

Quality Evaluation of Agricultural Products by Infrared Imaging Method

II. Discrimination of Fertilized and Unfertilized Eggs during the Incubation Period

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Introduction

Discrimination of fertilized and unfertilized avian eggs during the incubation period has been carried out by the visual inspection of the egg candling method¹⁾. However, this method consumes too much time. A simple, rapid and automatic method for the discrimination of fertilized and unfertilized eggs has not yet been reported.

Infrared imaging method is capable of providing practical solution to this problem. Most of the successful applications capitalize on the ability of infrared imaging devices, to measure the surface temperature of hatching eggs without contact. Since the heat generated in various metabolic processes within the egg increases temperature simultaneously, an equipment that may be capable of sensing temperature changes between surface temperatures of fertilized and unfertilized eggs is considered to be useful for the discrimination of eggs.

As reported in the previous paper²⁾, thermal imaging device which was applied to the grading of fruits for bruise and other surface defects, appears to have been established as one of the more reliable methods available. The same device may be applied to the discrimination of hatching eggs. Preliminary results on the discrimination of fertilized and unfertilized eggs during the incubation period were discussed in the present paper.

Experimental Procedure

1. Chicken Eggs Tested

Fertilized and unfertilized chicken eggs were chosen. Fertilized eggs of broiler chicken (Arbor Acres) were kindly presented from Izumi Poultry Agricultural Co-operative Association, and unfertilized eggs of laying hen (Hy-line) were prepared from the University Farm, Faculty of Agriculture, Kagoshima University.

The number of fertilized and unfertilized eggs tested, the average diameters and weight of them, and the starting dates of the incubation period are listed in Tables 1 and 2.

The dead in shell were also tested. They were prepared by picking up hatching eggs from an incubator and putting them into a refrigerator for more than 13 hrs in order to kill the developing eggs.

Table 1. Average dimensions and weight of fertilized eggs

Starting date of hatching	Number of eggs	Average diameters		Average weight (g)
		Long axis (mm)	Short axis (mm)	
May 3, 1976	10	59.22	42.37	50.61
May 6, 1976	10	57.36	42.47	49.91
May 10, 1976	10	57.80	44.10	52.56
May 11, 1976	10	58.47	43.71	55.43
May 14, 1976	10	58.92	43.48	57.29
May 17, 1976	10	58.97	43.24	56.87

Table 2. Average dimensions and weight of unfertilized eggs

Starting date of hatching	Number of eggs	Average diameters		Average weight (g)
		Long axis (mm)	Short axis (mm)	
May 3-17, 1976	16	60.16	44.45	58.82

2. Conditions in Incubation

In order to measure the surface temperatures of hatching eggs during the different incubation periods, total number of 60 fertilized eggs were divided into 6 groups, each group being composed of 10 eggs, and then these eggs in each group were incubated on the starting dates of May 3, 6, 10, 11, 14, and 17, 1976, successively. Two or three unfertilized eggs were also added to the groups, and were held under the same incubation conditions in an incubator.

Two incubator were used. The larger one was TÖYÖ Incubator & Heater, Kanda Type, 100 V, 2 kW in capacity, made by Ashida Sangyo KK. The smaller one was Incubator EN-3, 100 V, 0.15 kW in capacity, made by Nakamura Rikagaku Kogyo KK.

During the hatching eggs were kept in the incubators, cares were taken at the following point^{3,4)}.

1). Since temperature is the most critical factor in hatching operation, temperature in the larger incubator was kept at $38.5 \pm 1.0^\circ\text{C}$.

2). Since the proper level of humidity in the incubator is just as important as proper temperature, approximately 60 per cent relative humidity was controlled.

3). A further important factor in the incubation is the frequency of turning eggs. In the actual operation of the incubation, eggs were turned only once a day.

4). Ventilation is also very important in the incubation. Ventilation was made by rotating fans.

3. Thermal Imaging Device

A Fujitsu Infra-Eye 102 A, a medical thermography, was used in the present experiment. The details of the apparatus were reported in the previous paper²⁾.

Fig. 1 shows a block diagram of the experimental arrangement. Samples were placed in a shielding box. Infrared radiations emitted from the samples were collected by an infrared vidicon camera, and the signal received was transmitted to the Infra-Eye 102 A. Thermal images were produced by a black and white T.V. monitor, and by a color T.V. monitor, respectively. While, the temperature-curve was represented by temperatures noted on a

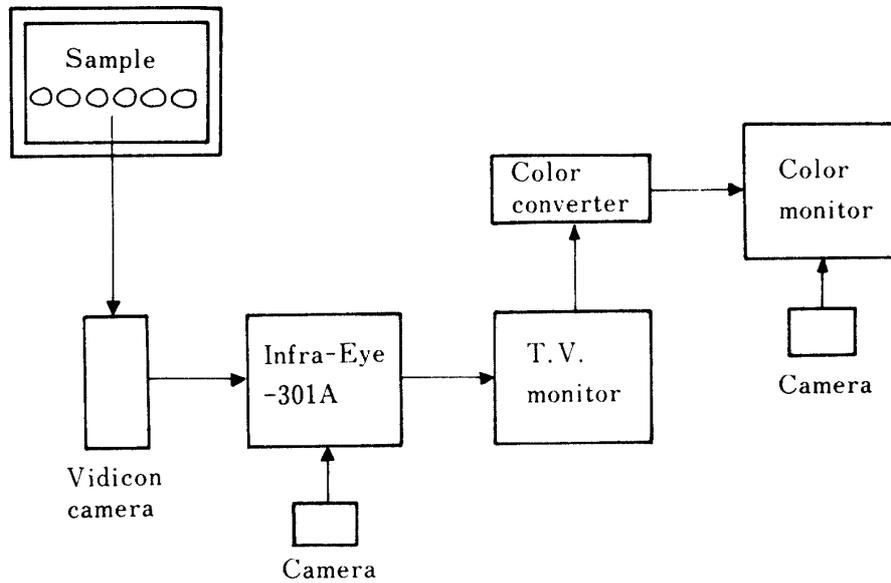


Fig. 1. Block diagram of experimental arrangement of the infrared measurement.

single scanning line passing through the samples at a given elevation.

A base temperature can be determined, to indicate the mean-value of temperatures on the surface of sample. While, a measuring-temperature-range can be selected, to cover the temperature difference between the maximum and the minimum temperatures of the sample.

4. Measurement of Surface Temperature and Temperature-Curve

Surface temperature of eggs was generated on a thermal image taken by the infrared camera, in much the same way as in a television picture, in a black and white T.V. monitor. The measuring-temperature-range was indicated by a glass-scale divided into 5 parts between white and black, and the 5 divisions of the glass-scale were shown at the lower part of the picture. The thermal image was taken by a 35 mm camera attached to the T.V. monitor.

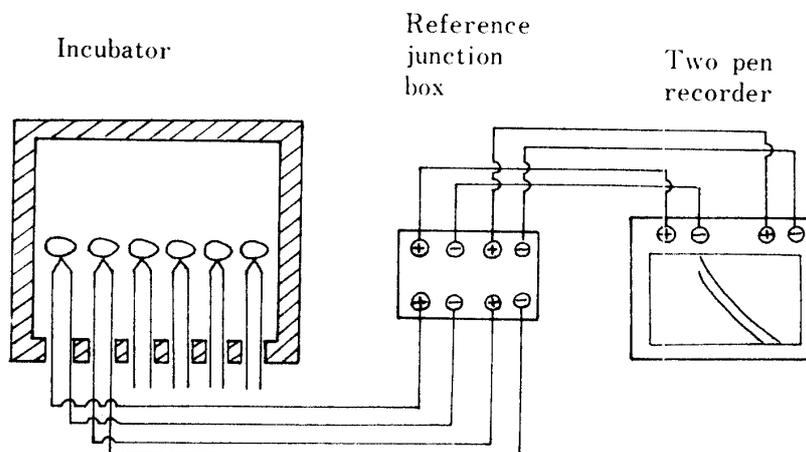


Fig. 2. Block diagram of the direct measurement of surface temperature of hatching eggs.

The temperature-curve was also shown in the T.V. monitor, independently. This can also be taken by a 35 mm camera attached to the T.V. monitor under the same photo-conditions as in case of the thermal image.

5. Direct Measurement of Surface Temperature of Hatching Egg

Surface temperature of hatching egg was measured directly by using thermojunctions (copper-constantan) on the surface of hatching eggs held in the smaller incubator. The surface temperatures measured by thermojunctions were recorded on the two-pen-recorder (QPD-73, made by Hitachi Ltd.). Fig. 2 shows a block diagram of the direct measurement of surface temperature of hatching eggs.

Fertilized eggs of 12 and unfertilized eggs of 2 were tested. They were divided into two groups, each group being composed of 6 fertilized eggs and one unfertilized egg. Each group was incubated day after day, and 6 fertilized eggs and one unfertilized egg were simultaneously laid in the incubator. Surface temperatures of eggs were measured every day during the incubation period.

Results and Discussion

1. Surface Temperatures of Fertilized and Unfertilized Eggs

Surface temperatures of fertilized eggs and that of unfertilized egg were observed by the infrared imaging method. Fig. 3 shows the thermal images of the fertilized egg at the incubation period of 11 days old, and that of the unfertilized egg held in the incubator at the same period. They were measured 6 min 53 sec after being removed from the incubator to the shielding box, at room temperature. The measuring-temperature-range was selected to be 3.0°C .

As seen from Fig. 3 (a), temperature distributions on the surface of the fertilized and unfertilized eggs were quite homogeneous over the wide area around the center, as observed in case of the model of spherical substance²⁾.

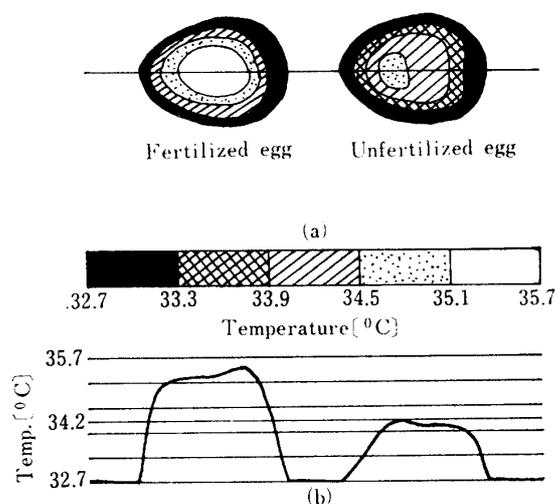


Fig. 3. Thermal images and temperature-curves of fertilized and unfertilized eggs at the incubation period of 11 days old.
 Base temperature: 34.2°C .
 Measuring temperature range: 3.0°C .
 The time measured: 6 min 53 sec.

Fig. 3 (b) shows the temperature-curve passing through the center of eggs. The temperature-curves of fertilized and unfertilized eggs show rather monotonous variation. Therefore, it is assumed that the surface temperature of the egg was represented by the maximum temperature on the temperature-curve.

In the comparison of the temperature-curves of fertilized eggs with those of the unfertilized eggs, the surface temperature of fertilized egg (estimated to be 35.5°C) is slightly higher than that of unfertilized egg (estimated to be 34.2°C). The temperature difference between them is significant, and estimated to be 1.3°C .

From this result, it is observed that the surface temperature of fertilized egg is usually slightly higher than that of unfertilized egg, and that of the slight temperature difference between them is to be easily detected by the thermal images.

2. Surface Temperature of Fertilized Eggs at a Given Incubation Period.

During the entire period of the incubation of chicken eggs, 5 fertilized eggs and one unfertilized egg in the group were removed from the incubator to the shielding box, and the thermal images of them were measured at room temperature. The given incubation period at the measurement was selected to be 1, 3, 4, 6, 7, 12, 15 and 17 days old counting from the beginning of incubation, respectively.

Fig. 4 shows the thermal images and the temperature-curves of the eggs at the incubation period of one day old. In this figure, 5 fertilized eggs, No. 1, No. 2, No. 5, and

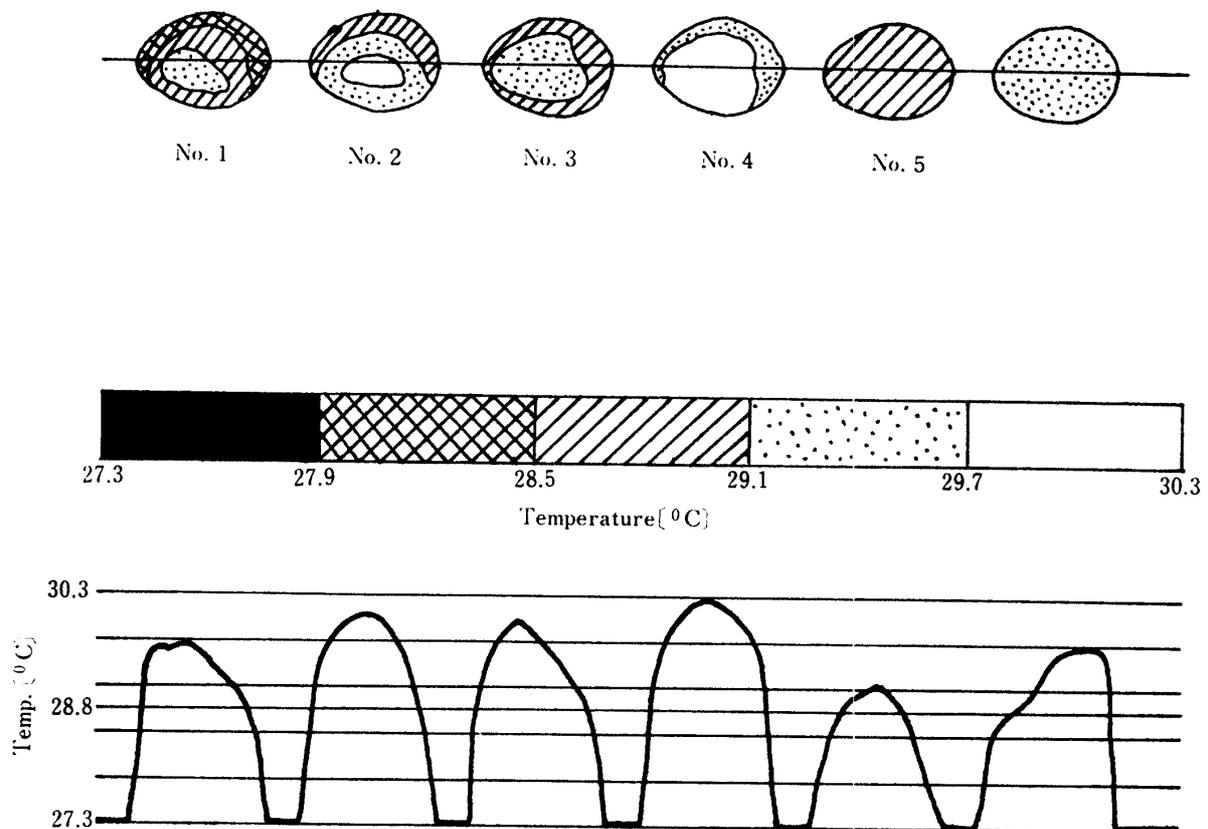


Fig. 4. Thermal images and temperature-curve of the eggs at the incubation period of one day old.

Base temperature: 28.8°C .

Measuring temperature range: 3.0°C .

The time measured: 20 min 12 sec.

one unfertilized egg are arranged in a line from the left to the right. Surface temperatures of No. 2, No. 3 and No. 4 fertilized eggs are slightly higher than that of the unfertilized egg. While, the surface temperature of No. 5 fertilized egg is slightly lower than that of the unfertilized egg. From this result, it is observed that temperature difference between fertilized eggs and unfertilized egg is not so obvious at the beginning of the incubation period.

Fig. 5 shows the thermal images and the temperature-curves of the eggs at the incubation period of 4 days old. In this figure, arrangement of the fertilized eggs and of unfertilized egg show the same order as in case of Fig. 4.

Surface temperatures of fertilized eggs are slightly higher than that of unfertilized egg. The pattern of the temperature-curves showed similar variation during the series of measurements, but the surface temperatures of these eggs decreased gradually in accordance with the time elapsed. Results from the time dependency of surface temperature of eggs on the time measured are to be discussed in the later section.

Figs. 6, 7 and 8 show the thermal images and the temperature-curves of the eggs at the incubation period of 7, 12 and 15 days old, respectively. In these figures, 5 fertilized eggs and one unfertilized egg are arranged in the same order as in case of Fig. 4.

It is observed that, as seen in these figures, surface temperatures of the fertilized eggs are significantly higher than that of the unfertilized egg, and temperature differences between the former and the latter are apt to become gradually increasing in accordance

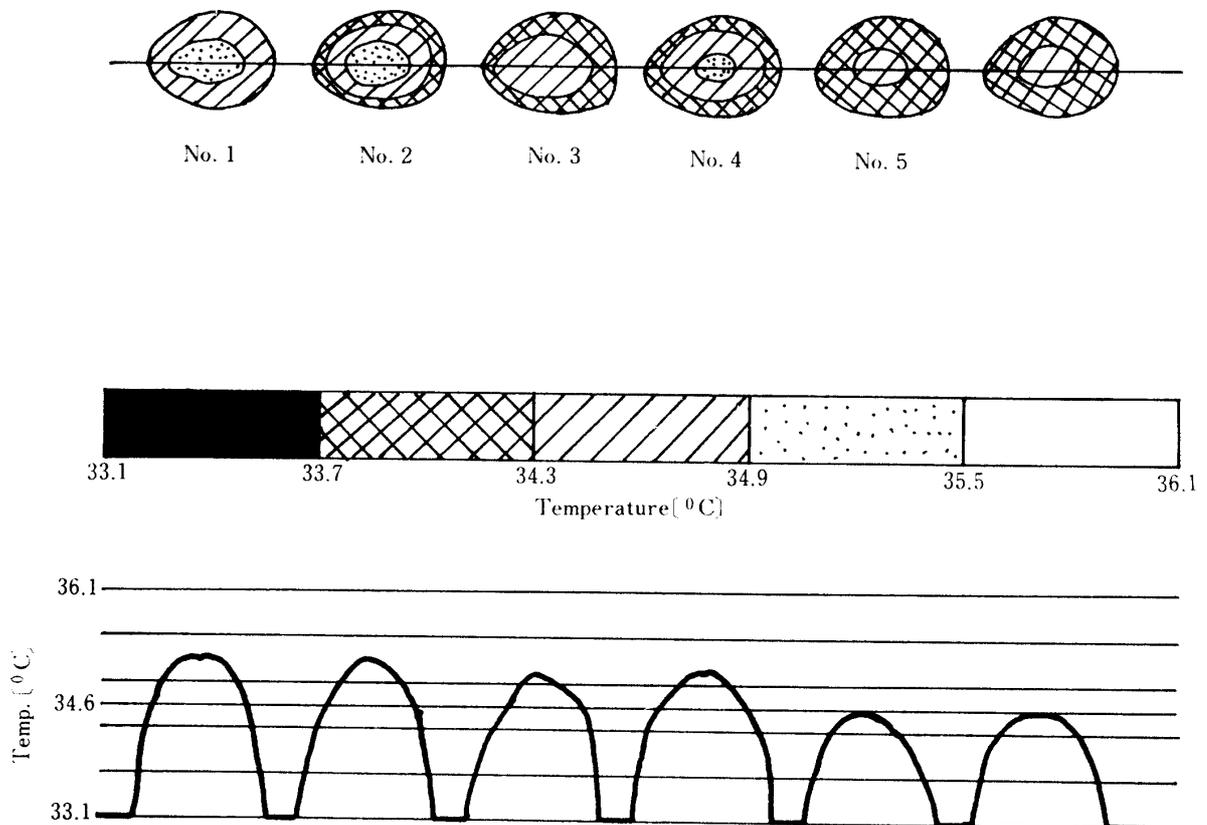


Fig. 5. Thermal images and temperature-curves of the eggs at the incubation period of 4 days old.
 Base temperature: 34.6°C.
 Measuring temperature range: 3.0°C.
 The time measured: 4 min 46 sec.

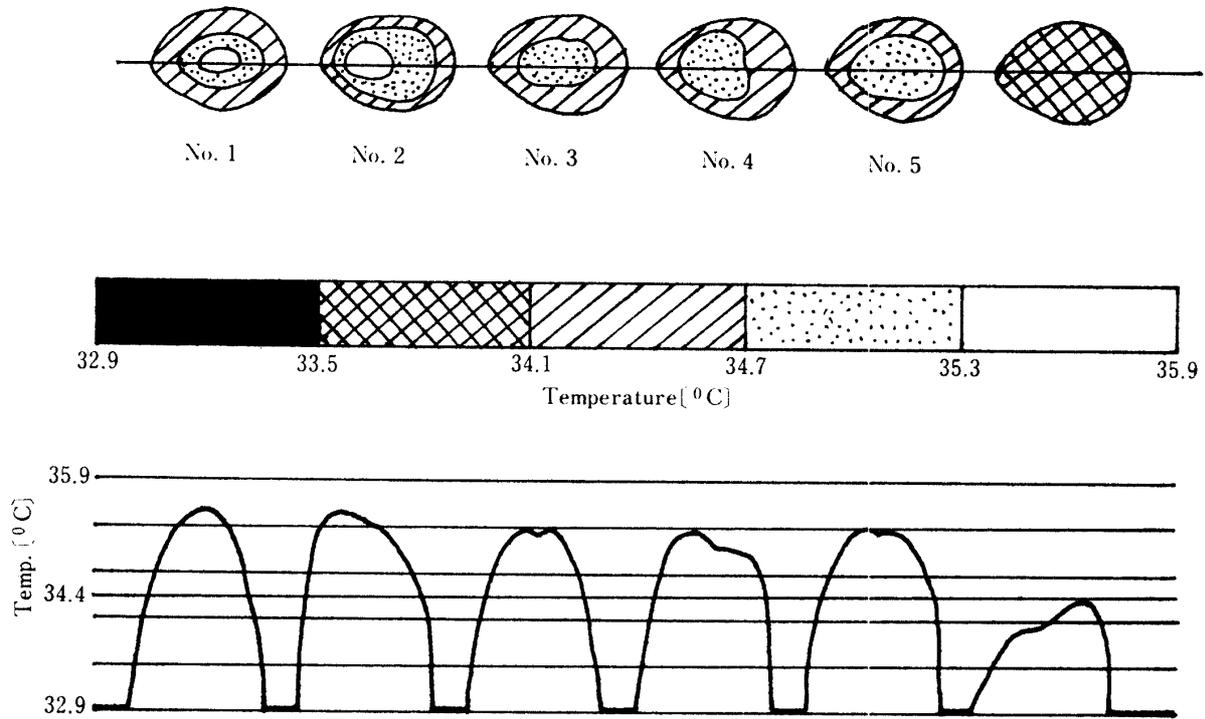


Fig. 6. Thermal images and temperature-curves of the eggs at the incubation period of 7 days old.
 Base temperature: 34.4°C.
 Measuring temperature range: 3.0°C.
 The time measured: 6 min 20 sec.

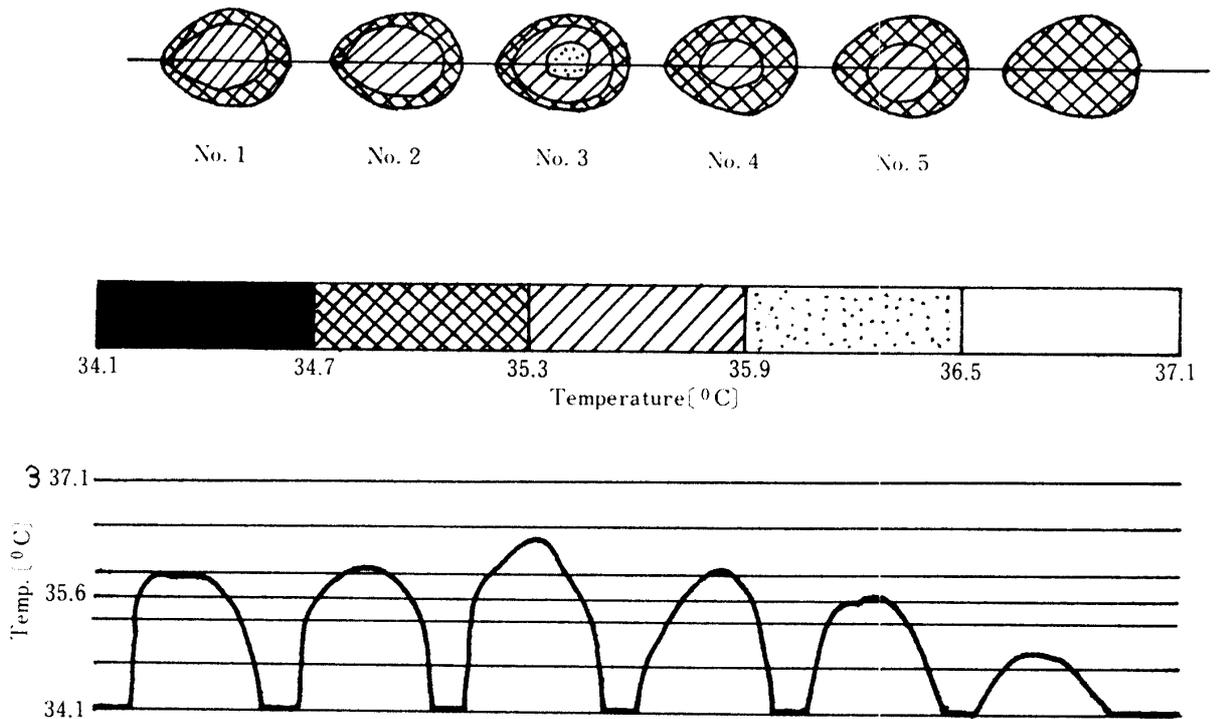


Fig. 7. Thermal images and temperature-curves of the eggs at the incubation period of 12 days old.
 Base temperature: 35.6°C.
 Measuring temperature range: 3.0°C.
 The time measured: 10 min 5 sec.

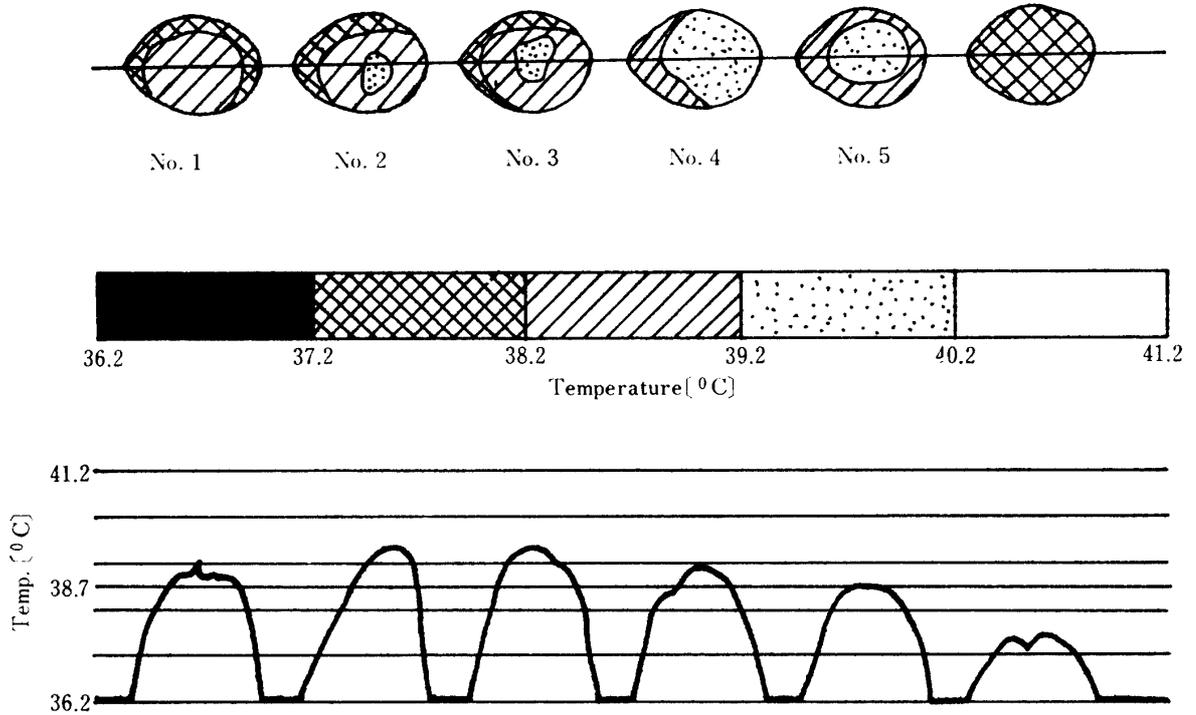


Fig. 8. Thermal images and temperature-curves of the eggs at the incubation period of 15 days old.
 Base temperature: 38.7°C.
 Measuring temperature range: 5.0°C.
 The time measured: 7 min 18 sec.

with the incubation period.

From these results, it is concluded that surface temperatures of the fertilized eggs, obtained by the thermal image and the temperature-curve, are definitely higher than those of the unfertilized eggs at the incubation period longer than 4 days old.

Fig. 9 shows a fine structure of the thermal image of the fertilized egg at the incubation

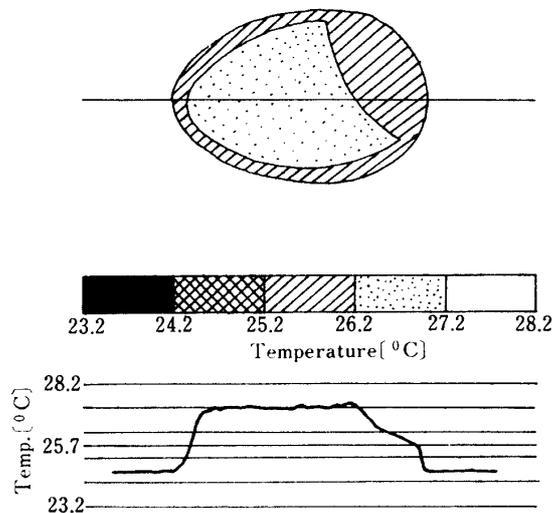


Fig. 9. Fine structure of thermal image of fertilized egg at the incubation period of 18 days old.
 Base temperature: 25.7°C.
 Measuring temperature range: 5.0°C.
 The time measured: 85 min 41 sec.

period of 18 days old. It was measured 85 min 41 sec after the removal of the egg from the incubator to the shielded box. Therefore, surface temperatures of the egg decreased gradually, but they were still higher than room temperature. As seen in Fig. 9, the surface temperature at the left side of the thermal image is about 27.3°C , and that at the right side is about 26.2°C . From the shape of the egg, it may be seen that the part at the left side is corresponding to the chick-embryo, and the part at the right side is corresponding to the air cell.

3. Comparison of Dead in Shell to Fertilized Egg

During the incubation, when a fertilized egg died accidentally, then a dead in shell was produced. In the present experiment, the dead in shell was added to hatching eggs, and changes in the thermal images of fertilized egg and that of the dead in shell were observed.

Fig. 10 shows the thermal images of the fertilized egg at the incubation period of 8 days old (at the left side), that of the dead in shell (at the center), and that of the unfertilized egg (at the right side), which were measured 15 min 41 sec after their removal from the incubator to the shielding box.

Surface temperature of the fertilized egg is estimated to be 36.9°C , that of the dead in shell 36.3°C , and that of the unfertilized egg 36.5°C , respectively.

While, Fig. 11 shows the thermal images of the fertilized egg at the incubation period of 11 days old (at the left side), that of the unfertilized egg (at the center), and that of the dead in shell (at the right side), which were measured 6 min 53 sec after their removal from the incubator. Surface temperature of the fertilized egg is estimated to be 40.0°C , that of the unfertilized egg 38.9°C , and that of the dead in shell 39.2°C , respectively.

From these results, it is observed that the surface temperature of the fertilized eggs is usually higher than that of the dead in shell, while temperature difference between the dead in shell and the unfertilized egg is not to be distinguished.

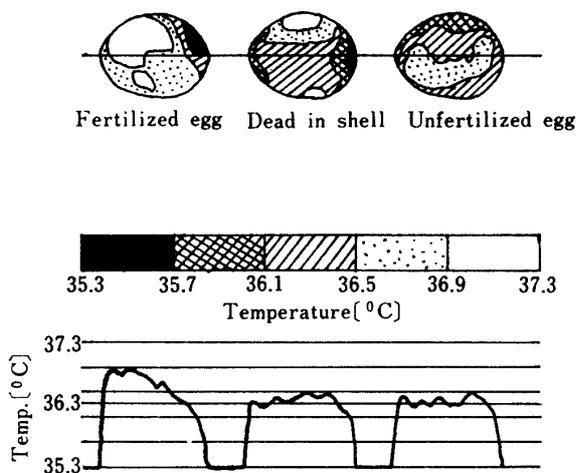


Fig. 10. Thermal images of fertilized egg (8 days old, left), dead in shell (center), and unfertilized egg (right).
Base temperature: 36.3°C .
Measuring temperature range: 2.0°C .
The time measured: 15 min 41 sec.

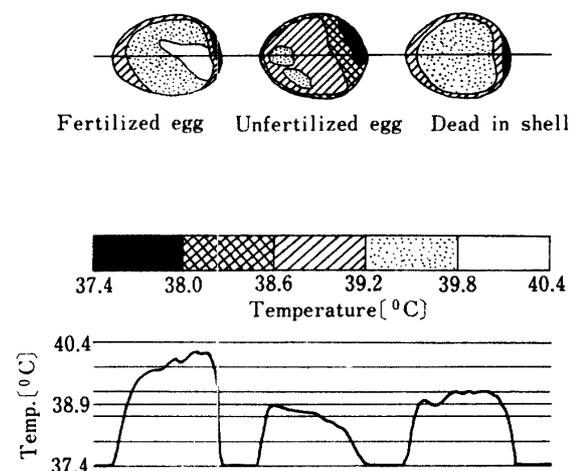


Fig. 11. Thermal images of fertilized egg (11 days old, left), unfertilized egg (center), and dead in shell (right).
Base temperature: 38.9°C .
Measuring temperature range: 3.0°C .
The time measured: 6 min 53 sed.

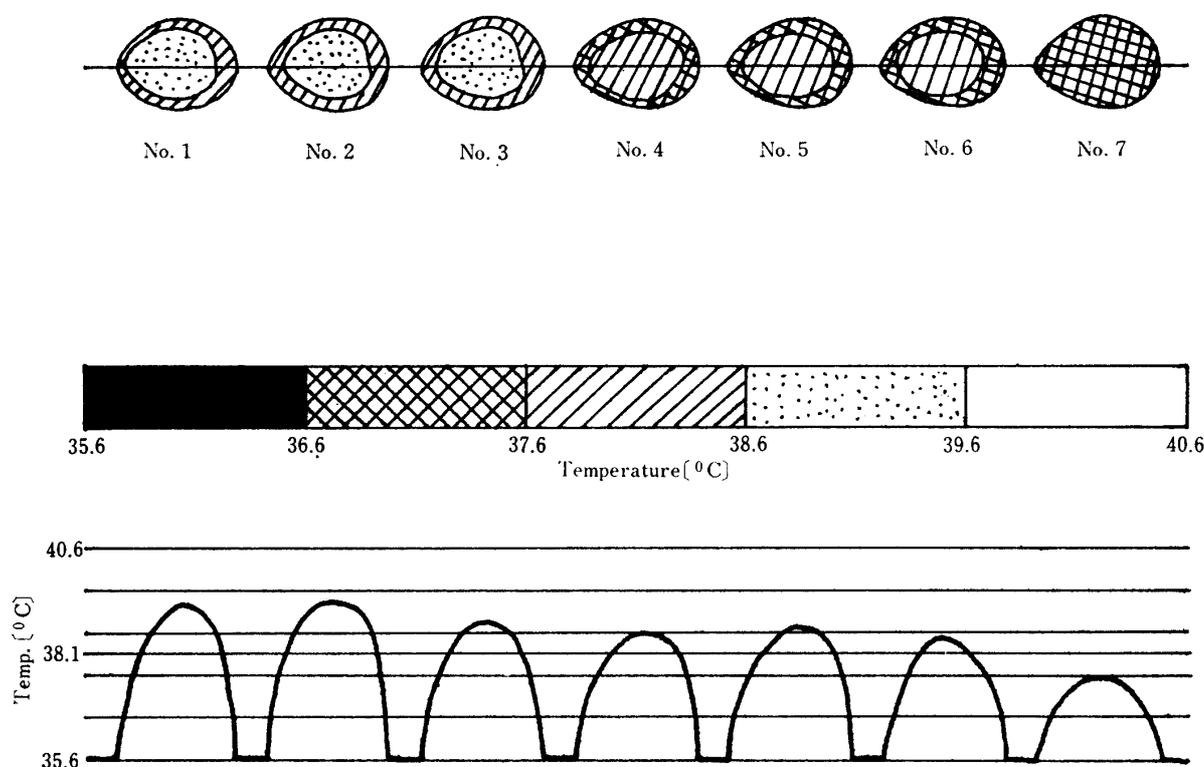


Fig. 12. Thermal images and temperature-curves of the eggs at the different incubation periods. No.1 (17 days old), No.2 (14 days old), No.3 (10 days old), No.4 (9 days old), No.5 (6 days old), No.6 (3 days old), and No.7 (unfertilized egg) are arranged in a line from the left to the right.

Base temperature: 38.1°C.

Measuring temperature range: 5.0°C.

The time measured: 8 min 30 sec.

4. Surface Temperature of Fertilized Eggs at Different Incubation Periods

During the incubation period of the chicken eggs, one egg from each group in the incubator was removed to the shielding box, and the thermal images of these eggs were measured at room temperature.

Fig. 12 shows typical thermal images and the temperature-curves of the eggs at the different incubation periods. In this figure, 6 fertilized eggs; No.1 (17 days old), No.2 (14 days old), No.3 (10 days old), No.4 (9 days old), No.5 (6 days old), No.6 (3 days old); and on unfertilized egg, No. 7, are arranged in a line from the left to the right.

Surface temperatures of these fertilized eggs at the different incubation period became gradually increased with the increasing, of the incubation period, while, that of the unfertilized egg indicated the minimum value. Since the temperature differences between the eggs at the different incubation periods were not so significant, the linear relationship between the surface temperatures of fertilized eggs and the incubation period was not always observed.

5. Time Dependency of Surface Temperature of Fertilized Eggs

The infrared measurements of fertilized eggs during the incubation period were made in the shielding box at room temperature immediately after their removal from the incubator. Since there was some temperature difference between the temperature in the incubator

and room temperature, surface temperatures of eggs varied from time to time. A series of measurements were made to elucidate the relationship between the surface temperature of eggs and the time measured.

Fig. 13 shows the changes in surface temperatures of the fertilized and unfertilized eggs, held at the incubation period of 4 days, as a function of the time measured. The surface temperatures of 5 fertilized eggs were measured at the same time, and the mean values of them were indicated in this figure.

The surface temperatures of the fertilized and unfertilized eggs became gradually decreased together with the time elapsed. As seen in Fig. 13, surface temperatures of fertilized eggs and that of the unfertilized egg decreased continuously in accordance with the time measured, and the temperature differences between them were not so obvious, being within the range of 0.3°C .

Figs. 14, 15 and 16 show changes in surface temperature of the fertilized and unfertilized eggs, held at the incubation periods of 7, 12 and 15 days, as a function of the time measured. As seen in these figures, surface temperatures of fertilized eggs and that of unfertilized egg decreased linearly in accordance with the time measured. Temperature differences between them were quite significant, being within the range of 0.4, 0.7 and 1.3°C , respectively. From these results, it is concluded that temperatures of fertilized

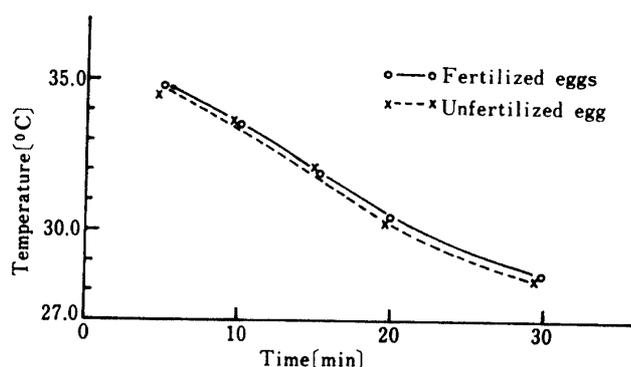


Fig. 13. Relationship between surface temperatures of fertilized and unfertilized eggs (4 days old) and the time measured.

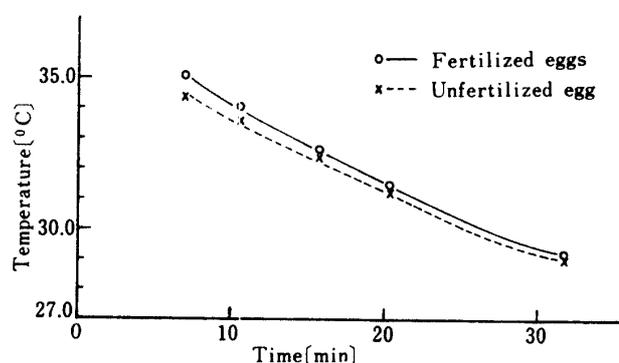


Fig. 14. Relationship between surface temperatures of fertilized and unfertilized eggs (7 days old) and the time measured.

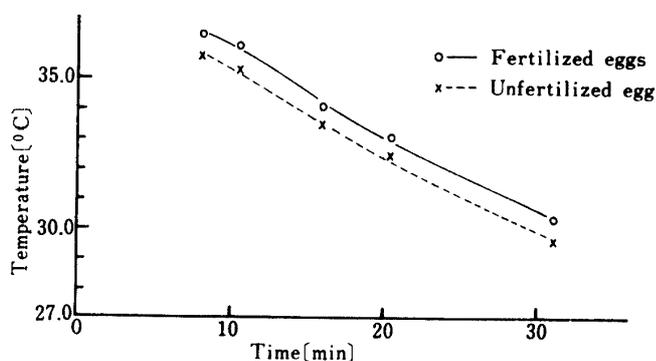


Fig. 15. Relationship between surface temperatures of fertilized and unfertilized eggs (12 days old) and the time measured.

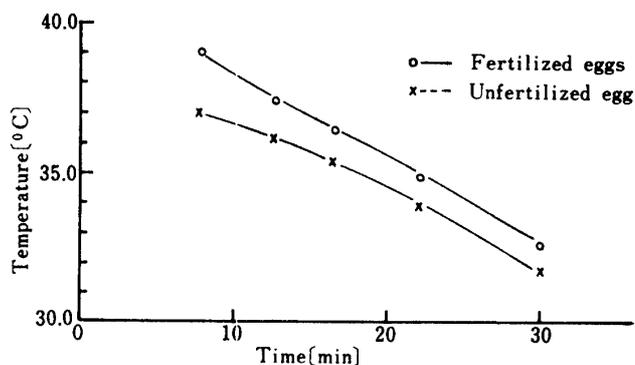


Fig. 16. Relationship between surface temperatures of fertilized and unfertilized eggs (15 days old) and the time measured.

eggs increase progressively in accordance with the incubation period, and temperature difference between fertilized and unfertilized egg become more significant.

Fig. 17 shows changes in surface temperatures of fertilized eggs at different incubation periods of 4, 7, 12, 15 and 18 days old, and that of unfertilized egg as a function of the time measured. It is observed that surface temperatures of fertilized eggs increase with the increasing of the incubation period, and that of unfertilized egg indicates the lowest value.

6. Direct Measurement of Surface Temperature of Hatching Egg

Surface temperatures of hatching eggs laid in the incubator were measured every day during the incubation by using the thermojunctions attached to the eggs. Fig. 18 shows the relationship between surface temperatures of fertilized eggs in the incubator and the incubation period. As seen in Fig. 18, surface temperatures of fertilized eggs increased progressively in accordance with the incubation period. On the other hand, surface temperature of the unfertilized egg was independent of the holding time in the incubator.

Fig. 19 shows changes in surface temperatures of fertilized eggs at the different incuba-

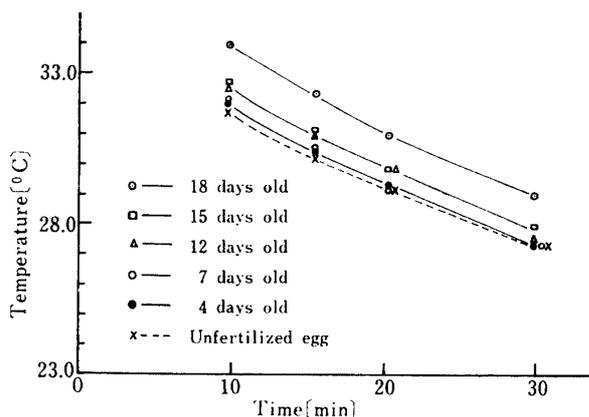


Fig. 17. Relationship between surface temperatures of fertilized egg at different incubation periods of 4, 7, 12, 15 and 18 days old and that of unfertilized egg.

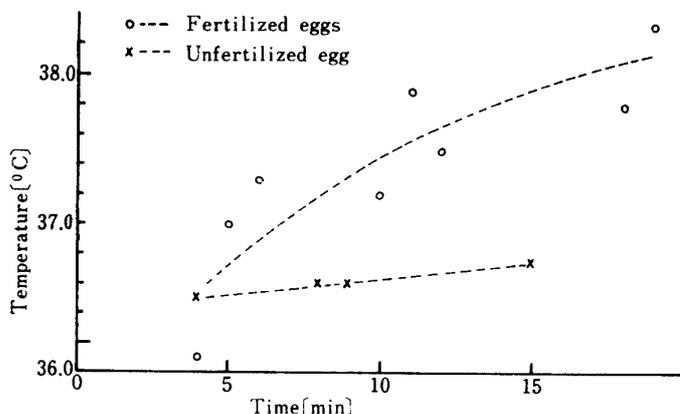


Fig. 18. Direct measurement of surface temperature of hatching eggs in the incubator by using thermojunctions.

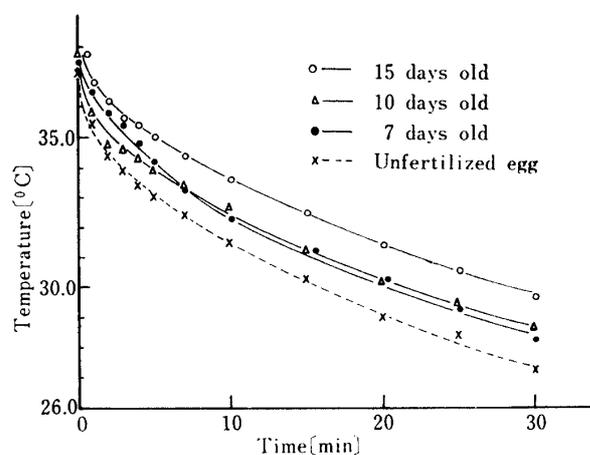


Fig. 19. Relationship between surface temperatures of fertilized eggs at different incubation periods of 7, 10 and 15 days old and the time measured.

tion periods of 7, 10 and 15 days old. These eggs were removed from the incubator to the shielding box, and measured at room temperature, as a function of the time measured. At the beginning of measurement, surface temperatures of the fertilized eggs decreased rapidly together with the time elapsed, and then began to decrease gradually.

The relationship obtained between the surface temperatures of fertilized eggs and the time measured is same as the one obtained in case of the infrared measurement, and the surface temperatures of fertilized eggs are noted to be always higher than those of unfertilized eggs. It is concluded that temperature of fertilized eggs during the incubation increases definitely in accordance with the incubation period, owing to the fact that various metabolic processes occurred in hatching generate certain amount of heat.

Conclusion

The infrared imaging method was investigated to discriminate the fertilized and unfertilized eggs during the incubation. Surface temperatures of hatching eggs were estimated from the thermal image and the temperature-curve. Surface temperature of the fertilized eggs was always slightly higher than that of the unfertilized egg. The same tendency was observed in case of the dead in shell. Changes in surface temperatures of the fertilized eggs, removed from the incubator to the shielding box, were measured at room temperature continuously with the time elapsed.

The experiments carried out on the discrimination of fertilized egg and unfertilized egg by the infrared imaging method show the following results.

- 1). Surface temperature of fertilized eggs is always slightly higher than that of unfertilized egg.
- 2). Temperature differences between surface temperature of fertilized egg and that of unfertilized egg are significant, and are within the range of 0.3 – 1.3°C, depending on the incubation period.
- 3). Discrimination of the fertilized and unfertilized eggs could be made effectively on the hatching eggs at the incubation period beyond 4 days old.
- 4). Discrimination of the fertilized egg and the dead in shell could also be made by this thermal imaging method.

Summary

An infrared imaging method was investigated for the purpose of examining the possibility of discriminating the fertilized and unfertilized eggs during the incubation period. By this method, surface temperature of hatching eggs could be measured without contact.

Fertilized eggs of broiler chicken (Arbor Acres) and unfertilized eggs of laying hen (Hy-line) were used in the present experiment. Surface temperatures of hatching eggs were estimated from the thermal image and the temperature-curve obtained by this method.

Surface temperatures of hatching eggs were always slightly higher than that of the unfertilized eggs. Temperature differences between them were quite significant, being more effective on the hatching eggs at the incubation period beyond 4 days.

Surface temperatures of hatching eggs in the incubator were measured directly by using thermojunctions. In both cases, the results obtained were the same.

Discrimination of the fertilized egg and the dead in shell was also investigated, and

the results similar to that in case of the unfertilized egg were obtained.

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