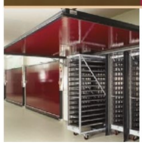

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Principles of moisture loss during incubation

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Why is water loss needed

During the development of the embryo, metabolic water is produced. This metabolic water is approximately 12-14 % of the initial egg mass. A minimum amount of approximately 9-10% of this water needs to be lost to create a sufficient air cell for the embryo to breath after internal pipping. If the total amount of moisture loss is more than approximately 17-18%, the embryo has a risk of getting dehydrated and stick to the shell membranes.

Eggs that do not contain an embryo do not produce metabolic water, but lose moisture at the same rate as fertile eggs. The presence of an embryo does not influence the moisture loss, as this is determined by relative humidity, temperature and shell conductance.

How do we determine water loss?

Next to water vapour, also oxygen and carbon dioxide are exchanged over the egg shell. However, the rate between oxygen and carbon dioxide is in such balance that there is no overall change in weight due to that, so all the weight loss comes from water loss. This means that we can determine water loss by simply weighing the eggs at two different moments and calculating the percentage difference. Expressed per time unit this gives us the water loss per day or water loss per 18 days. Weighing a total of 5 trays per machine is enough to determine moisture loss accurate. There is no need to weigh the eggs or the trays individually. A common mistake made with determining the moisture loss is that the tray is not subtracted from the total weight.

How is water lost?

The amount of water that is lost is controlled by the difference in water vapour pressure (the difference in “driving force”) over the egg shell and the conductance (the “openness” or in case of a low conductance the “resistance”) of the egg shell and its membranes. There is no other factor involved. So if we know the conductance of the egg shell and we know the water vapour pressure in the egg and in the surrounding of the egg, we can (with a basic knowledge of physics) predict or calculate the moisture loss per time unit very accurate.

Water vapour pressure is a function of temperature and relative humidity. If we increase temperature of the air surrounding the egg, this air can hold more moisture. In that case the “driving force” for the air to expel water to the air will go up and the egg will lose more water. If we decrease relative humidity (make the air more dry), there is also more “space” in the air to hold moisture, and we can again imagine that the driving force for water loss from the egg towards the air will go up as well.

The amount of moisture in the air is not only important for moisture loss but also for heat transfer. The more moisture the air contains, the more heat it can contain as well, making it easier for the eggs to loose or gain (“transfer”) heat.

- Water vapour pressure inside and outside the egg
    - Inside the egg there is water with a little bit of minerals, so there we only have to deal with temperature as the relative moisture is almost 100% and constant. If the temperature inside the egg goes up, there is a higher water vapour pressure and the egg will “push” more water out and moisture loss will be increased, even if outside conditions don’t change.
    - Outside the egg the situation is a bit more complex. The driving force is created by the amount of moisture that can be stored in a volume of air. The more there can be stored, the more moisture will try to move to that dry area. We normally calculate with relative humidity, which is the ratio between the amount of water in the air and the amount that could be in the air at that temperature. This indicates that temperature is an important factor, because the warmer air is, the more moisture can be stored in that air. If we warm up air, relative humidity will go down, and moisture loss will go up.
- Shell conductance
    - The shell has pores, which allows gases to pass through. Oxygen goes in, and carbon dioxide and water vapour goes out. The permeability of the shell (resulting in the rate of gas exchange) is determined by the number and size of the pores and the thickness of the shell and is named “conductance”. The higher the conductance, the more open the shell is and the more gases will pass through per unit of time.
    - Normally older flocks produce shells with higher conductance (more permeable, more “open”) because the calcium metabolism in a bird reduces over time (thinner shells) and because a bird produces more or less the same amount of grams of egg shell over time, so with bigger eggs (older age flocks) the same amount of shell mass is spread out more and therefore less thick.
    - Genetic selection in especially layer breeds focuses on shell strength. This is related with conductance, as selection on more tight shells also reduces conductance. This is why eggs of layer birds normally have more problems in reaching the desired level of moisture loss. Different broiler lines have differences in conductance as well, and usually a darker egg shell has less conductance.

Influences on moisture loss

- Moisture loss during storage

  People often want to limit the amount of moisture loss in storage, to avoid dehydration, but especially to avoid eggs becoming too light and therefore not being classified as hatching egg anymore.

  For the incubation process moisture loss of eggs during storage is of minor influence. Normally the moisture loss in storage is less than 1% for the total storage period, and hardly influences the required total of 12-14% in incubation, as you can add up the two moisture losses (storage and incubation). As normally in single stage incubation moisture loss in incubation is limited anyway, a slight increase of moisture loss during storage does not work negative. Preventing moisture loss often works more negative, as increasing the relative humidity during storage can result in wet eggs and bacterial contamination.

- Embryonic development

  Moisture loss is determined by shell conductance (which is constant for an egg over the incubation period) and water vapour pressure deficit. If temperature and relative humidity in a machine is constant during incubation, than moisture loss is expected to be constant too. Theoretically this is not completely true, because the embryo temperature increases and therefore the water vapour pressure inside the egg increases and moisture loss over time slightly increases. However, this is so marginal and partly compensated by the drop in temperature profile in single stage incubation, that we can assume moisture loss to be linear. This means that if we know the moisture loss (weight loss) at for instance 7 days of incubation, we can predict the moisture loss at 18 days.

- Pattern of moisture loss

  It has long been believed that moisture loss needed to be constant over time, so every day equal to keep the water balance in the egg constant. Since about 15 years it has been accepted that this is not necessary, as long as total moisture loss is achieved at the moment of internal pipping. We use this by increasing the moisture in the air in the start of incubation, thereby making it easier for the eggs to pick up heat. As we then “loose” some days of average moisture loss, we have to increase the moisture loss by lowering the humidity in the rest of the incubation period to ensure the total moisture loss is high enough.

- Air velocity

  Air velocity has <u>no</u> direct influence on moisture loss. Many people think that a high air velocity will increase the moisture loss (similar of the “drying” effect of wind on wet laundry), but the resistance of the water going through the shell is limiting, not the speed at which water is removed from the shell surface. Some researchers has reported a small influence of air velocity, but that is caused by the effect that air velocity has on cooling of the eggs, so egg temperature and with it water vapour pressure deficit is changed by air velocity.

- Turning and turning angle

  As far as known in the literature, turning and turning angle have <u>no</u> direct influence on moisture loss. One could speculate that the turning influences the formation and spreading out of the allantois membrane (which is the bladder right under the shell of which at the end of incubation the majority of moisture is evaporated) but that is never documented. Also one could argue that the turning influences the heat loss, therefore influences the temperature and the water vapour pressure deficit and with it the moisture loss, but at most that effect will be minor. I don't see any theory for a link between moisture loss and turning angle.

- Spraying and cooling

  Regulating the moisture loss by regulating the relative humidity often asks for spraying of water in the air. Evaporation of this sprayed water requires a lot of energy, which means that the eggs in the area of spraying will be cooled. This has a major effect on incubation, hatchability and chick quality, probably often bigger than the effect of the relative humidity itself. The use of the HatchTech U-Vaporator™ decreases this problem as the droplets will be more distributed before evaporated, although we must realise that evaporation of a gram of water requires always the same amount of energy, no matter how big or small the droplets are, and no matter what the temperature of that water is.