Calculating the water budget: a short introduction in physics…

By Ron Meijerhof

One of the aspects in our incubation process that creates a lot of discussion and questions is the actual relative humidity (RH) that we use in our machines. We used to work with a fixed RH level of about 55%, but recently we see more and more discussions and publications that suggest that this level is perhaps not that fixed as we used to think. In order to look at the influence of RH, it might be beneficial to go through some basic calculations. When people do these kind of calculations for the first time, it seems very complicated. However, getting a feel for these kind of calculations gives insight in what happens in our machines, and why c

Eggs need to lose a certain amount of water during incubation, to create a sufficient air cell for the embryo to get enough air for lung ventilation and escape from the shell. This amount should for a batch of egg be between 12 and 14 %, so on average about 0.6 to 0.7% per day. Experience has learned that this level is usually reached when we keep the relative humidity at approximately 55%.

We can calculate how much a machine has to spray to reach this target if we know the ventilation rate and the conditions of the incoming and outgoing air. Let's suppose we have a machine of 100.000 eggs, of 65 g average, and that we bring in 500 m3 air per hour of 24oC and 50% RH. Air of 24oC and 50% RH contains 9.3 g of water per m3, as we can find in the Mollier diagram. The air that leaves the machine is 37.5 and 55%, which means that each m3 of air holds 22.6 g of water. As we ventilate 500m3 per hour, this means that somewhere we have to put 22.6 – 9.3 = 13.3g x 500 m3 = 6.65 liter of water in the air, every hour. Our eggs are losing 0.6% of water per 24 hour, and as there are 100.000 eggs of 65 g, the total egg mass contributes 100.000 x 0.065 x 0,6% = 39 liter of water per 24 hour, or 1.63 liter per hour. As we need to add 6.65 liter per hour, the machine has to add 6.65 – 1.63 = approx. 5 liter of water per hour.

A change in either amount of ventilation, set RH level in the machine or conditions of the incoming air will change the amount of spraying in the machine. If we for instance set the machine on 37.5oC and 45% RH, the amount of water in the air is 18,4 g per m3 instead of 22.6 g, and we only have to add 18,4 – 9,3 = 9,1 x 500m3 = 4,55 liter. With 1.63 liter per hour coming from the eggs, we have to add 4.55 -1.63 = approx. 3 liter, instead of the 5 liter we were spraying before.

But an important effect of spraying water is cooling. Every gram of water that is sprayed in the machine needs to be evaporated, and evaporation of water requires 2.26 kJ per gram. But what does this mean for the temperature of our eggs, as they are the warm bodies in the machine that will supply the energy for evaporation? The developing embryo in our incubation process produces heat, about 0,16 W per egg at 18 days. If we have 100.000 fertile eggs in a machine, the total heat production in a machine at day 18 is approximately 16 kW, which will result in a rise in temperature of the eggs. How much this temperature will rise depends on how effectively we can remove this heat. But if we spray 5 liter of water per hour or 1.4 g of water per second, we remove 2.26 kJ x 1.4 g = 3200 joule per second. As 1 watt equals 1 joule per second, we take away 3.2 kW from the total of 16KW which is produced by the 100.000 embryos.

But what does this mean for our temperature? Eggs have a so called specific heat of approx. 3400 J/kg/oC. This means that if 3.4 kW (3400 J/s) is removed from 1 kg of eggs, the resulting temperature of the eggs will be 1oC lower than without this heat loss. As in our example we remove 3.2kW by spraying, the cooling effect for the eggs is almost 1oC.

In most situations the cooling effect of the sprayer will be in balance with the cooling coils in the machine. If the sprayers work less and therefore cool less, the cooling coils will work harder and remove more heat out of the machines. However, in situations where the cooling capacity of the machines is limited, a reduction of the cooling effect of the sprayer cannot be compensated completely by the cooling coils.

These calculations show that there is a significant effect of the sprayer on the temperature of the eggs. It also shows that in machines with limited cooling capacity, variation in spraying will result in variation in temperature of the eggs. As the amount of water spray is a function of the conditions and the amount of the incoming air and the settings of the machine, it is clear that a hatchery requires a constant and well controlled condition of the air entering the machines, to avoid temperature fluctuations of the eggs.