

The secrets of carbon dioxide, humidity and finally temperature

By Ron Meijerhof

During incubation the embryo, as any living organism, needs oxygen and produces carbon dioxide, metabolic water and metabolic heat. Besides that, the eggs need to be turned and a specific temperature needs to be maintained inside the egg, to allow an optimal developmental process of the embryo. If we take a look on how an incubator operates, this is exactly what the machine is doing.

Most machines have heaters, either electric or with warm water, and cooling coils with cold water. We set the machines on a certain set point for temperature and relative humidity. If the temperature is too low, the heater comes in. If the set temperature is exceeded because of the heat production of the embryo, the machine starts to send more cold water to the cooling coils, taking out more heat.

If the relative humidity is getting above the set point, dampers are opened and the machine starts ventilating more. If the relative humidity is too low, the sprayer comes in, increasing the relative humidity.

The function of ventilation

Machines need to ventilate to allow enough oxygen to come in and to allow the produced carbon dioxide and evaporated water to escape. Besides that, often machines also depend partly for their cooling capacity on ventilation. Exchanging warm air for colder air will have a cooling effect, which means that the metabolic heat of the embryo is partly removed by the cooling coils and partly by the exchanging air.

Most machines do not have enough cooling capacity to be totally independent of exchanging air. If we do the calculation on the ventilation demand of a machine of 100.000 eggs, simply looking at the demand of the oxygen and release of carbon dioxide by the embryos, it will be not more then 250 m³/hr for a single stage machine at day 18 of incubation and approximately 100-150 m³/hr for a multi stage machine. Many machines will actually ventilate more, simply because the temperature is exceeded and the machine asks for extra cooling.

However, let's take as a starting point a single stage machine of 100.000 eggs that ventilates 250 m³/hr.

Cooling by evaporation.

If we have to humidify the air in the machine because the relative humidity is too low, we spray water in the air. This water needs to be evaporated, and that takes a rather high amount of energy. As this energy is provided mainly by the eggs in the machine, it will have a cooling effect on the eggs. The problem with this evaporation is that it happens rather locally. The eggs that are close to the ventilator and sprayer get all the water and will be cooled a lot. Eggs that are far away from that sprayer will not have to provide energy to evaporate it, and will therefore not be cooled. This means that high amounts of spraying often lead to non-uniform temperatures of eggs. Eggs close to the sprayer get cold, eggs far away will stay warm. If water rolls are used instead of sprayers, the effect is less dramatic but will still occur.

Ventilation and humidity

What we have to realise is that if we start ventilating, we often start to humidify as well, because we bring in relatively dry air. Air of 37.5°C and 55% humidity holds approximately 22 g of water per m³. If the amount of water in the incoming air, combined with the water evaporated from the eggs in the machine is less then 22 g/m³, the machine will start spraying.

We try to lose approximately 12-14% of water during incubation. This means roughly 0.6-0.7% per day, or 0.025-0.03% per hour. If we have 100.000 eggs of 60 g each in the machine, the total egg amount will be 6000 kg. These eggs will loose 1.5-1.8 kg of water per hour. If we ventilate the machine with 250 m³/hr, the eggs will add 6-7 g of water to every m³ of air. If we only ventilate with 125 m³/hr, the eggs will add 12-14 g, if the machine ventilates 500 m³/hr, the eggs will add 3-3.5 g/m³.

If the machines needs 22 grams of moisture per m³ of air and the eggs add 6-7 g, then the incoming needs to hold 15-16 g of moisture to avoid the sprayer coming in. Air of 28°C and 65% R.H. contains approximately 16 g of water/m³, so if we bring that in the machine, the sprayer will not come in.

If we bring in the same air while the machine ventilates 500 m³/hr, the sprayer have to add 3 grams of water to each m³ of air, which means spraying 1.5 litre per hr.

If the machine ventilates less, the humidity in the machine will go up too much, and the dampers open, or the eggs do not loose enough moisture (egg weight).

As spraying means evaporative cooling, the amount of air ventilated and the temperature and relative humidity of the air used will have quite some impact on the cooling of the machine, directly by the temperature of the air but also indirectly by the amount of spraying that the machine will do as a result.

Ventilation by carbon dioxide

Nowadays, many machines are ventilated based on carbon dioxide levels. The carbon dioxide level in the machine is set at a certain amount, for instance at 4000 ppm (outside air contains about 300-350 ppm) and when the level in the machine gets higher, the dampers open and the machine starts to ventilate.

Although it is still not totally clear what the effect of either high or low carbon dioxide is on the development of the embryo, we can at least estimate what happens with the temperature and humidity.

Ventilation of the machine will force the carbon dioxide level down, as the air in the machine will be replaced with air only containing 300 ppm carbon-dioxide. If we ventilate based on a high level of carbon dioxide, we close the machine more, if we set our ventilation on a low level of carbon dioxide we open up the dampers more.

If we look at the influence that ventilation has on spraying (previous paragraph), it means that a high level of carbon dioxide automatically leads to a low spraying in the machine. Low levels of carbon dioxide requires more ventilation, more relative dry air coming in and less moisture of the eggs per m³ of air, and the sprayer will come in more.

The only way to avoid this, to keep the amount of spraying constant in the machines, is to bring in more moisture in the air that enters the machine if we ventilate more. That would mean that we have to adjust the moisture amount of the air in the setter room if we change the carbon dioxide requirements in the machine.

As this is not practically feasible, we have to accept and realise that the level of carbon dioxide that we use as set point in our machines will influence the amount of spraying in the machine.

Embryo vs eggs

One other thing we have to realise is that the source of carbon dioxide and of evaporated water from the eggs is not equal, although both come from the eggs in the machine.

All eggs in the machine evaporate water, regardless if they are fertile or not. However, only the living embryos in the machine produce carbon dioxide.

This means that if we ventilate on carbon dioxide, we have to take the fertility into account as well, or we will mess up the humidity and consequently the temperature.

If our fertility is low, we have a low level of carbon dioxide production, and to reach the same level of carbon dioxide in the machine, we have to close up the machine more. This means that the relative humidity in the machine will go up, and the sprayer will come in less. If we put the limits on ventilation for humidity rather high in the machine, we might find that the eggs did not lose enough water at the end of incubation, because the dampers didn't open enough to get rid of the metabolic water.

If the fertility is high, there is a high level of carbon dioxide in the machine, the dampers will open, take in more fresh, cold, dry air and the machine will start spraying water.

What do we do in the field

As ventilating on carbon dioxide can have an influence on the humidity, the amount of spraying and therefore on the temperature distribution of the eggs, we have to be careful with simply putting a standard carbon dioxide level for ventilation. We have to realise that the level of fertility by itself already has an influence on it.

We have to make sure that our carbon dioxide level does not influence our temperature distribution and our moisture loss, so we have to check if the sprayer comes in more or less in the way we expect, if the temperature distribution of the eggs is within our limits of expectation and if the eggs have lost enough moisture loss at the end of incubation.

If we foresee that the moisture loss is not adequate (minimum should be 10%), we have to allow a lower carbon dioxide level to force the machine to open the dampers and remove the water. If the dampers are opening too much and the machine sprays more than we want, we might choose for a higher level of carbon dioxide level, or a higher amount of moisture in the incoming air.

As we don't fully understand the dangers of high carbon dioxide levels on the embryo, the last one might be a better option.

We have talked mainly about single stage machines, as we can influence our settings there. If we work with multi stage machines, our choices are much more limited, but we still have to consider these things.