination of changes in temperature in eggs during any time interval must consider all the factors influencing the loss of heat from an egg if these determinations are to have any general applications. These factors are size, color, shape, density, specific heat, emissivity of heat, air movement at the surface of the egg, humidity of the atmosphere, and the difference in temperature between the egg and the surrounding air. In this investigation an attempt was made to control as many of these factors as possible by using eggs of near the same size (56 grams), color (white), shape (standard), density and specific heat (fresh eggs), and air movement and humidity (same room, refrigerator or incubator). With these factors fairly well standardized the temperature at approximately the center of the egg and the temperature of the surrounding air was determined at regular intervals. The values determined appear to conform fairly well to mathematical curves and therefore it is believed that under similar conditions they have general applications.

SUGGESTED PRACTICES

The results of these investigations justify the following recommendations:

Eggs should be gathered often during hot weather and placed in containers where they are exposed directly to cool air. Eggs held on a wire tray or in a wire basket will cool more rapidly than eggs held in a bucket or case. They should not be placed in cases until the temperature of the eggs has been reduced by exposing them to low temperatures. Germ development continues for several hours when warm eggs are placed in cases.

The use of cool cases instead of warm cases will help keep eggs cool. The flats, fillers, and cases carry considerable heat which should be removed by cooling them before the eggs are cased.

Circulating air in the egg room will speed up cooling very greatly, especially if the eggs are held in a wire basket or on a wire tray. If the air is dry, the circulation of air will increase evaporation so that the benefits from rapid cooling may be lost by the damage due to increased size of the air cell. Where facilities are available for increasing air circulation the practice would be advisable, particularly if a relatively high humidity can be maintained.

The use of case liners or other insulation tends to keep eggs cool when the eggs in their containers are exposed to high temperatures. When eggs are cooled on the farm or in the dealer's plant, and later exposed to high temperatures in transit, they should be protected by shade and insulation. The producer will find that wrapping a case in a piece of canvas or blanket and keeping the sun from shining on the case will help keep the eggs cool while they are being taken to market.

The front cover page shows a wire tray for cooling eggs, a wire basket for gathering eggs, the regular 30 dozen case for holding and transporting eggs and a front view of the Missouri Egg Cooler.* Eggs should be gathered in a wire basket, and held in a cool place in the basket, or on wire trays, over night to permit all heat to escape from the eggs. When cooled the eggs should be cased and held in a cool place until taken to market.

The room or cooler used should have a relatively high humidity because a dry atmosphere surrounding the eggs will cause rapid evaporation and therefore enlarge air cells in the eggs. The humidity may be kept high by keeping the floor damp and by hanging pieces of wet burlap in the room. Evaporation of moisture from the floor or the burlap will tend to reduce the temperature of the room or cooler.

Where adequate facilities are not available for holding eggs below 68°F during the summer months producers should provide these facilities by building an inexpensive egg cooler. Plans for such a cooler may be obtained from the county extension agent or from the department of poultry husbandry, College of Agriculture, Columbia, Missouri.

ACKNOWLEDGMENTS

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*Fully described in Agricultural Extension Service Circular 299.