Supplying what the embryo needs to successfully hatch

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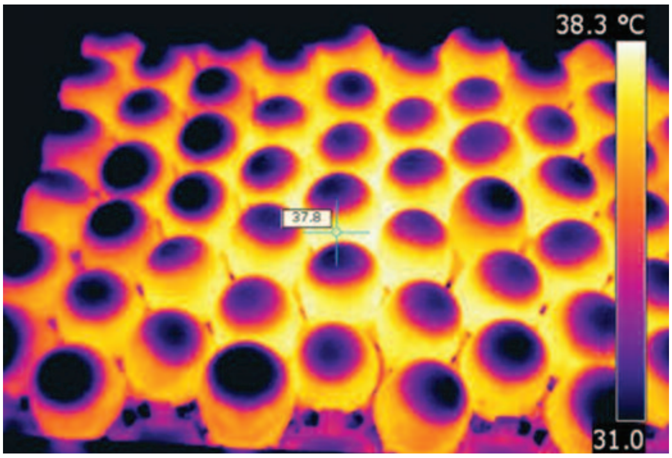
The requirements of the avian embryo to successfully hatch have long been understood: heat supplied either by the sitting bird or an artificial incubator, oxygen, and regular egg turning during the first half of incubation. In addition, the rate at which water is lost from the egg needs to be controlled by the humidity of the air surrounding the egg to ensure proper development of the air cell without dehydrating the embryo. The hatchery manager has known that to achieve good results, temperature, humidity, ventilation and turning within the incubator need to be carefully managed.



Thermal image of eggs on a setter tray. Note the cool air cell on the top of each egg (shown as black) and that eggs in the centre of the tray are hotter (whiter) than eggs at the edge of the tray.

Temperature

Of all the requirements for successful incubation, temperature is the most critical and small deviations from the optimum can have a major impact on hatching success and chick quality. Typically poultry species are incubated at 37.5 ± 0.5°C (99.5 ± 1°F) setter air temperatures, although the exact temperature will depend on the design of the machine and the type of egg.

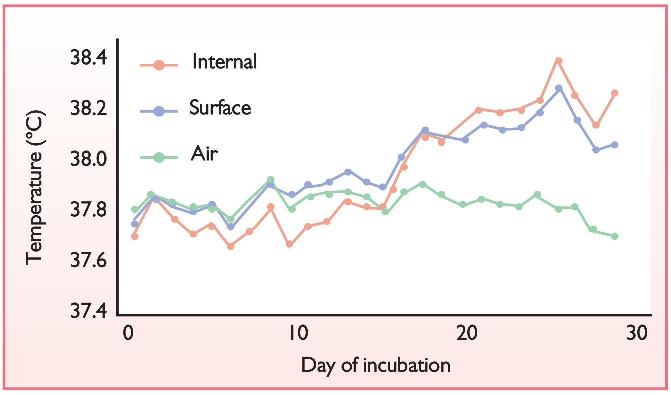
However, the incubation temperature is not temperature of the setter air but the temperature of the embryo inside the egg and they are not necessarily the same.

Fig. 1 shows the temperature recorded inside a turkey egg and the setter air temperature through the incubation process. The internal egg temperature during the first half of incubation is slightly cooler than the internal egg temperature and this is because of the small cooling effect of water being lost from the egg.

From approximately midway through incubation the growing embryo starts to generate more metabolic heat which causes the internal egg temperature to exceed the surrounding air temperature.

The degree of difference between egg and air temperature depends on how efficiently heat is transferred

Fig. 1. Incubator air, internal egg and shell surface temperatures of a turkey egg (French, 1997).



between egg and air and this is primarily dependent on air flow over the egg. The greater the airflow over the egg, the more efficiently heat will be transferred and the smaller the difference between egg and air temperature.

Other factors will also affect the difference between egg and air temperature. The amount of metabolic heat produced by the embryo has been found to vary between different genetic lines and between large and small eggs. The other eggs within the incubator will also be producing heat and this will also impact on the egg temperature.

In the picture above, from a thermal imaging camera, it can be seen that eggs in the centre of the tray are hotter than those at the edge of the tray.

Given that the egg temperature is affected by setter design and the type of egg, how is it possible to ensure that the correct embryo temperature is achieved and what should the optimum embryo temperature be?

Fig. 1 not only shows internal egg and air temperature, but also shell surface temperature. Shell temperature closely follows internal egg temperature and has been shown to be a useful tool for controlling incubation temperature and this can be done simply using infra-red technology such as the Braun ThermoScan Ear Thermometer.

Research is now focused on determining the optimum eggshell surface temperature to maximise hatch and post hatch performance.

For all types of eggs, maintaining a surface temperature within the range of 37.7-38.3°C (100-101°F) throughout the incubation period appears to give the best results.

Some researchers are suggesting that the temperature at the end of incubation can go higher during the transition from embryo to hatchling, but this has yet to be tested experimentally.

Humidity

Incubator humidity is important as it controls the rate that water is lost from the egg during incubation.

Eggs lose water because they have porous eggshells to allow oxygen in and carbon dioxide out. Indeed eggs need to lose water to allow the air cell to form in the egg: this space is needed by the embryo to allow it to inflate its lungs at the start of the hatching process. However, if the egg loses too much water then the embryo is at risk of dehydration.

The amount of water lost during incubation can be easily measured by weighing the egg. Eggs should lose on average 11-12% of their weight between setting and transfer (18 days in the chicken, 25 days in the turkey). If egg weight loss is greater than 12% then incubator humidity needs to be increased and if less than 11% then humidity needs to be decreased.

For most poultry species, it is only practical to control the average water loss for all the eggs within the incubator but for some high value species (for example ostrich) it is commercially viable to control the water loss of individual eggs.

It has been shown that better hatchability is achieved when eggs lose less water during the first half of incubation and more during the second half of incubation, still achieving the target of 11-12% at transfer.

A consequence of this is that single

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stage programmes use a high humidity for the first half of incubation and then subsequently a low humidity.

Oxygen and carbon dioxide

The embryo within the egg requires oxygen to survive and grow and to also lose the carbon dioxide generated by the metabolic process. As already noted, the eggshell is porous to allow the movement of respiratory gases in and out of the egg.

Typically over the whole incubation period a turkey egg will require 6.9l of oxygen and produce 5.0l of carbon dioxide.

The ventilation system of the setter is designed to supply oxygen and remove carbon dioxide and needs to be sufficient to meet the requirements of all the eggs within the machine.

In some setter designs the ventilation system has an additional function of removing heat from the setter and where this is the situation then the amount of ventilation is driven by the temperature control requirement rather than the oxygen supply requirement. Typically 10 times more air needs to be ventilated to remove heat from a setter if no other cooling system is used than to supply the oxygen requirement of the eggs.

Measuring eggshell temperature using a Braun Thermo-Scan ear thermometer.

The amount of oxygen required by the embryo during the first third of incubation is very small and it is normal practice in single-stage incubation to provide no ventilation in this period.

Keeping the ventilation closed in the early incubation period results in a more uniform temperature environment within the machine, a high humidity and an increased level of carbon dioxide and there is evidence that all three factors can benefit hatchability. When the ventilation is closed carbon dioxide levels can rise to 0.7-1.0%, although it is not yet clear if there is an optimal level during this stage.

In the last two thirds of incubation, the setter ventilation needs to be opened to provide oxygen and carbon dioxide levels will drop, typically to 0.3%.

As yet there is little evidence to suggest what would be the optimum carbon dioxide level at this stage.

During hatching elevated carbon dioxide levels have been shown to stimulate the pipping process.

Some hatchers with carbon dioxide sensors have used short periods of 2% carbon dioxide at the onset of pipping to stimulate all the chicks to hatch together.

Turning

Eggs need to be turned regularly during the first two thirds of the incubation period to grow and develop successfully. In most artificial incubators eggs are held vertically, pointed end down and then turned 45° from the vertical for one hour in one direction and then the next hour in the opposite direction.

Turning eggs less than 40° from the vertical has been shown to increase the incidence of early embryo mortality and malpositioned embryos. Some studies have also shown that turning the eggs four times per hour improves hatch, but this has not yet been tested in commercial incubators.

The potential problem of increasing the frequency of turning is the mechanical wear and tear on the turning mechanism.

Final thoughts

Recent research has shown that we can fine tune the incubation process to match the type of egg to the type of setter by monitoring the egg temperature and egg moisture loss.

Using these techniques has resulted in better and more uniform performance. More research is needed to define the optimum oxygen and carbon dioxide levels during incubation and this could lead to some further small improvements in performance.

While most hatcheries measure the success of incubation by the number hatched, it is becoming clear that the hatchery can also have a significant impact on subsequent performance on the farm.

Holding chicks in hatchers for too long after they have emerged from the shell has been shown to increase early chick mortality and slower early growth. Similarly, sub-optimal incubation conditions can adversely affect performance on the farm, particularly high incubation temperature. Today's hatchery needs to pay as much attention to subsequent farm performance as to hatchability, if they are to truly evaluate the needs of the embryo. ■