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Methods of incubation and important factors before and after hatching

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Introduction

Poultry production across all operational scales relies significantly on the consistent supply of day-old chicks. The fertility and hatchability of eggs play pivotal roles in influencing the availability of day-old chicks in poultry production. Hatchability, defined as the proportion of eggs that successfully complete incubation to yield chicks, is a critical economic trait in the poultry industry due to its substantial impact on chick output (Malik *et al.*, 2015). Traditionally, eggs were hatched by broody hens; however, this method proved inefficient for large-scale chick production. As a result, modern incubators, designed to emulate the environmental conditions provided by broody hens but with greater efficiency, are currently employed for egg hatching. Despite these advancements, certain factors still contribute to energy loss for both egg-laying and incubating birds, leading to failed hatching attempts.

Fertility and hatchability are interconnected heritable traits that exhibit variation among breeds, varieties, and individuals within a breed or variety (King'ori, 2011). Several factors influence these traits, including egg age, storage conditions, flock age, husbandry systems, rearing technology, mating systems, incubation parameters such as relative humidity and egg turning. The hatching potential of an egg is contingent upon the developing embryo and the micro and macronutrients supplied by the hen through various components—shell, yolk, and albumen (England *et al.*, 2012). Strong correlations have been reported between hatched chick weight and yolk as well as albumen weights (Wolanski *et al.*, 2007). Additionally, the age of the broiler breeder hen influences the yolk-to-albumen ratio (Peebles *et al.*, 2000).

Key egg parameters influencing hatchability, according to King'ori (2011), include weight, shell thickness and porosity, shape index (defined as the maximum breadth-to-length ratio), and the consistency of the egg contents. Furthermore, heat stress has been identified as a factor affecting both external and internal egg qualities, thereby influencing the hatching process.

Incubation

Incubation is the physiological process employed by certain oviparous (egg-laying) animals for hatching their eggs, involving the developmental progression of the embryo within the egg. Various factors play a crucial role in the incubation process across different animal species. For instance, in certain reptile species, there is no fixed temperature requirement; instead, the actual temperature influences the sex ratio of the offspring. In contrast, avian species exhibit genetically determined sex ratios, but many necessitate a consistent and specific temperature for successful incubation. In the context of poultry, the act of sitting on eggs to facilitate incubation is termed brooding. The inclination or behavioral predisposition to incubate a clutch of eggs is referred to as broodiness, and selective breeding has often eliminated this behavior in egg-laying poultry breeds to enhance production efficiency.

Incubators are mechanical or electronic devices designed for the artificial incubation of fertilized eggs. These devices create and maintain a suitable environment for the embryos to develop and eventually hatch, bypassing the need for parental incubation. The utilization of incubators is motivated by several factors, including cost-effectiveness and practicality. They are cost-effective because there are readily available options that can be either homemade or purchased at reasonable prices. Moreover, incubators are considered practical, particularly in large-scale egg hatching facilities, as they provide a safer and more efficient alternative, saving both time and energy.

There are three types of egg incubator. They are:

1. Forced Air Incubator

The forced air incubator, a prevalent and widely employed device for egg incubation, operates through the utilization of a fan to uniformly distribute warmth throughout the egg chamber. This mechanism facilitates the incubation of a larger quantity and a broader range of egg sizes simultaneously, ensuring even heat distribution within the incubator. The standard temperature maintained in a forced air incubator ranges between 99-100°F. Additionally, humidity levels, assessable using a wet-bulb thermometer, are set between 82-88°F during the setting phase and elevated to 94°F for the hatching phase.

2. Convection Type

An alternative category of egg incubator operates on the principle of convection. Convection-type incubators incorporate ventilation apertures strategically positioned at the top, sides, and bottom of the apparatus. These apertures enable the upward movement of warm air, creating a convection current that draws in cooler air from below, establishing a uniform thermal environment for the eggs. However, convection-type incubators are susceptible to desiccation, necessitating meticulous monitoring of humidity levels.

Despite this drawback, convection-type incubators offer the advantage of facile construction using recycled materials available at home. Specifically:

- The housing of the incubator can be fashioned from a robust container, such as an unused cooler or cardboard, equipped with a lid. To enhance heat retention within the enclosure, aluminum foil may be employed as a lining for the lid.
- The water tray, vital for maintaining appropriate humidity, can be improvised using disposable aluminum containers typically utilized for pies and cakes.
- Heat provision can be achieved using light sockets with a power rating of approximately 25 watts or less.
- Airflow, essential for the convection process, can be facilitated by drilling ventilation holes, each measuring about 1/2 inch, at strategic corners of the housing.

3. Still Air Incubator

In contrast to the convection type, still air egg incubators lack air holes. The operation of still air incubators is intricate and necessitates precision in setup. Radiant heat warms the air, but due to the absence of circulation, meticulous egg placement is crucial. Proper setting of still air incubators is imperative, with a precise temperature of 103°F required to avoid temperature and humidity anomalies. To facilitate fresh air intake, still air egg incubators must be opened at least four times daily.

The three common types of egg incubators—forced air, convection, and still air—are generally effective for artificial egg incubation. To ensure successful hatching, the following considerations should be taken into account:

- At least three turns daily to relocate the embryo away from waste and toward fresh nutrients within the egg.
- For forced air incubators, external turning devices are recommended, with cessation three days before anticipated hatching.
- Regular temperature checks to ensure precise settings, with variations depending on the specific incubator type in use.
- Vigilant oversight to maintain adequate moisture levels, with settings adjusted based on the ventilation and airflow characteristics of the incubator.

Adhering to these considerations with care and precision assures successful incubation and hatching, irrespective of the chosen incubator type. The successful hatching of eggs, whether pursued as a business or hobby, is contingent upon selecting the appropriate chicken egg incubator tailored to specific needs and specifications. Therefore, acquiring the optimal incubator becomes crucial for achieving timely and healthy hatching outcomes.

Five major factors are involved in the incubation and hatching of poultry eggs. They are:

Temperature

Temperature constitutes the most critical environmental parameter during the incubation process, as the developing embryo demonstrates limited tolerance for fluctuations. Embryonic development initiates when the temperature surpasses the Physiological Zero, defined as the threshold temperature below which embryonic growth is arrested and above which it recommences. For chicken eggs, the Physiological Zero is approximately 75°F (24°C). The optimal temperature range for chicken eggs in the setter phase, spanning the first 18 days of incubation, is between 99.50 and 99.75°F. Subsequently, during the hatcher phase, covering the final 3 days of incubation, the recommended temperature is 98.50°F.

Humidity

Incubation humidity is a crucial factor influencing the pace of moisture depletion from eggs throughout the incubation process. Typically, humidity levels are expressed as relative humidity, determined by contrasting temperatures registered by wet-bulb and dry-bulb thermometers. The recommended relative humidity for the initial 18 days of incubation, particularly in the setter phase, falls within the range of 55% to 60%.

During the final 3 days of incubation, notably in the hatching phase, the advised relative humidity spans between 65% and 75%. Elevating humidity levels during the hatching period is imperative to mitigate the risk of dehydration in the emerging chicks.

Ventilation

Ventilation plays a crucial role in incubators and hatchers, ensuring the supply of fresh, oxygenated air essential for the respiratory processes (oxygen uptake and carbon dioxide release) of developing embryos, spanning from egg setting to chick removal from the incubator. Oxygen requirements during the initial developmental stages are relatively modest compared to the later stages. The baseline oxygen content of air at sea level is approximately 21%, and, generally, the oxygen content in the setter remains consistent at this level. A decrease of 1% in oxygen concentration corresponds to a 5% reduction in hatchability.

Carbon dioxide, a natural by-product of metabolic activities during embryonic development, is released through the eggshell. The permissible CO_2 tolerance level for the first 4 days in the setter is 0.3%. CO_2 levels surpassing 0.5% in the setter lead to diminished hatchability, with complete lethality observed at 5.0%. Given that the standard oxygen and CO_2 concentrations in ambient air appear to provide an optimal gaseous environment for incubating eggs, no specialized measures to control these gases are necessary. The primary requirement is to sustain adequate circulation of fresh air at the appropriate temperature and humidity levels.

Positioning of eggs

The optimal positioning of eggs during artificial incubation involves maintaining their large ends in an upward orientation. This alignment is natural, as the chick's head tends to develop near the large end, adjacent to the air cell, with the developing embryo naturally orienting itself so that the head is positioned upwards. When eggs are incubated with the small end upwards, approximately 60% of embryos will exhibit development with the head near the small end. Consequently, during hatching, the chick may encounter difficulty breaking into the air cell for the initiation of pulmonary respiration. Eggs positioned horizontally can undergo normal incubation and hatching processes as long as they are consistently turned. Standard practice involves setting eggs with the large end upwards during the initial 18 days in the setter, transitioning to a horizontal position for the final 3 days in the hatcher.

Turning of eggs

Birds, including species such as chickens and quail, instinctively turn their eggs during natural nest incubation. In the context of artificial incubation, eggs should be turned a minimum of 8 times per day to replicate the beneficial effects observed in natural settings. This turning process is integral for preventing the developing embryo from adhering to the extra-embryonic membranes, thereby reducing the likelihood of embryo mortality.

In large-scale commercial incubators, automated turning mechanisms are employed, ensuring eggs are turned every hour, totaling 24 times a day. The standard turning procedure involves rotating eggs to a position of 45 degrees from the vertical and then reversing the direction to 45 degrees in the opposite direction. Rotations of less than 45 degrees are deemed inadequate for achieving optimal hatchability. It's important to note that turning is not required during the hatching phase in a hatcher.

The impact of various factors on egg hatchability is assessed as follows:

Storage: Eggs stored for an extended duration, beyond a few days, or those set when aged 10-14 days exhibit reduced hatchability. This phenomenon results from the loss of carbon dioxide (CO_2) through the eggshell, causing an increase in alkalinity. Consequently, the albumen becomes more transparent or watery (Ebenebe, 2014). Stored eggs exhibit elevated early-embryo mortality, and surviving embryos tend to develop slowly, resulting in delayed hatching. As the age of the egg increases, hatchability diminishes. This issue can be mitigated by implementing Short Periods of Incubation During Egg Storage (SPIDES).

SPIDES involves periodic incubation during the storage period, akin to the natural behavior of a farmyard hen. In this process, the hen periodically warms the eggs in her nest each time she returns to lay an egg, providing the older eggs with brief periods of incubation. A well-implemented SPIDES treatment has the potential to restore 60% or more of the hatchability lost in untreated stored eggs. For instance, if 10% hatchability is presently lost due to storage, the use of SPIDES can enhance hatchability by 6-7%.

Nutrition: Nutrition plays a pivotal role in animal breeding, particularly concerning avian species. The provision of appropriate quality and quantity of feed is crucial for birds, as it supplies the energy required for mating processes and allocates essential nutrients to egg development. Feed regulation is essential to prevent excessive weight gain, a major contributor to poor-quality ejaculate and ovulation, and in extreme cases, it can lead to premature ovarian and testicular regression (Brillard, 2007).

In various poultry species, such as ostriches, egg size serves as an indicator of maternal investment in the egg (Dzoma, 2010). Improving egg size can enhance hatchability rates through the manipulation of fat levels, protein content, and the addition of enzymes (Abiola *et al.*, 2008). Eggshell quality is economically significant for both hatching eggs and table eggs. Feeds containing mycotoxins, such as ochratoxin A, can adversely affect kidney function by impairing vitamin D3 production, subsequently impacting calcium metabolism (Biomin, 2013). This can result in reduced shell quality, increased breakage, and diminished hatchability. Certain nutrients play varying roles in hatchability, depending on bird species. For instance, calcium and zinc exhibit documented competition for gastrointestinal tract absorption in ostriches (Dzoma, 2010). Abnormal increases in specific feed ingredients, such as conjugated linolenic acid (CLA), can adversely impact hatchability by reducing egg weight and yolk size, leading to embryo mortality in fertile eggs (Ayidin and Cook, 2004). Other nutrients influencing hatchability include vitamins E, B, folic acid, etc. Conversely, feed ingredient supplements like organic selenium have been shown to improve hatchability of fertile eggs (Hanacy *et al.*, 2009).

The presence of anti-nutrients, such as gossypol toxicity, which exhibits varying degrees of species susceptibility, can also affect egg hatchability. Excessive cottonseed in a layer's diet may cause the laying of eggs with rubbery or mottled albumen, a condition known as pink white disease. This is attributed to gossypol increasing the permeability of the yolk sac membrane, allowing the release of substances, including pigments, into the egg white (King'ori, 2011).

The Hen: The age of laying hens exerts a notable influence on the fertility of eggs, affecting not only the size of the eggs but also their yolk and albumen components (Uni *et al.*, 2012). Research by Tomhave (1958) indicates greater variation in fertile eggs during the early production cycle compared to later stages. Hatchability, likewise, exhibits variation among breeds and strains. Light breeds of birds, as reported by Isam *et al.* (2002), tend to demonstrate higher fertility in comparison to heavy breeds such as the Rhode Island Red. Additionally, there are documented instances of higher hatchability in meat strains of birds when contrasted with egg strains (King'ori, 2010). However, when considering all hatchability traits, the breed, according to Islam *et al.* (2002), has minimal impact.

The age of the broiler breeder hen is also a factor influencing the yolk-to-albumen ratio (Peebles *et al.*, 2000). To ensure successful hatching, it is imperative that eggs are fertile. Maintaining the optimum hen-to-cock ratio is crucial to the production of fertile eggs. Common ratios, such as 1:5 or 10 hens, are employed depending on the production system (extensive or intensive) and the size of the breed (heavy or light). Inseminating a hen within 30 minutes after oviposition is recommended to ensure the flaccidity of the connective tissue around the vaginal wall, preventing venting and thereby avoiding deep insemination associated with embryo mortality during hatching, which can lead to pathological polyspermy (Bakst and Dymond, 2013).

The Egg: Various aspects of the egg can significantly influence hatchability, encompassing both external and internal factors. External properties include egg shell thickness and porosity (Gonzalez *et al.*, 1999), egg shell weight, egg shell breaking strength, egg shell chemical composition (England *et al.*, 2012), egg shell color, and egg specific gravity (Bramwell, 2009). These external traits are quantifiable parameters that help determine their impact on the hatching success of an egg. Measurement techniques include the use of a colorimeter for egg color, checking specific gravity with a salt solution or Archimedes' method, weighing the egg shell, and measuring shell thickness with a micrometer screw gauge (England *et al.*, 2012).

Internal properties, such as yolk and albumen characteristics, are assessed by checking the color and strength of the perivitelline membrane using the Roche scale and measuring albumen quality with Haugh units (Roberts, 2004). Poor egg quality has implications for hatching ability. Specific gravity values of 1.070 or higher result in better hatchability than values below 1.065 (Bramwell, 2009). Specific gravity below 1.080 not only leads to poor hatchability but also induces embryo mortality (Bennett, 1992). Lighter-colored eggs (color scores above 87) exhibit lower hatch rates compared to darker eggs (Bramwell, 2009). Egg shell pigment is typically added just before laying, and light color may indicate prematurely laid eggs (Bramwell, 2009).

Eggs with low porosity and increased thickness tend to hatch poorly. Excessive porosity can allow spoilage organisms to enter and result in significant moisture loss from the egg, potentially leading to contamination lethal to the embryo. Eggs should be free from visible and hairline cracks to prevent contamination. The correlation between hatchability and egg size is noted to be positive (Abiola *et al.*, 2008). Washing eggs with liquid disinfectant before incubation may disrupt the protective cuticles of the egg shell; thus, routine fumigation is recommended before setting eggs in the incubator (Mastic *et al.*, 2008). A reduced yolk proportion may negatively affect nutrient supply to the embryo and, consequently, the hatchability of larger eggs (Cavero *et al.*, 2011). A weak perivitelline layer in the yolk indicates an aged egg, making the yolk prone to breakage and resulting in lower hatchability rates.

The Environment: Upon oviposition, the development of the embryo in fertile eggs becomes contingent on the environmental temperature to which the egg is exposed. The success of incubation relies on maintaining favorable conditions for hatching fertile eggs, influencing embryo growth, hatchability traits, and the morphology, physiology, and behavior of chickens (Shafey *et al.*, 2005). Temperature and photoperiod are identified as two primary environmental factors influencing the fertility and hatchability of eggs. The recommended conditions include a temperature range of 37.2-39.4°C, relative humidity of 56-60%, and ventilation with 21% oxygen (Oluyemi and Roberts, 2000). The incubation temperature for hatching most poultry eggs, including domestic birds and some wild species, is generally uniform at 99–100°F.

Laying hens exposed to abnormally high environmental temperatures (heat stress) experience reductions in egg production and shell quality. The decline in shell quality is linked to reduced blood pH resulting from hyperventilation induced by heat stress (Husvéth, 2011). Heat-stressed birds also exhibit decreased food intake, contributing to declines in both egg quantity and quality, consequently impacting hatchability. Extreme temperatures, whether high or low, can lead to embryo death at any incubation stage. High temperatures affect albumen deterioration rates due to rapid CO_2 loss from the egg. Excessive water loss from low relative humidity impairs the chorioallantoic process and its role in respiratory exchange. Both oxygen and CO_2 are crucial for efficient hatching, with the latter being essential for muscle tone toward the end of incubation.

Providing adequate light during hatching and incubation periods enhances hatchability traits and post-hatch chick performance (Shafey, 2004). Increased environmental temperatures may divert metabolizable energy from growth and development to functions related to thermoregulation (Meijerhof and Albers, 1998). Shafey *et al.* (2005) reported that an Electric Field (EF) of 30 kV/m at 60 Hz during incubation enhances embryonic growth and hatchability traits, thereby reducing the incubation period of layer-type breeder eggs. The incubation environment is intricately connected to the metabolism, heat production, and growth of embryos, influencing hatchability and incubation length (Shafey *et al.*, 2006). Consequently, any alterations in the environment of set eggs may either enhance or diminish their hatchability.

The Equipment: Facilities play a crucial role in ensuring the continuous production of chicks through the hatching of fertile eggs. These facilities encompass a range of equipment, including incubators, hatchers, storage crates, thermometers, barometers, among others. Various factors impact the functionality of incubators, such as egg turning practices, humidity levels, and sanitation procedures. Incubation can occur naturally through brooding hens or artificially using modern incubators designed for efficient egg hatching. In artificial incubation, maintaining a constant temperature of 38.6°C facilitates embryonic growth, efficient nutrient utilization, and energy extraction from yolk and albumen reserves. However, prolonged incubation at this temperature can hinder embryonic development due to restricted metabolic processes resulting from inadequate oxygen exchange (Louren *et al.*, 2005). Notably, the hatchability of eggs stored for approximately 10-14 days before incubation significantly diminishes in artificial incubators (Roma *et al.*, 2008).

The positioning of eggs in the incubating tray is a critical factor influencing hatchability. Research by Tiwari and Maeda (2005) indicates that eggs stored with the small end up exhibit higher hatchability rates, potentially attributed to reduced water loss from the exposed surface area. However, in the incubating tray, it is recommended to set eggs with the large end up. Setting small ends up results in a 17% reduction in hatchability in breeder boilers and prolonged incubation periods in quail eggs (Mahdi *et al.*, 2010). Neglecting egg turning during incubation leads to lower hatchability and delays in hatching by several days. Consistent laying of eggs on one side of the shell may result in the extra-embryonic membranes and the embryo adhering to that side of the shell (Oluyemi and Roberts, 2000).

Ensuring adequate sanitary conditions across all incubation and hatching facilities is imperative for successful egg incubation. Sanitation practices must be rigorously maintained to optimize the hatchability of eggs.