1 Successful incubation

Following on from the Aviagen articles in International Poultry Production during 2006 we will be producing a series of articles with an incubation and hatchery theme for International Hatchery Practice during 2007.

The process of incubation and transport of eggs to, and chicks from, the hatchery is critical to the success of a poultry production operation.

Improvements in hatch enhance the measure of breeder performance and equally the quality of the day old chick delivered to the broiler farm will have a significant affect on the broiler performance.

The latter is increasingly important as the growing time for broilers reduces.

Focus on quality

Hatchability and chick quality is therefore an important focus for the managers of poultry operations.

The former is easily measured and can be broken down into various components, whilst the latter is much more subjective and may, in fact, vary between the time of dispatch from the hatchery and the time of receipt at the farm.

Critical to assessing hatching success is an understanding of the difference between hatch of set and hatch of fertile, whilst the former is a useful overall measure it gives little information about the possible causes of week to week and flock lifetime variations.

Therefore, adequate, consistent, standardised record keeping is essential for good hatchery management.

This must include a routine breakout of unhatched eggs at a time when meaningful interpretation of the cause of losses can be made. Breakouts around 6-8 days are essential if an assessment of fertility is envisaged and this must then be linked to a breakout of hatch debris on the same sample to allow an accurate assessment of total losses.

In this regard it cannot be overstated that hatch of fertile eggs is the responsibility of the hatchery manager and this is what must be known and monitored to provide a measure of the success of the hatchery process.

Having decided to follow this routine of comparative data collection it will be necessary to understand some of the principles of incubation which may contribute to improvements in hatch of fertile.

Therefore, in this series of articles we will consider some of the basic principles which are relevant to successful incubation.

Weight loss from eggs is critical to success but this process must be understood in terms of the interaction between the conditions of temperature and humidity in the environment and the porosity, or more correctly the gas conductance characters, of the egg shell.

Subsequent articles will cover the principles and practice of this topic.

The requirements for egg storage and the consequences of not meeting these will be examined.

Total incubation times (set to pull times vary around the world) and the factors which affect these and the critical 'hatch window' will also be covered.

Many articles have appeared in recent years concerning the heat production of modern strains of broiler breeders and this topic, along with changes in setter and hatcher management, will be the subject of subsequent articles.

Recognising the hatchery as the meeting point of breeder and broiler performance will be an underlying theme of these future articles. ◆

by Ken Laughlin, Group V. P. Policy and Strategy

2 Correct egg weight loss

In order to avoid the need to return to water to breed, reptiles, birds and mammals have had to evolve ways of ensuring an adequate supply of water for the developing embryo.

For most mammals and a few reptiles, this was by the embryo developing within the mother's body. For most reptiles and birds it was by the development of a 'shelled' egg.

Most snake and lizard eggs have shells that are often described as flexible, leathery or parchment-like. Harder pliable shells are found in many turtles, whilst some lizards, turtles, crocodiles and alligators lay hard, rigid-shelled eggs.

Nevertheless, the shells of reptile eggs do not allow them complete freedom on the land. In particularly harsh environments, some reptiles retain and incubate the eggs inside the oviduct. When incubated outside the body, the eggs have to be incubated in a damp environment.

In fact, so damp is the nest usually that most reptile eggs do not lose water during incubation and flexible-shelled reptile eggs usually take up moisture from the nest environment.

Birds lay hard-shelled eggs which have allowed them access to more secure and drier nesting sites, for example in trees and on cliff faces.

However, the eggshell has to be porous because the developing embryo needs to take up oxygen from the atmosphere and lose the carbon dioxide produced as a result of metabolism.

Therefore, water loss from the egg needs to be controlled either through nest location, nest design and/or behaviour of the incubating bird in the wild or through control of incubator humidity in commercial hatcheries.

For practical purposes, any loss in weight of eggs is due to the loss of water which in turn affects the water balance of the embryo.

Obviously, if an egg loses too much water during incubation then the embryo may not hatch because it becomes too dehydrated. Water loss from eggs affects both hatchability and chick quality.

In addition to maintaining a suitable state of embryo hydration, the correct egg weight loss during the setter period appears to be important in order to develop an air cell of a suitable size from which the embryo will initially ventilate its lungs before proceeding to escape from the egg.

How we know whether we have achieved the optimum incubator humidity can be learned from birds incubating in the wild.

Irrespective of bird or egg size, there appears to be a common rule in nature that, on average, bird eggs lose 15% of their fresh weight during the total incubation period. Of this, 12% is lost until the time the embryo first makes a hole in the shell ('pips' the shell) and a further 3% is lost during the hatching process itself.

Multi-stage setters run with one humidity setting whilst modern single-stage machines give us the ability to develop elaborate programmes for changing humidity as incubation progresses.

Both types of incubator enable us to adequately control the water loss from the eggs.

Yet many hatcheries still do not routinely weigh eggs during incubation to confirm that their humidity programmes result in eggs losing 12% of their fresh weight to the time of transferring the eggs to the hatcher. If every bird on the planet is following this rule, why do we so often ignore the rule with our poultry species?

Accurate electronic scales are relatively cheap and using them to monitor weight loss from trays of eggs in various locations in all your incubators is an invaluable way to check that your eggs are receiving the ideal humidity conditions.

The use of this method helps you check that your humidity programmes and your humidity control systems are working in all your machines and across all flock ages and strains.

Quite simply, the routine weighing of eggs is an essential management tool in the hatchery. ◆

by Dr Steve Tullet, Poultry Consultant

Aviagen 3

Essential weighings

In the last article, achieving a 12% fresh egg weight loss by the time of egg transfer to the hatcher was suggested as an important management goal in the hatchery.

Essentially, egg weight loss is due to water loss. The rate of water loss is determined by the eggshell porosity and the difference between the water vapour pressure inside and outside the egg.

The hen determines the porosity of the eggshell, although bad egg handling and sanitation techniques can change it. Eggshell porosity varies widely between eggs (the coefficient of variation in one tray of eggs can be 25%) and monitoring individual eggs is not practical in commercial situations. The percentage weight loss should be measured by weighing whole trays of eggs.

Egg temperature must be held within a narrow range to maintain hatchability. Egg temperature determines the water vapour pressure inside the egg, so this shows little variation. Therefore, the only significant way to influence egg weight loss is by altering the water vapour pressure outside the egg by altering the humidity in the incubator.

By monitoring egg weight losses in the setter, it is easy to correct any machines that are not achieving the suggested 12% egg weight loss. In a multi-stage setter, a change of 1% in weight loss (for example from 13 to 12%) is achieved by a change of about five percentage points in relative humidity or a change in wet bulb temperature of 1°C or 2°F. Increasing the relative humidity or wet bulb temperature will decrease the loss in weight from the egg, and vice versa.

In the single-stage incubation programmes where the setter ventilation may be closed for the first 8 -10 days of incubation, the egg weight loss during this period may be as low as 2% of the fresh egg weight. This means the eggs then have to lose 10% of their fresh weight during the 8 -10 days remaining to transfer.

When ambient humidity is high, achieving the correct egg weight loss may not be possible. Eggs benefit from the high humidity at the start of incubation when the setter is closed up, but switching off the humidity system for a number of days later in incubation when the machine is being ventilated may help. If weight loss to transfer has been 12% of the fresh weight and the chicks are taken from the hatcher at the optimum time, then the chick weight at take-off will be about 67% of the fresh egg weight.

FRESH EGG WEIGHT	100%
Egg weight loss to transfer to the hatcher	**12%**
Egg weight loss from transfer to the emergence of the chick	3%
Shell and residue weight at the time of emergence of the chick from the egg	11%
Chick weight at the time of emergence from the egg	74%
Chick weight loss from time of emergence from the egg to optimal take-off time	7%
Chick weight at optimal take-off time	**67%**

Measuring average chick weight from trays where egg weight loss has been monitored is an essential hatchery management tool. It helps ensure good practice in relation to the setter humidity programme. If eggs lose 12% to transfer and the chicks are not 67% of the fresh weight then the take-off time of the chicks may need to be adjusted by monitoring the 'hatch window'.

These targets are recommended for broiler chicks which can usually be sent to farms quickly after hatching. However, when hatching breeding stock, which may require several procedures before dispatch or extended delivery times, then a reduction of weight loss to 11% could be considered. The chicks could also be pulled earlier, but it is recommended that the weight at take-off should be no more than about 69% of the egg weight.

Egg weight losses and percentage chick weights show wide variation. Good hatchery practice is about achieving the correct averages as a percentage of the fresh egg weight. ◆

by Dr Steve Tullett, Poultry Consultant

Aviagen 4

Heat production

Several articles have appeared in the poultry press suggesting that as a result of the genetic selection for rapid growth in the yield-type broiler, modified incubation programmes were now required to deal with the increased heat output of broiler eggs.

However, in the scientific literature, there is no evidence that the heat production of broiler eggs has changed over recent years.

At the end of the setter phase, O'Dea et al (2004) found identical carbon dioxide production (about 0.5 litres per day) from eggs of a broiler line that had remained unselected from 1978 and broiler lines selected either for the whole bird market or for high breast meat yield. Embryos use fat as the main energy source (RQ [CO2:O2 ratio] ~ 0.71), so the oxygen consumption would be about 0.7 litres per day (29.2 ml/hour).

Animals generate about 20 watts of heat for each ml of oxygen consumed per second. Thus, the peak heat production would have been 0.162 watt/egg in all three broiler lines.

Janke, Tzschentke and Boerjan (2004) reported peak setter oxygen consumptions of up to 28 ml/hour (0.156 watts/egg) in Ross 308 and 508 broiler eggs. They refer also to Tullett and Deeming (1982) and Burton and Tullett (1983) who measured oxygen consumptions in broiler eggs of about 30ml/hour on days 17 and 18 of incubation – equivalent to 0.167 watts/egg.

Thus, it appears in the setter phase that a broiler egg produces a maximum of about 0.167 watts of heat and this value has not changed for more than 20 years, despite intense selection for growth and yield in the adult broiler. This may be because the simultaneous selection for better FCR has improved metabolic efficiency.

Egg laying strains generally have a lower embryonic heat production than broiler strains which may be related to the specific selection for shell quality in layer strains which influences gas exchange.

Janke, Tzschentke and Boerjan (2004) measured a peak setter oxygen production in the Lohmann White Leghorn of almost 20 ml/hour – equivalent to almost 0.111 watts/egg.

Over the last 20 years there has been a modest rise in fertility (about 2%) and in the hatchability of fertile eggs in broilers (2-4% depending on strain) which will have increased the total heat production in incubators.

In addition, some setters had their setting capacity increased through the addition of more trays in each stack. There has also been a move away from multi-stage towards single-stage incubation.

By day 18 of incubation, a single-stage machine has to deal with about 2.5 times the heat production found in an equivalent sized multi-stage machine.

Embryos are resistant to periods of cooling, but short periods of heat stress can be lethal.

Therefore, it is prudent to regularly monitor eggshell temperatures for signs of overheating of older embryos. This can be done using a relatively cheap infra-red thermometer such as the Braun Thermoscan. The work of Lourens et al (2005) suggested that an eggshell temperature of 37.8°C may be an appropriate benchmark.

All setters have 'hot spots' and 'cold spots' and it is important to check eggs in the hot spots, especially during days 16-18 of incubation. Eggshell temperatures up to 38.3°C are probably tolerable. If eggshell temperatures approach 38.9°C then some heat stress of the embryos is likely.

Eggshell temperatures of 39.4°C are almost certainly detrimental to hatchability and chick quality and necessitate a reduction in the incubator temperature.

In the hatcher, heat production almost doubles as the hatchlings ventilate their lungs, escape the confines of the egg and become active. Thoughtful reduction of hatcher temperature is essential in order to prevent heat stress and preserve chick quality as the hatch progresses. ◆

by Dr Steve Tullett, Poultry Consultant

5 Incubation periods and hatch windows

Look in any textbook and it will tell you that the incubation period for a chicken egg is 21 days. However, a recent survey by Technical Service Managers at Aviagen has revealed a wide variation in the incubation period for broiler breeder eggs around the world.

The total incubation time allocated to Aviagen strains ranged from 500 to 525 hours, with peaks at about 504, 512 and 520 hours. The shortest incubation periods were in the USA, Middle East, Southern Europe and Far East. The mid-range was mainly from Western Europe, with the exception of the UK where the longest incubation periods were found.

Incubation temperature affects the total incubation period, but incubation temperature also has a major effect on hatchability and therefore varies little from country to country.

Whether the geographical region itself is an important influencing factor on incubation period is not clear. Initial investigations suggest that of more importance is the way the hatchery building and incubators are ventilated. The make of incubator, seasonal temperature effects, strain of bird, egg size, eggshell porosity, flock age, length of egg storage and pre-warming treatments are also known to influence embryo development.

All this demands that the hatchery must have a dynamic approach in deciding which eggs to set together and what setting and chick take-off times are appropriate to maximise chick quality and uniformity.

Good day-old chick quality and uniformity is essential for broiler growers who have to meet the weight sensitive demands of processing plants and supermarkets.

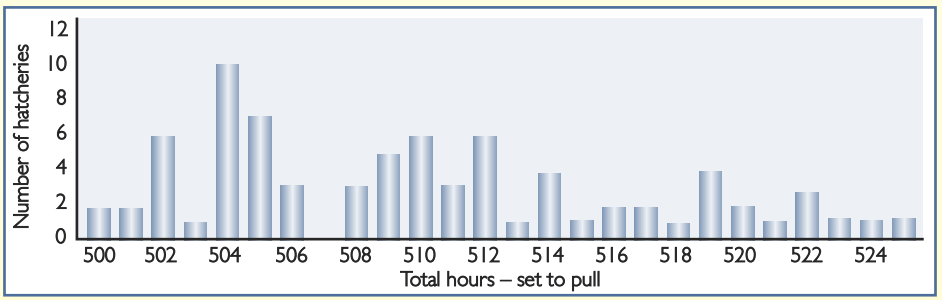
The hatcher environment is harsh for young chicks and being able to remove the chicks at the optimal time without jeopardising hatchability will add greatly to the ability of the broiler farm to rear a better and more uniform broiler flock.

Chicks that have been held too long in the hatcher will become dehydrated and it is well known that the sooner day-old chicks can be given feed and water, the better their posthatch performance will be in terms of bodyweight gain, FCR and mortality.

It is therefore critical that set and pull times are planned to give the best chick quality, but equally it is clear that practices (total hours) vary worldwide.

Hatchery managers can assess whether the chicks are being removed from the hatcher at the optimal time in their hatchery by monitoring the 'hatch window' which will be explained in the next article. ◆

Fig. 1. Distribution of total incubation times.



by Dr Steve Tullett & Dr Ken Laughlin

Aviagen 6

Hatch windows

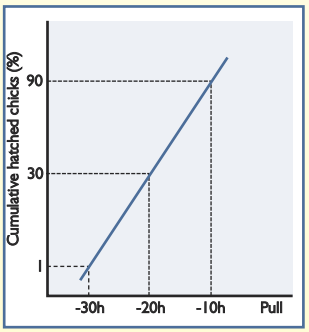
The term 'hatch window' was first used by Mark Bollinger, who was Hatchery Specialist for Nicholas Turkeys, to describe the period of time over which chicks are hatching. The hatch window has also been called the 'spread of hatch' and it is assessed relative to the time of taking the chicks out of the hatcher.

Thus, for the Ross genotype, we know that ideally about 1% of the chicks should be hatching around 30 hours before chick take-off.

About 30% should have hatched by 20 hours before chick take-off, and 90% by 10 hours before chick take-off.

Of that 90%, about 10% will still be wet. Looking across all broiler strains, the spread of hatch should not be more than 36 hours and certainly no more than 1% of the chicks should be hatching 36 hours before take-off (Fig. 1).

Fig. 1. The Ross genotype hatch window.



Different Ross products have different hatch windows (Fig. 2).

Given the large spread of incubation times worldwide attention must be paid to ensure that the hatch window to pull time is correct.

Every setter has hot spots and cold spots and the amount of internal variation in temperature will influence the spread of hatch.

In order to take account of this spatial variation in temperature, the trays used for monitoring the hatch window should come from several different locations.

For example, top, middle and bottom trays, front and back, left and right of the machine.

Incubator manufacturers are predicting that with improvements in design, and particularly the achievement of more even temperatures throughout the setter, the spread of hatch may eventually be as short as 18 hours.

In addition to counting the hatched chicks at regular intervals during the hatching process, other observations may be made during monitoring of the hatch window that will help the hatchery manager judge if the hatch is occurring too early or too late.

If there is a lot of meconium on the shells, all the chicks are dry and the wing feathers of the chicks have spread a lot from the end of their sheaths then the hatch is probably occurring too early. An even spread of hatched chicks on the hatcher tray during monitoring of the hatch window and reasonably clean eggshells at chick take-off are indicators of good conditions during incubation and the correct take-off time.

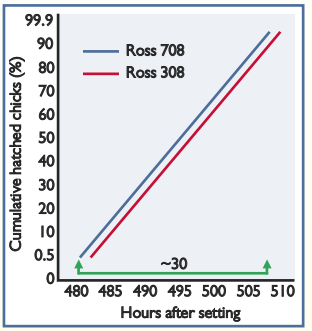


Fig. 2. Specific Ross genotypes.

Female chicks tend to hatch first therefore where chicks are sexed and placed separately observation of more dehydration in females would indicate the hatch window starts too early relative to take off.

Equally, fewer males may indicate the pull is too early. Some hatchery managers do not like opening their hatchers during the hatching process, but the counting of chicks on hatcher trays can be done very quickly and does not affect hatchability or chick quality.

Enlightened managers find there is a lot to be gained from monitoring the hatch window in detail as it can result in significant improvements of chick quality and even hatchability. ◆

by Dr Steve Tullett & Dr Ken Laughlin

7 Increasing chick numbers

Large differences exist in the number of hatching eggs and chicks produced per breeder hen in the best and worst performing companies worldwide.

The strategic direction of the Aviagen programme means that further genetic improvements in egg production in the future will be small, as genetic selection focuses on improving the commercially important broiler and health and welfare traits. But what scope is there for improving the hatchability of fertile eggs in commercial practice?

As a result of cell division in the oviduct, the blastoderm in the fertile chicken egg comprises about 60,000 cells in a small area on the top of the yolk.

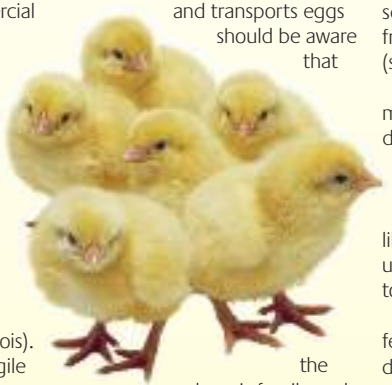
About 500 of these cells are the embryo itself, the rest are the beginnings of the formation of the extra-embryonic membranes (for example yolk sac membrane, amnion, allantois).

The blastoderm cells are fragile and eggs need to be handled gently if the integrity of the blastoderm is to be maintained.

But, many farm and hatchery staff forget that the fertile egg contains a delicate living embryo and we see instances when eggs are subjected to shaking and jarring as they are collected, sorted, trayed, transported, maybe re-trayed again and then moved around the hatchery. Any disruption to the blastoderm cells that has occurred on the farm or in transport can be partially rectified by allowing the eggs time to settle in the egg store in the hatchery for 24 to 48 hours before setting.

This period of settling will allow the cells to regroup and hatchability will be improved compared to setting the eggs directly on arrival at the hatchery.

The important message is that everyone who handles and transports eggs should be aware that the embryo is fragile and that small improvements in the manner in which eggs are handled and transported will make a difference to hatchability.



More careful handling will also reduce the number of cracked eggs which can introduce contamination into the hatchery and to other eggs.

The idea of pre-storage incubation is not new and is based on the assumption that the blastoderm is not at the most ideal stage for egg storage when it arrives at the hatchery. Incubating eggs for up to six hours before placing in storage has been shown to be beneficial for eggs stored for 14 days.

However, there may be benefits for shorter storage periods also. The final article in this series will look in more detail at egg storage practices.

If storing eggs for more than seven days, then they benefit from being stored upside down (small end uppermost).

Whilst it is not usually recommended to incubate eggs upside down, there are reports of benefits if eggs are incubated upside down for the first week of incubation. Eggs that have been deliberately or accidentally set upside down can be inverted up to day eight of incubation.

Hatchability is adversely affected if eggs are inverted from day nine onwards because the some of the extra-embryonic membranes begin to attach to the inner shell membrane at this stage and inversion of the egg can rupture the membranes and blood vessels.

These and other possibilities may have to be explored if improving the hatchability of fertile eggs becomes a major priority in your company. ◆

by Dr Steve Tullett

8 Egg storage and sweating

Egg storage has important consequences for maximum hatchability and chick quality. Eggs usually hatch best after storage for 2- 4 days but after this, even with the best storage conditions, you should expect a decrease in hatchability of about 0.5% per day. And, for every day in storage, the incubation period will also be longer by about one hour.

Storage must be at a temperature below 'physiological zero'. That is, the temperature that allows the blastoderm cells to divide. Try to cool eggs to below 'physiological zero' within 4- 6 hours of lay.

Estimates of physiological zero have ranged from 19 to 27°C but, recently, Keith Bramwell (University of Arkansas) found that blastoderms of broiler breeder eggs only enlarged during storage when the temperature was more than 23.9°C. A physiological zero of about 24°C fits with other recent observations on egg storage (see Table 1).

The relatively low temperatures used in egg storage can cause problems when the eggs are moved into a warm environment. For example, when eggs are moved out of the farm egg store to the hatchery or when eggs are moved from the hatchery egg store to begin incubation there is a risk that condensation may form on the eggshell. This is called egg 'sweating', but the source of the water is vapour in air around the eggs which condenses on the cold surfaces. When the surface of the egg becomes wet there is a risk of bacteria on the shell surface passing through the pores and causing contamination, rots and exploding eggs during incubation.

Storage period (days)	Temperature (°C)	Humidity (%RH)	Pre-warming period (hours)
1-3	20-23	75	4
4-7	15-18	75	8
>7	12-15	80	12
>13	12	80	18

Table 1. Recommended conditions for different egg storage periods.

Dew Point is the temperature at which water vapour in the air condenses. The eggshell must be maintained above Dew Point temperature to prevent sweating. Table 2 gives the Dew Points for a variety of ambient temperatures and humidities.

Thus, an egg stored at 18°C will sweat if exposed to 20°C and 90%RH; 25°C and about 67%RH; 30°C and 50%RH; 35°C and 40%RH. It can be seen that an egg stored at 18°C could be pre-warmed in a setter room at 25°C if the humidity was less than about 67%RH. It can also be seen that when the egg has a shell temperature of 25°C it could be moved to an incubator at about 38°C, provided the humidity is no more than 50%RH.

There is a trend towards using the higher storage temperatures within each of the time periods given in Table 1. This can reduce energy costs, but it can also help reduce the risk of sweating when the eggs are removed from storage. Conversely, storing at lower temperatures increases the risk of condensation. ◆

Table 2. Dew point temperatures for various ambient conditions.

Temperature (°C)	Percentage relative humidity (%RH)					
	40	50	60	70	80	90
15					11	13
20			12	14	16	18
25	10	13	16	19	21	23
30	14	18	21	24	26	28
35	18	21	25	28	31	33
Incubator	21	25	28	31	34	36
40	23	27	30	33	36	38

by Dr Steve Tullett