The Egg Takes Control

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Introduction

Recent developments in incubator technology have resulted in a shift in the thinking of how turkey eggs should be incubated. The new technology allows the physiological response of the developing embryo to control the incubation process rather than just placing the egg in a predetermined environment that it is hoped will meet the needs of the embryo. Several factors have contributed to this change in how the incubation process is controlled, namely:

- The change by a significant number of turkey hatcheries from multi-stage to single-stage incubation.
- The development of new, cheaper and more reliable environmental sensors.
- A better understanding of the requirements of the turkey embryo.

The intention of this paper will be to discuss the likely benefits of these new technologies and how they can be applied to the incubation of turkey eggs now and in the future.

Incubating eggs at the correct temperature is the most important factor for successful incubation. The actual temperature experienced by the developing embryo is not the same as the incubator operating temperature and is determined by the incubator air temperature, the metabolic heat production of the embryo, the efficiency of heat transfer between egg and air (primarily determined by airflow) and the slight cooling effect of egg water loss (French, 1997). Direct measurement of embryo temperature is difficult in commercial situations, as it requires inserting a thermocouple inside the egg. However, the egg surface temperature has been shown to be a close approximation to the internal temperature, as the main barrier to heat loss from the egg is the air surrounding the egg (Sotherland et al, 1987).

While it was possible to measure egg surface temperature with traditional thermocouple technology, in practice this was difficult in a commercial incubator: it would require the attachment of thermocouples to the eggs with the potential catastrophic results if the probe became detached from the egg and the inherent practical problem of wires having to run through the eggs within an incubator. The development of infrared (IR) temperature measurement technology has made the measurement of the temperature of surfaces much easier as the sensor does not have to be in direct contact with the egg. The technology works by measuring the IR energy emitted by a surface, the greater the temperature of the surface the more IR energy it emits. While the basic concepts of IR temperature measurement have been around since the 1930's, it is only in recent years that improvements have become available to make the technology reliable and relatively inexpensive.

Figure 1: IR ear thermometer for egg surface temperature measurement

The first use of IR temperature measurement for monitoring incubation temperature was with medical handheld devices designed to measure ear temperature (Figure1). These devices were ideal for spot checks of egg surface temperature within incubators as they were relatively cheap, easily available from any pharmacy and designed to work with the range of normal incubation temperatures. The IR ear thermometer works well in machines where it is possible for the operator to work within the machine while it is operating. However, in most modern single-stage incubators it is only possible to check egg temperatures when the machine has stopped working.

More recently, incubators that utilise IR technology to continuously monitor egg surface temperature have become available. These systems monitor surface temperature of 12 eggs within each incubator and then use computer algorithms to check whether all the eggs being monitored are alive and giving consistent results with each other. Any egg temperatures that are significantly different from the other monitored eggs are rejected from the calculation of average egg temperature. This is necessary to ensure that infertile eggs or dead embryos that do not generate any metabolic heat do not affect the estimate of egg temperature. The measured egg surface temperature can then be used to control the incubator temperature so as to maintain a constant egg temperature.

The effect of using egg temperature to control incubator air temperatures is shown in Figure 2. In this incubator the egg temperature was maintained at 100ºF after day 7 of incubation and it resulted in the machine air (operating) temperature dropping to 97.7ºF by day 25 of incubation to compensate for the metabolic heat production of the eggs. By comparison, a normal turkey single-stage temperature programme (example also shown in Figure 2) would maintain an air temperature at the end of incubation of typically between 98.8 – 99.2ºF.

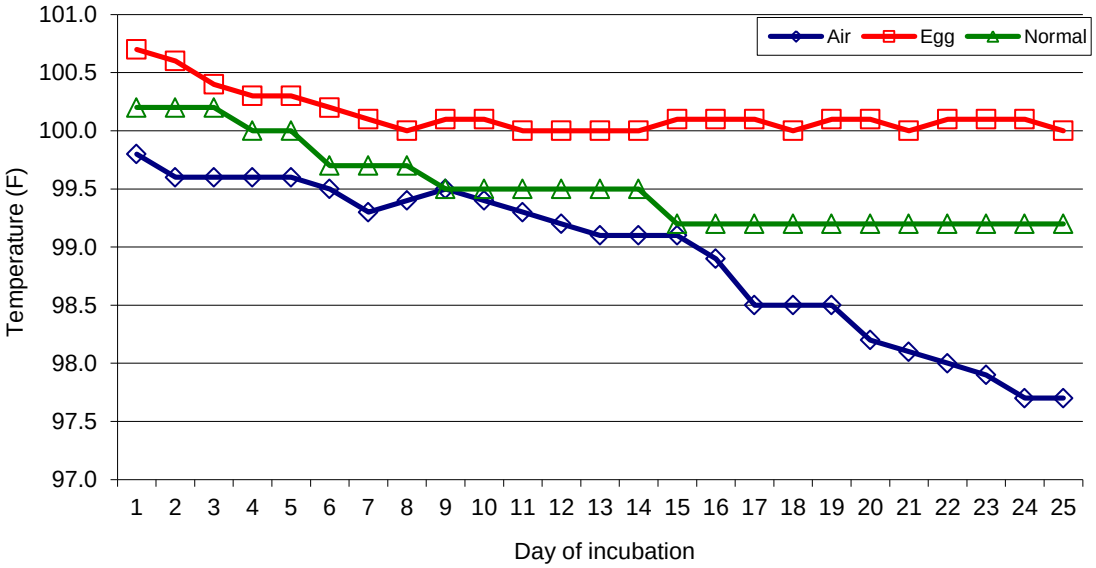

Figure 2: The effect of continuously controlling egg temperature at 100ºF on the incubator air temperature. A normal single-stage temperature profile is also shown for comparison.

The development of IR technology to control egg temperature raises an issue that now needs to be resolved, what is the ideal egg surface temperature for a turkey egg? All of the available scientific evidence has looked at the effect of incubator air temperature on hatch performance. In most of the trials using this technology, 100ºF has been chosen as the target egg surface temperature based on the experience with chicken eggs. In most, but not all, cases this has resulted in improved hatchability suggesting that the correct egg temperature is around this level. However, there is a lack of research data to indicate what is the correct eggshell temperature for a turkey egg and clearly more work is needed.

The humidity in an incubator is important as it controls the rate of water loss from the egg. Eggs lose water because they have a porous eggshell to allow the exchange of oxygen and carbon dioxide and that also allows water vapour to escape the egg. Eggs must lose some water so that there is a sufficiently large aircell that allows the embryo to inflate its lungs before it starts to hatch. However, the egg cannot lose too much water otherwise the embryo will become dehydrated and die. Typically, all bird eggs lose approximately 15% of their fresh egg weight up to the time of pipping and this weight loss is entirely due to the loss of water (Ar and Rahn, 1980). Studies on turkey eggs have shown the highest hatchability of can be achieved when the eggs lose between 10 – 12% of the fresh egg weight by day 25 of incubation (Meir *et al*, 1984; Meir & Ar, 1987; Hulet *et al*, 1987).

Checking the humidity settings of an incubator by weighing eggs has been a common practice in hatcheries for many years: it is possibly the first example of using the egg to control the incubation process. The process is relatively simple, requiring the manual weighing of trays of eggs before setting and at transfer. In most hatcheries it is not carried out as a routine but as an occasional check on humidity settings. If egg weight loss is too high, the humidity needs to increased and *vice versa*.

More recently, systems have been developed to continuously monitor egg weight loss within the incubator using load cells. These systems allow the humidity to be continuously adjusted so that egg weight loss can follow a specific course through the incubation period. Studies have shown that chicken and turkey eggs have better hatchability if they lose less water during the first half of incubation and more during the second half of incubation, still achieving the final weight loss target of 10 – 12% (Snyder & Birchard, 1982; Meir & Ar, 1987).

The continuous monitoring of egg weight loss does allow the incubator humidity to be matched to the properties of the eggshell so that the correct water loss is achieved for the average egg within the machine. Whether the hatch gains

from so closely following egg water loss are sufficient to justify the extra expense and complication of these systems remains to be seen. Studies that have matched incubator humidity to the shell porosity of individual eggs have shown hatch gains in the region of 2 – 3.5%, but the benefits of matching humidity to the average shell porosity of a large batch of eggs is likely to be much smaller (French, 2002).

The third requirement for successful incubation is the provision of oxygen and the removal of carbon dioxide from the incubator. The developing embryo needs to be able to breath and its requirement for oxygen increases as it grows through the incubation period. As a consequence there is an increasing requirement for fresh air to be brought into the incubator as incubation progresses to meet the oxygen requirement of the embryo. The production of carbon dioxide by the embryo matches the uptake of oxygen at a constant ratio and therefore measurement of either gas provides information about the other gas.

Practically, the measurement of carbon dioxide levels in an incubator is normally a simpler method for controlling ventilation rates than measuring oxygen levels. Many incubators are now available that are fitted with carbon dioxide sensors that can be then used to control ventilation levels. Early research (reviewed by Lundy, 1969) indicated that carbon dioxide levels above 2% reduced chick hatchability but there were differences depending on the age of the embryo. More recent studies have looked at the effect of lower carbon dioxide levels on turkey hatchability and have suggested that there may be benefits from increasing the level to 0.3% during the first half of incubation (Gildersleeve & Boeschen, 1983; Ernst *et al*, 2001). In chickens, carbon dioxide levels of 1.5% were shown to increase embryo and post hatch growth rate (De Smit *et al*, 2005).

In commercial trials, closing the ventilation completely during the first 12 days of incubation resulted in improved hatchability: in incubators that could be completely sealed carbon dioxide levels increased to 0.6 – 0.8% by the 12th day. However, it should be noted that other parameters of incubation such as elevated humidity and more uniform thermal environment resulted from closing the ventilation and therefore it cannot be certain that the gains were due to elevated carbon dioxide levels.

The current evidence available suggests that the carbon dioxide levels during the first half of incubation can raise to at least 0.8% without harming the hatch and may well be beneficial. Less evidence is available on the required carbon dioxide level during the second half of incubation, but it is during this stage that the embryo will have the maximum oxygen requirement. It is therefore logical that incubator carbon dioxide levels should be minimised during this phase, this will require more ventilation and therefore more oxygen will be available. In incubators that do not have carbon dioxide control systems, levels up to 0.7% have been recorded, but with carbon dioxide control it is possible to lower the carbon dioxide level to 0.3% throughout the second half of incubation. The hatch benefits of maintaining carbon dioxide levels below 0.3% are not known.

In addition to using carbon dioxide to control incubator ventilation levels, it has also been suggested that carbon dioxide levels can be used to control incubation temperature (Meijerhof, 2002). The hypothesis proposes that the optimum incubation temperature is that which results in maximum metabolic rate and therefore maximum carbon dioxide production. However, Janke *et al* (2002) showed that the metabolic rate of chicken and muscovy duck embryos increased in a linear fashion over the range of embryo temperatures 99.5 – 105ºF, the upper end of the range being higher than would be expected for good hatchability. This evidence would not suggest that maximum metabolic rate coincides with optimum incubation temperature.

In the future other physiological responses of the embryo may be used as a control mechanism for the incubation process. An example comes from recent Israeli research on the production of nitric oxide gas from chick embryos that has been shown to change when the embryo is stressed by low temperatures or altered respiratory gasses (Ar *et al*, 2000). These researchers are now testing whether it is practical to measure nitric oxide in commercial incubators.

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