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Differentiated incubation of chicken eggs

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Abstract

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This article compares two modes for incubating eggs from Radonezh crossbred chickens: (1) in a stable incubation environment at 37.6°C in a setter and at 37.2°C in a hatcher (relative humidity 52% and 53%, respectively); (2) differentiated, with a sharp temperature increase (by almost 1°C) from the end of the second day to day four. In both cases, specific indicators were determined, such as water loss, embryo mass trajectories, healthy hatches, hatchability, the number of eggs failed to hatch, and the duration of embryogenesis. The research was performed on the Borovskaya Poultry Farm (Borovsky, Tyumen Region, Russian Federation), specialized in egg production, in 2016 /2018.

The research shows that differentiated incubation, unlike the incubation in a stable environment, improves hatch rates (by 4.6 to 5.0% on average) and hatchability (by 4.1 to 4.4%) through the reduced percentage of dead-in-shell embryos and blood rings. This incubation mode synchronizes the hatching by 23.7% and reduces the period of embryonic development by 6-8 hours. It was revealed that during incubation, experimental and control embryos had their heart rates decreasing with time. When this happens, experimental embryos demonstrate a heart rate 5-6 beats per minute higher compared to control ones incubated in a stable environment. At high temperatures, differentiated incubation entails increased water evaporation, followed by shifts in energy metabolism towards a more intensive use of lipids for the production of metabolic water and glucose synthesis.

Keywords: chicken egg; incubation; differentiated incubation; crossbreeding

Introduction

World science achievements in poultry breeding, convincingly, show that it's potential and actual productivity increases in recent years (Chu, 2019). The egg incubation is one of the main categories of modern poultry farming. Scientists consider that a certain temperature association, humidity and gas composition in the incubator are required, in order to create optimal conditions for the development of the embryo during artificial eggs incubating (Dyadichkina et al., 2003; Glavatskikh, 2005; Tzschentke & Janke, 2006). Temperature is one of the main factors of microclimate during incubation (Siviter et al., 2017). During the first stage of the incubation process, heat must be transferred from the air. Only after 10–11 days of incubation, the embryo has its temperature homeostasis formed, i.e. the ability to create constancy of the environment independently. Until that time, temperature change influences the embryo's speeding-up or slowing in growth, respectively (Dyadichkina, 1985; Glavatskikh, 2005). During the first three days of incubation, reactions associated with heat absorption occur, therefore, embryos during this period are especially sensitive to insufficient egg heating. At the same time, steps on the path of most intensive growth. During the first days of incubation, its mass increases more than 10 times (Rolnik, 1968; Pchulkin et al., 1985). Further, the absolute mass of the embryo increases and its growth rate decreases. Thus, the high efficiency of artificial incubation is achieved only with accurate mainte-

nance of a certain temperature in the incubator. In this case, the temperature, humidity, and air velocity should be constantly regulated to create the necessary temperature for the embryos. Some incubatorsuse the stable temperature regime (Otryganiev and Otryganyeva, 1989; Bessarabov, 2006), and others offer 2-4 step decrease of setter temperature during the incubation period (Tanraeva, 1988; Gvetadze, 2010).

Despite the improvement of conditions and incubation techniques, the hatching rate of highly-productive crossbreeding chickens did not increased (in some cases even decreased). Incubation failures make up approximately 20-25% of placed eggs. At the same time, during hatching by clucking hen, the brood is usually high and reaches 100% of fertile eggs, despite the natural incubation conditions. (Bilous, 1991). Rolnik (1968) indicates that even if transfer eggs from the incubator to the nest in the last three days of development it may reduce the number of dead embryos by 4.9%. Under the clucking hen, the number of dead embryos from the 19th to the 21st day of incubation is 6 times lower than in the incubator. During natural incubation, the eggs in the nest, constantly, overcome temperature changes. There are differences in temperature between the upper and lower surfaces of eggs, and such a temperature difference is 34–32°C on average (Tretyakov et al., 1990). Egg temperature depends on whether the egg is in the centre of the nest or beyond. Even from the first day of natural incubation, the hen regularly rolls the eggs – from the centre to the edge of the nest, where they cool down and vice versa. From the 1st up to the 11th day of incubation, on average, the hen moves the eggs 35 times a day, from the 12th up to the 21st day – 48 times. During pipping and before hatching, the hen almost continuously rolls the eggs in the nest. During incubation, the hen leaves the nest to eat. At the time the egg temperature depends on the hen absence duration and outside weather, decreases in cold and increases in warm weather. In general, the egg temperature decrease is approximately the same each time, 4–6°C. The temperature in the nest depends on day time. Thus, diurnal heat variations in egg reaches 3–4°C (in the morning from 4 to 8 and in the afternoon from 14 to 16 hours) (Rolnik, 1968). When hatching eggs in a nest with a hen, on the first day, they have a temperature of up to 38.5°C, and in the incubator the constant temperature is – 37.4°C; before hatching, the temperature is 40.4°C in egg and 41° C in incubator.

Thus, the research shows that periodic cooling of eggs and egg turning are an evolutionarily necessary mechanism for chicken hatching. The process of artificial incubation is premised on natural hatching. However, according to Tretyakov (1990), in the course of natural hatching there is almost no death of embryos from hyperthermia in the proceeding incubation period (even when the eggs are cooled during the absence of the hen). The author believes, that, obviously, the need in heat variations for embryos is a general biological regularity. It was also established that the natural hatching differs from artificial one by greater airflow, active evaporation, rating and rolling eggs from edge of a nest to the centre.

All above makes clear that the reserves of improving hatching rates are in their effective artificial incubation in combination with features of the natural eggs hatching. In this regard, this research made using non-stationary thermal conditions (Rud, 2004) and the development of a differentiated incubation of chicken eggs (Shcherbatov et al., 2012). This article highlights the results of a differentiated incubation used on the conditions of the Tyumen region poultry farm. RF.

Material and Methods

The selection and assessment of eggs quality for incubation were carried out on Radonezh crossbred chickens eggs under the Public Joint-Stock Company “Borovskaya Poultry Farm named after A. A. Sozonov” (Borovsky, Tyumen Region, Russian Federation), in 2016 /2018. Characteristics of eggs examined took into account following indicators: the large and small diameter of eggs, the shape and the mass index of eggs. The mass of yolk, albumen, and shell were measured after break opening. In total, 1,000 egg units were used in the experiment. The individual number was put on the sharp end of the egg with pencil. The experimental and control groups consisted of a random egg samples. Eggs were placed in Mossales incubators, 200 units per group, simultaneously. During the experiment, chicken eggs were incubated in stable environment with 37.6°C in an setter and 37.2°C in the hatcher, under relative humidity 52 and 53% (until piping), respectively. Experimental eggs were incubated under differentiated conditions, with a sharp temperature increase (by almost 1°C) from the end of the second day to day four (Table 1).

Table 1. Differentiated incubation

Incubation period	Temperature, °C	Relative air humidity,%
Under 45 hours	37.5 – 37.7	65
46 – 96	38.4 – 38.5	61
97 hours – 13 days	37.5 – 37.6	52
14 – 17 days	37.2 – 37.4 for 4 hours every day to set the temperature 38.4 – 38.5	52
		48
After 17 days and before hatching	37.1 – 37.2	53 before piping

During second period (14–17 days) the temperature was lower than that of the traditional incubation. However, during this period, once a day, the embryos were exposed to high temperature for 4 hours. In both cases, specific indicators were determined, such as water loss, embryo mass trajectories, healthy hatches, hatchability, the number of eggs failed to hatch, and the duration of embryogenesis.

Control eggs check-ups were carried out on the 7th, 11th and 19th days of incubation. Biological control was carried out by egg candling. These days, eggs were weighed and the initial weight lost was determined. Eggs were opened with live embryos inside for direct measurement and examination of the embryo and its membranes in order to verify the results of egg candling. For break opening, 5 egg units were taken from each group. The eggs were broke open on the 7th, 11th and 19th days of incubation.

The experiment included monitoring over the hatching process and measuring of blood biochemical profiles of day-old chickens. The research respond to: the period of egg pipping start, the increase in pipped egg mass, the time of the first hatch, the number of hatched chickens and the end of hatching.

The number of blood corpuscle was determined by Folch method using Gorjaev's chamber. Haemoglobin was measured using Sahli's hemoglobinometer. Total protein, urea, cholesterol, calcium and phosphorus in the serum were determined according to Raetsky et al. (1970), and the protein fraction – by Kamyshnikov (2000). Biometric data processing is carried out with Microsoft Excel.

Table 2. The results of eggs incubation at different temperature and humidity

Indicator	Control Group		Experimental Group	
	units	%	units	%
Placed eggs	200	100	200	100
Fertile eggs	193	96.5	194	97.0
Early embryonic mortality	3	1.5	5	2.5
Blood ring	6	3.0	2	1.0
Dead-in-shell embryos	9	4.5	5	2.5
Late dead	7	3.5	4	2.0
Incubation break ups	2	1.0	2	1.0
Hatches	166	83.0	131	88.3
Hatchability		85.8		89.9

Results and Discussions

Data on the results of differentiated incubation and incubation in stable environment are shown in Table 2. The received data indicate that temperature affects embryo development during critical periods and significantly increases hatch rates (by 5.0%) and hatchability (by 4.1%). Under differentiated incubation, the number of blood ring, dead-in-shell embryos and late dead are sharply reduced, by 1.6 – 2.7 times.

Egg water loss, after 18 days of incubation, is one of the evaluation criteria for the embryos hydro osmatic balance. Osmotic load has a significant impact on the physiological parameters of embryos, their growth rate, gas exchange the use of egg nutrients and, as a result, viability and hatch rates. These data indicate a significant difference in water loss between groups during incubation. Differences in water loss became obvious by day seven. During hatching in stable environment, the water loss on day 19 was 13.8%, which fits the standard for stable incubation. At the same time, the use of a differentiated temperature regime encouraged the intensive water loss. Herewith, by the time of hatching, the difference in water loss between groups amounts to a reliable 3.2% (Table 3).

The most intensive water loss was observed at the stage of closed allantois (11 days), when the embryos start to release warmth. The more intensively the embryos develop, the greater water loss. The mass of embryos in groups slightly differed. However, there was a tendency of mass growth during differentiated incubation that was slightly higher with the use of a differentiated incubation.

Heart rates were tracked throughout the incubation period at various stages of development, depending on the incubation mode used. According to records, heart rate tends

Table 3. Difference in water loss between incubation regimes

Group	Indicator	Egg mass before hatching, g M±m	Incubation period, days			
			7	11	14	18
Control	Egg mass, g M±m	58.84±0.6	56.63±1.2	55.58±0.7	53.64±0.4	50.74±1.1
	Water loss, g M±m		2.21±0.4	3.26±0.29*	5.20±0.23*	8.10±0.3*
	%		3.75	5.54	8.83	13.8
Experimental	Egg mass, g M±m	58.68±0.7	55.73±0.4	54.48±0.7	52.47±0.5	48.7±0.7
	Water loss, g M±m		2.95±0.3	4.20±0.2*	6.21±0.2*	9.98±0.2*
	%		5.0	7.16	10.58	17.00

Note: differences are significant at $P \leq 0.01$

to decrease with incubation time (Table 4). At the same time, heart pulsations in embryos were always higher in the experimental group. Moreover, the difference in heart pulsation was almost twofold higher to 18 days of incubation.

High heart rate increases the circulation rate with the usage of differentiated incubation. At the same time, the tissues and organs of the embryo receive more nutrients and oxygen per unit of time, which contributes to intensive growth and development.

Table 4. Embryo heart rate at different incubation

Group	Heart rate, BPM (M±m)				
	12 days	13 days	14 days	18 days	Day-old chicken
Control	263 ± 4.	255 ± 3.3	246 ± 3.2	225 ± 2.4*	197 ± 1.6*
Experimental	271 ± 4.3	263 ± 3.2	252 ± 2.9	242 ± 2.1*	203 ± 1.7*

Note: differences are significant at * P≤0.95

The use of differentiated incubation in the experimental group significantly changed synchronization of hatching. Under the differentiated regime, piping and hatching both began 6 hours earlier than under the stable incubation regime.

By the end of 21 days of incubation (504 hours), the hatch rate was 89.8%, which is 23.7% higher compared to incubation in a stable environment. Differentiated incubation allows synchronization of hatching time. Thus, between 487 and 502 hours of differentiated incubation number of eggs hatched was 57.1%, while with the traditional incubation it was only 35.1%.

According to data received, embryogenesis in the experimental group lasted 480.2 – 508.4 hours, in the control group – 486.8 – 515.1 hours. The hatching lasted 30 hours in both groups. However, the hatching in the experimental group started earlier and synchronized hatching time. The hatching peaks (at 502 hours) under differentiated and stable incubation coincide in time but under the differentiated incubation it was higher by 23.7% which indicates effectiveness. Hatching peaks coincided only once and wasn't observed further, which indicates biorhythmic dependence on temperature regimes of incubation.

Table 5 highlights biochemical blood profiles of day-old chickens, hatched under conditions of stable and differentiated incubation.

The groups did not differ in lactate dehydrogenase activity. Thus, glucose synthesis in embryos with different incubation regimes were of the same level, but the substrates for this synthesis were different.

The experimental group exceeded the control group by more than 2.5 times in terms of alkaline phosphatase. High alkaline phosphatase indicates on development of a glucose-alanine cycle with the release of glucose by dephosphorization, as well as a lack of energy necessary for the cells.

Table 5. Biochemical blood profile of day-old chickens at different incubation

Indicator	Unit of measure	Control Group	Experimental Group	Standard indicator	
				Min	Max
Crude protein	g/l	25.	30.7	43.0	60.0
Egg albumen	g/l	21.5	17.5	31.0	35.0
ALAT	u/l	20.8	29.6	–	–
HSNP	u/l	355.4	553.3	–	–
LDH	u/l	1743.5	1791.5	–	–
Amylase	u/l	1422.8	1411.6	–	–
AlkPhos	u/l	2146.9	833.5	–	–
Total bilirubin	mcmole/l	7.7	7.3	0.2	1.7
Direct bilirubin	mcmole/l	5.4	13.9	–	–
Cholesterol	mol/l	9.8	4.5	2.8	5.2
BUN	mol/l	2.6	1.9	2.3	3.7
Calcium	mol/l	2.4	2.5	2.0	3.0
Creatinine	mcmole/l	64.6	71.9	123.7	353.6
Phosphorus	mol/l	1.5	2.2	1.8	2.4
Ferric	MHV%	144.6	129.5	–	–
Magnesium	mol/l	0.3	0.4	0.8	1.2
Glucose	mol/l	11.5	9.8	4.4	7.8
Chloride	mol/l	74.2	72.6	–	–
Uric acid	mcmole/l	200.3	427.8	44.0	108

Therefore, in the experimental group the process of glucose synthesis is more intense, probably because of yolk lipoproteins that replace the energy loss of the cells. The level of glucose in the blood was of particular interest to us as the main energetic material necessary for cells respiration of the embryo. A standard value statement points to hypoglycaemia in both groups. At the same time, an elevated glucose in blood may indicate increased glycogen mobilization from the liver. Blood was taken in day-old chickens, that's way nutritional, stress, and other factors were not taken into account.

To our opinion, the high temperature led to an increase in water loss during incubation. This, in turn, shifted the energy metabolism towards more intensive use of lipids for the formation of metabolic water that supports the water homeostasis of the embryo. Thus, the glucose as an energy material is consumed less. That's way, the increase of glucose in experienced chickens' blood needed to be take into account.

After hatching, all chickens were put in a battery cage for further growth. The findings indicate that during all periods of incubation the mass of living chickens from the experimental group exceeded the mass of those hatched in stable environment. By the end of growth, the difference in weight was over the point of 5%. The average daily weight gaining corresponded to 55.1 g in the experimental group and 52.5 g in the control group. Thus, thermal effects of differentiated incubation used at the most sensitive periods in embryogenesis, make not only the period of embryonic development shorter, but also affect the growth rate of chickens after hatching.

Conclusion

The research shows that unlike the incubation in stable environment, differentiated incubation improves hatching rates (by of 4.6 – 5.0% on average) and hatchability (by 4.1 – 4.4%) through the reduced number of dead-in-shell embryos and blood ring in eggs. The differentiated incubation synchronizes the hatching rate by 23.7% and reduces the period of embryonic development by 6–8 hours. It was revealed that during incubation, experimental and control embryos had their heart rates decreasing with time. When this happens, experimental embryos demonstrate a heart rate 5-6 beats per minute higher compared to control ones incubated in a stable environment. At high temperatures, differentiated incubation entails increased water evaporation, followed by shifts in energy metabolism towards a more intensive use of lipids for the production of metabolic water and glucose synthesis.

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