Measurement of incubator humidity

Aviagen Turkeys Ltd ®

Definition

- Humidity is important for correct incubation as it controls the rate at which the eggs lose water.
- Humidity in incubators is normally measured as either wet-bulb temperature (Twb) or % relative humidity (RH).
- This advice sheet will describe how Twb can be related to RH.

Principles of humidity measurement

Basic principles

The microbial or bacterial test results received from labs are Total Plate Count of Aerobic (oxygen loving) Bacteria (TPC) as measured by CFU/ml (Colony Forming Units/ml). These results do not indicate whether the bacteria present is harmful or harmless but it can tell if the system is dirty and therefore at risk to the presence of less desirable bacteria.

The water holding capacity of a given volume of air changes with temperature: the warmer the air the more water vapour it can hold. For example, a cubic meter of air can hold at maximum 6.8 grams of water at 5ºC but can hold 39.6 grams of water at 35ºC.
The amount of water in the air is normally measured as vapour pressure with units of millibars (mbar). From the example above, the 6.8 grams of water at 5ºC equates to a vapour pressure of 8.72 mbar.
The maximum amount of water the air can hold at any given temperature is known as the saturation vapour pressure (e_s). Table 1 shows the e_s for a range of temperatures that are useful for hatcheries. It is also possible to use the following formula to estimate e_s over the range of –5ºC to +45ºC:

$$e_s = 0.0006127t^3 + 0.0054035t^2 + 0.4955028t + 6.224$$

where t = temperature in °C

e.g. at 22ºC then

$$e_s = (0.0006127 \times 22^3) + (0.0054035 \times 22^2) + (0.4955028 \times 22) + 6.224$$
$$= 6.524 + 2.615 + 10.901 + 6.224 = 26.26 \text{ mbar}$$

This calculation will not give the exact answer (e_s at 22°C is actually 26.43 mbar) but is usable for practical purposes.

Relative Humidity:

The commonly used measure of humidity is %RH. This expresses the actual pressure of water vapour in the air (e) as a percentage of e_s. Therefore e_s = 100%RH.

If %RH at 37.5°C is 50%, then:

$$e_s \text{ at } 37.5°C = 64.51 \text{ (from Table 1)}$$
$$e = e_s \times 50 \div 100 = 64.51 \times 0.5 = 32.25 \text{ mbar.}$$

It is important to note the %RH of the air will change if the water vapour content of the air stays the same and we alter the temperature of the air. For example, if we take the air at 37.5°C, with a RH of 50% and therefore an e = 32.25 mbar and cool this air to 30°C then e_s will change from 64.51 to 42.42 mbar. The effect is to change the RH from 50% to (32.25 ÷ 42.42) x 100 = 76%. *The amount of water in the air has not changed, only the capacity of the air to hold water.* It is important to understand that the measurement of relative humidity is not an absolute measurement of the water vapour in the air but it is an expression of the water vapour as a percentage of the water carrying capacity of the air – and this changes with temperature.

A practical consequence in hatcheries is the drying effect of bringing incubator room air at 25°C and 50%RH into an incubator operating at 37.5°C and 50%RH. The room air has a water vapour pressure of e = 31.67 x (50 ÷ 100) 15.84mbar. As it is brought into the incubator the air is warmed to 37.5°C and so the RH of the air entering is then reduced to %RH = (15.84 ÷ 64.51) x 100 = 24.5%. The incubator will then have to add water vapour into the machine through the humidifier to raise the humidity of the new air from 24.5% to 50%RH.

Wet Bulb Temperature

A second commonly used measurement of humidity is wet bulb temperature and this is often used in artificial incubators. This is an indirect measurement of humidity based on a technique for measuring humidity that uses the cooling effect of water evaporation.

If we place a wet wick around a thermometer bulb (called a wet bulb), then as the water evaporates from the wick, it cools the thermometer. The lower the humidity of the air, the faster the rate of evaporation, so the lower the measured temperature of the wet bulb. The difference between the wet bulb temperature and the actual temperature of the air as measured by a dry thermometer (dry bulb) will be indicative of the humidity of the air.

The calculation of the humidity of the air from wet and dry bulb measurement will depend on the rate of airflow over the wet bulb. If the airspeed is low (taken as less than 1 m/s) then the following formula can be used to calculate humidity:

$$e = e_w - 0.799\,(t_d - t_w)$$

Where: e_w = the saturated vapour pressure measured at the wet bulb temperature (mbar); t_d = temperature of the dry bulb (°C); and t_w = temperature of the wet bulb (°C).

In incubators airspeed is normally greater than 1 m/s and so the following formula should be used:

$$e = e_w - 0.666\,(t_d - t_w)$$

For example, if the dry bulb temperature is 37.5°C and the wet bulb temperature is 30°C, then the water vapour pressure can be calculated as:

e_w at 30°C = 42.43 (from Table 1)

e = 42.43 – 0.666 (37.5 – 30) = 37.43 mbar

This can be shown as relative humidity:

%RH = (37.43 ÷ 64.51) x 100 = 58%

Wet bulb measurements require that the water and wick are clean and routinely replaced.

Table 1: Temperature (°C) and saturated water vapour pressure (mbar).

Temperature	e_s	Temperature	e_s	Temperature	e_s
25.0	31.67	30.0	42.43	35.0	56.24
25.5	32.64	30.5	43.68	35.5	57.83
26.0	33.61	31.0	44.93	36.0	59.42
26.5	34.63	31.5	46.24	36.5	61.09
27.0	35.65	32.0	47.55	37.0	62.76
27.5	36.73	32.5	48.93	37.5	64.51
28.0	37.80	33.0	50.31	38.0	66.26
28.5	38.93	33.5	51.76	38.5	68.10
29.0	40.06	34.0	53.20	39.0	69.93
29.5	41.25	34.5	54.72	39.5	71.86

To convert temperature from Centigrade to Fahrenheit: (°C x 1.8) + 32

Related Management Advice Sheets:

a. Measurement of Egg Water Loss

Useful sources of information:

- Microclimate measurement for ecologists by D.M Unwin (1980) Academic Press, London
- http://www.engineeringtoolbox.com/air-psychrometrics-properties-8.html

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