Thickness and Thermal Gradients across Broiler Hatching Eggshells

The eggshell plays an important role in the development of a chicken embryo. It is a major respiratory component, and the chicken embryo gets approximately 80 percent of its skeletal calcium from the eggshell after 10 days of incubation. Eggshell thickness is one of several factors that influence heat transfer by conduction (Boleli et al., 2016).

Eggshell thickness reflects pore length in broiler hatching eggs, and an excessively thick shell may account for some early embryonic deaths (Peebles & Brake, 1985). This research also found that an abnormal distribution of pores over the eggshell surface may contribute to reduced hatchability and, more specifically, that optimum hatchability may depend on a proper pore concentration in each eggshell region (large end, equator, and small end).

Embryonic temperature determines the development and growth rate of domestic chicken embryos. Temperature must be optimized throughout the different stages of incubation to achieve maximum hatchability and peak chick quality. Researchers have shown that a developing embryo produces heat, often most significantly in the second half of the incubation period (Janke et al., 2004; Lourens et al., 2006). Assessing the internal temperature of an egg during incubation is important to determine the embryo's body temperature, its associated heat production, and its level of metabolic activity (Sotherland et al., 1987).

Eggshell temperature depends on three variables:
1. temperature of the surrounding air,
2. level of heat transfer between the egg and the surrounding environment, and
3. amount of heat produced by the embryo (Van Brecht et al., 2005).

Therefore, the internal egg temperature and eggshell surface temperature may be different. An implantable transponder in the air cell can reliably detect the core body temperature of broiler embryos from 14.5 to 18 days of incubation (Peebles et al., 2012). This method effectively detects actual body temperature by avoiding the confounding effects of eggshell thermal barrier properties and surface airflow.

Research has shown that genetic selection significantly alters the shell and the internal contents of eggs (Collins et al., 2014). Therefore, the first objective of this experiment was to determine air cell temperature, eggshell surface temperature at the equator, and eggshell surface temperature at the large end of modern-strain (Ross 708) commercial broiler hatching eggs (**Figure 1**). The second objective was to determine the possible relationship between large-end shell thickness and the temperature gradient between the interior and exterior of the shell at the equatorial and large-end regions of the egg (**Figure 2**).
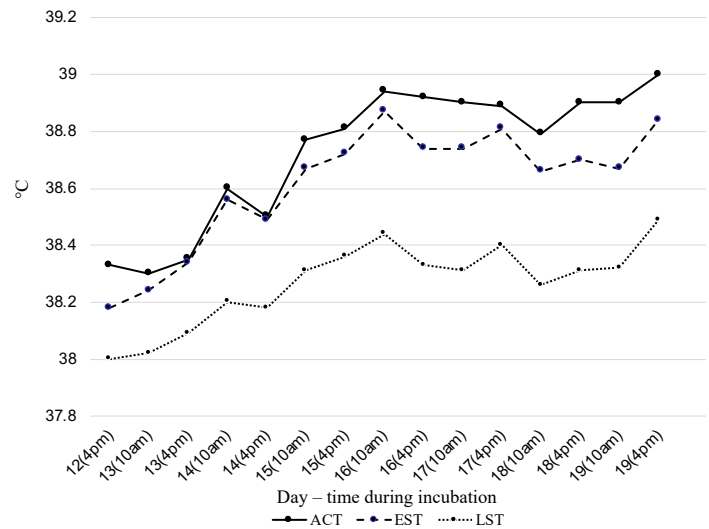

Figure 1. Mean air cell temperature(ACT) and equator (EST) and large-end (LST) eggshell temperature readings from 4 p.m. at 12 days of incubation through 4 p.m. at 19 days of incubation.
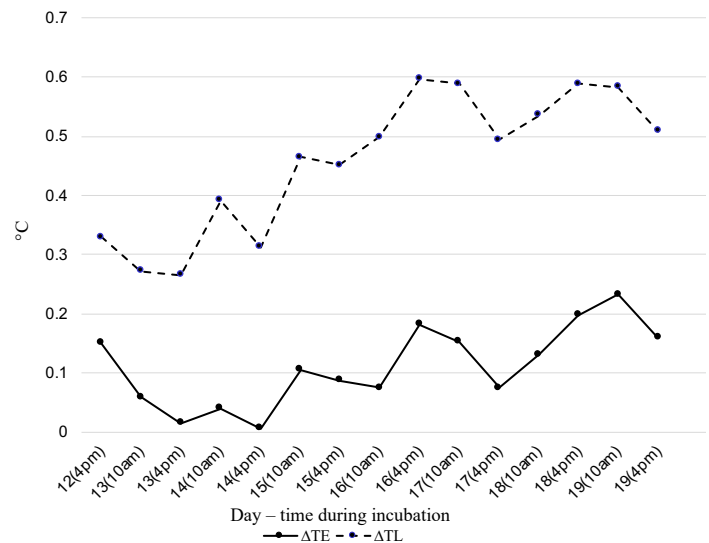

Figure 2. Mean temperature reading differences between the air cell and eggshell equator (ΔTE) and between the air cell and eggshell large end (ΔTL) from 4 p.m. at 12 days of incubation through 4 p.m. at 19 days of incubation.

Broiler hatching eggs were collected from a 36-week-old breeder flock; the 344 eggs used in the study were within 10 percent of the average weight of all eggs collected. Eggs were incubated at 99.5°F (37.5°C) dry bulb and 85°F (29.4°C) wet bulb. At 10 days of incubation, 80 eggs containing live embryos were selected, weighed, and placed on the outer edge of trays for easy access from

inside the incubator. These 80 experimental eggs were incubated with the other eggs to maintain an even air flow pattern over the eggs.

Percentage egg weight loss was measured at 0–10 days of incubation and 12–19 days of incubation. This weight loss in both time periods was calculated by subtracting egg weight at the end of each period from egg weight at the beginning of each period (procedure developed by Pulikanti et al., 2011). These differences were divided by set egg weight (at day 0), which was then multiplied by 100.

Implications

Air cell temperature readings using a transponder are more reliable and accurate in determining embryo core body temperature than measuring eggshell temperature with an infrared thermometer (Peebles et al., 2012). This is largely because the air cell temperature is unaffected by the thermal barrier properties of the eggshell and, particularly, the flow of air across its surface.

Results of the current study have shown that, during the 12–19 days of incubation interval, air cell temperature was higher than eggshell temperature at 13 of 15 time periods and that eggshell temperature at the equator was higher than large-end eggshell temperature at all 15 time periods. These relationships are in agreement with previous studies (Peebles et al., 2012), which also demonstrated that air cell temperature readings using a transponder were significantly higher than eggshell temperature readings using either a transponder or infrared thermometer, and that transponder and infrared eggshell temperature readings were similar and not significantly different.

This suggests that, because eggshell temperature at the equator is consistently higher than at the large end between 12 and 19 days of incubation, more metabolic heat is transferred to the shell surface at the equator than at the large end. In addition, the embryo is closer to the eggshell surface at the equator than at the large end, so heat transfer is lower at the large end. Further study is needed to better determine the role of equator and large-end eggshell thickness as thermal barriers in broiler hatching eggs.

Air cell transponders measure temperature accurately because they are placed near the developing embryo. Further study may improve the development and design of thermistor probes and determine optimal implantation timing.

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