A Discussion of Multi-Stage and Single-Stage Incubation by Someone Not Selling Incubators

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Obviously, most papers that have been written and most presentations that have been given recently expound the virtues and advantages of new single-stage incubators. However, one must remember that single-stage incubation is not new as it preceded multi-stage incubation. Multi-stage incubation became predominant largely because of lower cost of operation. In fact, within the past 30 years so-called "bottom hatchers" still existed. These machines had turning racks in the top of the machine and hatching baskets in the bottom. The machines were always full of chick down but there were apparently no major problems. However, single-stage hatchers were developed as a means to improve biosecurity. The industry has used these single-stage hatchers from many years, with varying degrees of success.

In order to make a comparison of the two types of machines we first need to understand the critical time periods for embryonic development. The critical time periods, as I conceptualize them, are:

- Breeder house egg gathering
- Grading and transporting the eggs
- Cold storage
- Pre-incubation
- Early incubation (E0-E3)
- Middle incubation (E4-E18)
- Hatching (E19-E21)

The term "physiological zero" has been used by many to describe the period of relative quiescence experienced by the embryo during storage prior to incubation. This is a relative term as it does not mean that the embryo is not growing. If the embryo stops growing it is most probably dead. Thus egg gathering, classification, storage, and transportation should properly be considered "low temperature incubation." As such, a uniform environment must be maintained so that all of the embryos can be maintained in a synchronous manner. The only way to achieve adequate uniformity is with good air circulation at all times. Upward directed fans do a good job of destratifying and circulating air. It is important that adequate spacing be maintained between eggs until the internal egg temperature has equilibrated with the surrounding air temperature during the process of cooling the eggs after they are removed from the nests. During storage egg spacing may be decreased as long as the containers holding the eggs continue to be surrounded by circulating air. During pre-incubation warming spacing between eggs must again be increased in order to uniformly change egg temperatures.

The velocity of the circulating air should be highest during the cooling and warming stages of egg management prior to incubation. This is logical because this is what happens under natural conditions. At the moment of oviposition the single egg loses heat very rapidly and at the start of incubation the hen puts its featherless “brood patch’ in direct contact with the eggs in order to increase the temperature of the egg quickly.

Adequate air circulation during egg gathering, classification, and storage can be easily accomplished with adequately placed and distributed upward directed fans, cooling eggs rapidly and uniformly should be more simple than increasing egg temperature during preincubation. The second generation of single-stage machines generally has increased pre-incubation heating and air circulating capacity. This was not universally true for initial first generation models of single-stage machines that were manufactured just a few short years ago. Evidently, manufacturers have become aware of this critical point. It has been said by some that rapid temperature change would be detrimental to the developing embryo but there is much evidence to the contrary. For example, eggs in the bottom of a chick master setter experience the highest initial air velocity, remain cooler throughout incubation, and produce the best quality chicks. The tunnel ventilation of a Jamesway setter subjects all eggs to a high air velocity. Thus, the use of quite large fans during pre-incubation should be encouraged with a goal to increase internal temperature from storage temperature to 28-30°C in less than 3 hours. Second generation single-stage setters hold eggs for an extended period of time at such a pre-incubation temperature. However, similar pre-incubation conditions can be created in a simple pre-incubation room equipped with adequate fans and heaters. Pre-incubation for as much as 12-18 hours has been successful commercially.

Once pre-incubation has been completed the process of incubation perse can begin. It has long been clear that an air temperature of approximately 100.5°F for the first three days (E0-E3) of incubation stimulates early angiogenesis (development of the blood system), utilization of the yolk sac, and embryo growth that results in heavier and longer embryos at E15 of incubation. The greater utilization of yolk sac material apparently helps reduce egg temperature during the first stages of incubation. In the case of properly managed multi-stage Jamesway setters the air temperature in position 1 (E0-E3) should be 100.5°F, similar to a single-stage profile. In the case of a properly managed Chickmaster setter the eggs in the lower trays are exposed to a high air velocity and experience an increase in internal temperature in a manner that is somewhat similar to being placed into 100.5°F environment. Thus, eggs in the lower trays are more advanced at transfer than eggs in the upper trays. The less advanced embryos with larger yolk sacs appear to benefit from adequate fresh air. Oxygen has been shown to be required for proper and complete utilization of the yolk sac lipids. This can be best insured by maintaining machine room temperatures above 27°C at all times (night and day). Eggs in the upper and lower trays can be interchanged during incubation as well. It is also important to maintain the machine room static pressure positive at all times to insure adequate fresh air in the machines.

These have also been discussion of the benefits of elevated carbon dioxide levels during early incubation. This was also promoted by the short-lived Hensway Incubator Company some years ago. The major benefit of elevated carbon dioxide appears to be involved with maintaining optimum albumen quality especially in eggs from older flocks or in eggs that have been stored for an extended period. However, there are many ways to manage egg storage to minimize the need for elevated dioxide during early incubation.

In a similar manner, there has been considerable discussion about the benefits of reduced ventilation, thus increased relative humidity, during early incubation. The probable reason for this perceived benefit is that humid air is a better conductor of heat than is dry air. The result would be that humid air would do a better job of increasing egg temperature in a uniform manner. That being said, adequate fan capacity that generates a high air velocity should accomplish the same objective during both pre-incubation and early incubation.

Once past E3 of incubation the egg temperature should be reduced to a typical 99.5°F and ideally maintained until hatching. While this may be possible in single-stage incubators, and multi-stage Jamesway setters, it is difficult to accomplish in Chickmaster style setters where there is a difference in air velocity, and thus egg temperature, between the lower and upper trays. It is very critical in this scenario you always maintain an open damper so that there is adequate air circulation.

Beginning about E12 of incubation the embryo begins to produce sufficient heat to elevate egg temperature above air temperature. It is during this time that single-stage machines begin to lower their dry bulb set points in order to keep the eggs cool. While this would seem beneficial, our data has demonstrated that, in presence of adequate ventilation, chicks that hatched from eggs that reached 105°F grew to 180 and 900 grams at 7 and 21 days of age, respectively.

There is also a growing body of data that strongly suggests that some heat stress between E7 and E16 of incubation better prepares the hatchling for heat stress after 35 days of age in the broiler house. Carcass yield, as a result of certain amounts of heat stress during E7 to E16, also appears to be improved. Thus, the absolute control of egg temperature throughout incubation could be detrimental in many ways. One should remember that incubation temperature is probably not constant under natural conditions and this may be the means by which wild birds adapt to the wild variations of their post-hatching environment.

A properly managed multi-stage Jamesway machine, in which the eggs had been adequately pre-incubated, will have an egg temperature in position 6 of 99.0°F. This would normally require a dry bulb set point of 98.0-98.3°F. In the presence of adequate air entering the machine, this will generate an air temperature in position 1 of approximately 100.5°F. Thus, a correctly managed Jamesway multi-stage machine will produce an incubation temperature profile among the six positions that somewhat resembles a single-stage profile, and can produce absolutely great quality chicks.

The hatcher that is generally used for E19-E21 has always been a single-stage machine. In spite of this, poor management of these machines is apparent in many hatcheries. One only needs to realize that hatchers are really not necessary to produce chicks. Eggs can be taken directly from setters and placed on properly heated litter in a broiler house and they will hatch perfectly well in this well ventilated environment. Recognition of these facts suggests what the critical points of hatcher management must be. They must be adequate air circulation and temperature control.

Adequate fresh air must be supplied from the moment of transfer. This should be obvious given the simple fact that the machine is full of E18 embryos that require oxygen to fully utilize their yolk sacs. How can it be logical that the dampers on the hatchers be allowed to close their eggs are transferred? Following the discussion above, what should the dry bulb set point be for the hatcher after transfer? It would have to be less than 98°F. In fact, depending upon the situation, set points from 96.5-98.0°F have been successfully utilized. A key point to remember is that the dry bulb temperature functions more to control the hatcher ventilation than the egg temperature.

Apparently both types of machines can be managed in such a manner as to produce good hatchability and chick quality. However, in the case of multi-stage machines, management of machine room conditions and pre-incubation are apparently more critical. So, as in much of the poultry industry, the quality of management and economics must drive the decision making process. However, it is absolutely clear that satisfactory results can still be obtained from properly managed multi-stage setters and hatcheries. The importance of management of the hatchery machine rooms can not be over-emphasized.