Biological Rhythm Research

ISSN: 0929-1016 (Print) 1744-4179 (Online) Journal homepage: https://www.tandfonline.com/loi/nbrr20

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To cite this article: Mohamed E. Abd El-Hack, Cesar Betancur Hurtado, Dairon Más Toro, Mahmoud Alagawany, Essam M. Abdelfattah & Shaaban S. Elnesr (2019): Impact of environmental and incubation factors on hatchability of duck eggs, Biological Rhythm Research, DOI: 10.1080/09291016.2019.1628394

To link to this article: https://doi.org/10.1080/09291016.2019.1628394

Published online: 22 Nov 2019.

BIOLOGICAL RHYTHM RESEARCH
https://doi.org/10.1080/09291016.2019.1628394

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REVIEW ARTICLE

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Impact of environmental and incubation factors on hatchability of duck eggs

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ABSTRACT

Hatchability is the most important elements for producing more ducks. Hatchability is an indicator used to determine the economic value for any commercial hatchery. Optimal conditions during the incubation process may be defined as those leading to maximum hatchability of healthy ducklings. One of the main factors in the success of the duck hatching process is to adjust the appropriate temperature and humidity with the ventilation of the eggs enough as well as a proper turning of the eggs. In addition, the complete disinfection of eggs and incubator machine, and the process of egg candling to define the fertile eggs in order to maintain the hygienic conditions of the incubator and ensure a high hatchability. By knowing the simple steps of hatching duck eggs, successful management can access different ways to improve the hatchability. Therefore, this review was conducted to reveal the incubation factors that influence the hatchability of duck eggs and also the new ways to improve the hatchability.

ARTICLE HISTORY
Received 22 May 2019
Accepted 19 September 2019

KEYWORDS
Hatchability; environmental factors; incubation; egg; ducks

Introduction

The ducks are waterfowl that belong to the *Anatidae* family. Ducks are very proliferating birds and they can lay between 45 and 150 eggs/year (Idahor et al. 2015). Duck production plays a main role in the economy of world due to its contribution as a source of animal protein. Successful duck production, both at a large or small level, depends on a regular supply of day-old ducklings. The production of day-old ducklings is influenced by the hatchability of the eggs. The ducks production costs can be depressed by increasing the hatchability during the incubation period. Therefore, it is recognized that hatchability is an important economic parameter, and it is affected by some factors, such as egg quality, egg weight egg storage and handling (Kamanli et al. 2010; Weis et al. 2011), and one of the most important factors is incubation conditions (Ipek and Sozcu 2017). Also, these factors affect embryo development and yolk absorption during the incubation process.

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The incubation process of the eggs can be natural or artificial, is the process by which are given to the fertile eggs optimum conditions of temperature, relative humidity (RH), ventilation and rotation, to allow good embryonic development from oviposition to hatching (Ramli et al. 2017; Bhosale et al. 2018). The incubation period in ducks varies according to species (for example, in Pekin ducks is 28 days and the Muscovy ducks is 34–35 days). The temperatures and RH for incubation of Pekin ducks are 37.8 °C and 60% from day 0 to 24 days of incubation and 37.3 °C of temperature and 80% RH during the hatching period (24–28 days) (Onbaşılar et al. 2007). A better hatchability can also be obtained from duck chicks when new methods are used to increase the hatching rate (Harun et al. 2001). One of these ways is duck eggs injection with certain nutrients that improve hatchability (Giri et al. 2012; Nowaczewski et al. 2012; Awad and Abd El-Halim 2015)

The ultimate goal of ducks incubation is to increase the hatching rate and to produce healthy hatched ducklings. In this process, there are serious elements that need attention to reach the highest hatchability rates; therefore, there was a need for further studies to clarify these elements. Thus, the objective of this review article is to provide advanced information about the incubator factors that impact the hatchability of duck eggs and ways to improve these essential parameters.

Effect of temperature

Temperature is the most important factor in incubation (Hester 2017). Lourens et al. (2005), it is the easiest function to regulate; however, a series of good, sensitive, easy to handle and reliable controllers are needed to regulate and maintain it in the optimal range. Errors in the control of temperature cause a loss in the percentage of hatchability and quality of the chicks. The temperature for large incubators and hatchers is 99°F while the smaller ones operate at 100°F. It is necessary to place minimum (97°F or 98°F) and maximum (102°F) temperature sensors to detect potential hazards for embryos.

According to El-Hanoun et al. (2012), during the period between 14 and 24 days of incubation, all eggs should be cooled to 30–32°C twice a day for 15 min, and then placed back again according to the incubation temperature. Wilson (1990) and Lourens et al. (2007) planted that the best hatchability and development of the chicken embryo is reached with constant temperatures of 37.5°C during incubation. Also, they stated that to reach thermal homeostasis, incubator temperature should be maintained at 37.5°C.

In this sense, Lourens et al. (2005) found that the use of nutrients and energy during the first days of incubation improves with maintaining a constant temperature of 37.5°C, improvement the growth of the embryo; however, an insufficient exchange of oxygen limits the metabolic processes and delays embryonic growth. Variations in temperature significantly affect embryonic mortality. A decrease below 35°C for 3 or 4 h decreases the chick's metabolism; however, an increase above 40.5°C for 15 min causes the death of the embryo (Lourens et al. 2005; King'ori 2011). The increase in the endogenous heat production in duck eggs containing large amounts of fats will be reflected in a decrease in hatched eggs (King'ori 2011). The temperature of the external environment also influences embryonic development; drafts and direct sunlight modify the temperature of the incubators (Ramli et al. 2017). During summer (Temperate areas) and dry season (Tropical areas), the environmental temperature is usually higher than 20°C and hatchability declines. Thus, incubation temperature is one of the most important factors, which determine and influence duck embryo development and hatchability.

Effect of relative humidity

The quality of the duckling on the day of hatching depends to a large extent on the RH maintained during the incubation, for our knowledge, there is little scientific evidence to demonstrate these effects (Buhr 1995). Several authors recommend that RH should be maintained between 60% and 80% (King'ori 2011), during the first 18 days the RH should be 60% to avoid accelerated dehydration of the egg, while during the final phase should be increased up to 80% (Mortola et al. 2015). It is important to note that a high RH in the incubation will prevent normal evaporation of the eggs and thus decrease the number of eggs hatched, also an excessive decrease causes a high dehydration, and the ducklings will be born stuck to the shell or paralysed (Vedder et al. 2017).

Christensen (1983) and Ang et al. (2003) reported that the dehydration of the egg is due to the presence of pores in the shell, is determined by the speed of the air inside the incubator and causes a resignation of the weight of the eggs. The air velocity is inversely proportional to the moisture loss of the egg (Ghonim et al. 2008).

It is recommended that RH be measured with a wet bulb thermometer (El-Hanoun et al. 2012). The regulation of the RH can be done in different ways, the humidity of the incubator increases when the ventilation holes are moistened with water, placing a container with water under the tray of eggs or placing a wet sponge, to increase the surface of evaporation, suitable concentrations of RH are obtained (Hossain et al. 1998). Thus, RH during the incubation period is essential to end excess moisture loss from the duck eggs contents through the eggshell membranes and porous.

Effect of CO_2 concentration and ventilation

Cellular respiration is important from the first days of life of all living beings, a correct gaseous exchange between the internal environment of the egg and the outside is crucial for the life and development of the ducklings (Reis et al. 1997; Peebles et al. 2001). Both in the incubator and in the hatchery optimal ventilation conditions are needed to allow the entry of oxygen and the release of carbon dioxide through the three to six thousand pores presented by the eggshell, according to Gildersleeve and Boeschen (1983) the oxygen demand increases as it increases the development and respiration of the embryos.

The concentration of gases in the incubation varies according to the conditions of the external environment, the concentration of CO_2 increases from 0.05% to 0.90% while the oxygen decreases from 20.9% to 20.3% during the natural incubation (Walsberg 1980). Considering that there are air currents that surround the nest, it is difficult to establish standard gas concentration values in its interior (Rahn et al. 1977; Molenaar et al. 2010). However, in artificial incubation, the CO2 concentration is around 0.30% during the whole process, at the beginning, it is 0.05% and increases with the development of the embryos (Gildersleeve and Boeschen 1983; Molenaar et al. 2010). In this sense, Onagbesan et al. (2007) stated that the maximum concentration of CO2 is 0.50% depending on the fertile eggs and the rate of ventilation.

Effect of egg turning

To ensure the correct distribution of temperature, relative humidity and ventilation inside the incubator it is necessary to perform a proper rotation and turning of the eggs. Incorrect rotation delays egg hatching and decreases hatchability (Van Schalkwyk et al. 2000; Yoshizaki and Saito 2003). There is a discrepancy between the frequency of turning eggs, some authors suggest that 96 times per day (Wilson 1990; Elibol and Braket 2003), while others say that with 24 turns per day acceptable levels of hatching are achieved (Van Schalkwyk et al. 2000). To guarantee the correct turning it is necessary to tilt the eggs with an angle of rotation between 200 and 450 from the vertical; however, they can be tilted up to 450 (Elibol and Brake 2008).

The time of turning is decisive to ensure a correct distribution of incubation conditions, in addition to reducing early embryonic deaths, putrefaction, broken buds, contamination, poor breeder nutrition and avoid malfunctioning incubators and hatchers (Van Schalkwyk et al. 2000; Malecki et al. 2005). Turning the eggs in the first weeks could cause adhesions between the chorion membranes and the shell, due to the loss of liquid from the albumin to the yolk, a uniform movement allows the envelope and its membranes to move perpendicularly with respect to the contents (Elibol and Brake 2008). It is advisable to rotate the eggs between 8th and 11th (Elibol and Brake 2008). No turning of the eggs causes the allantois to adhere to the yolk sac (Moreno-Jiménez et al. 2017), the embryo adheres to the shell membranes (Elibol and Brake 2008); delay in the formation of the albumin sac and abnormality in the physical properties of amniotic and allantoic fluids (Moreno-Jiménez et al. 2017).

Candling and testing for fertility

Determine the fertility of the eggs is important to maintain the hygienic conditions of the incubator and ensure a high hatchability. In laying hens, it is recommended to perform the control at 7 and 14 days of incubation, however, in the ducks is at 7 and 21 days (Kusuma 2017). Eggs should be observed through a beam of light in a dark room. Figures 1 and 2 show how to develop an ovoscope, using a box with a bulb inside it and a hole where to place the egg (Figure 1) and in the other case lighting the egg with a battery torch through a box or tin can (Figure 2). In fertile eggs the presence of blood vessels should be observed around a dark red spot in the centre of the egg, unlike the fertile eggs the yolk of the infertile ones is observed as a floating spot without the presence of vascular network, in addition, eggs are observed opaque.

Sanitation

The disinfection of incubators plays an important role in the development of the embryo and the early stages of life of the ducklings. Losses from poor disinfection during incubation may be greater than losses caused by low hatchability.

To clean the incubators, it is advisable to use anti-irritant, anti-corrosive disinfectants, low toxicity, low residual effect, good germicides and effective in the presence of organic matter, the most commonly used in incubation trays and incubators are quaternary ammonia compounds (quats), multiple phenolic compounds and iodine compounds (iodophors)

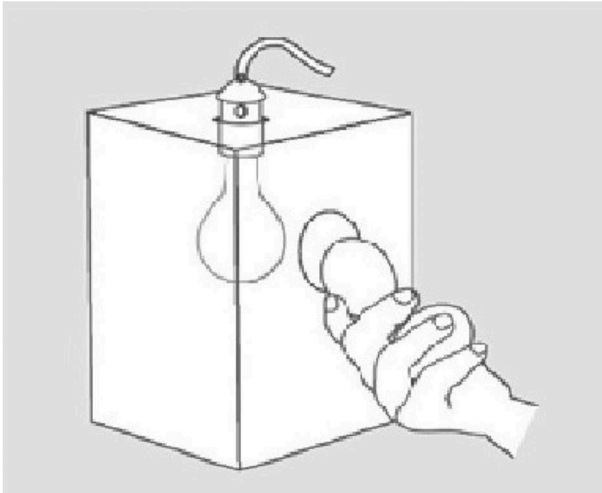

Figure 1. Candler using a light bulb.

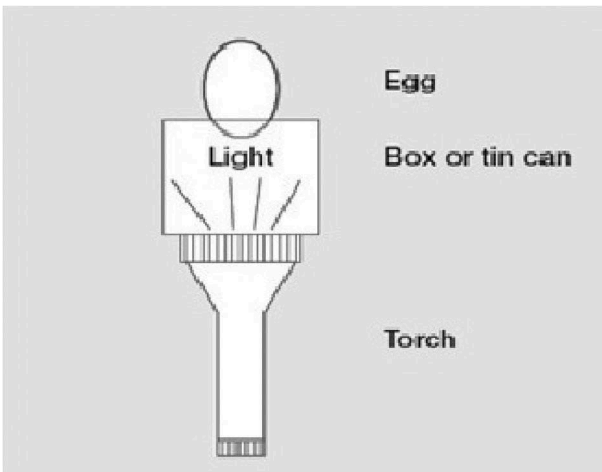

Figure 2. A torch Candler.

(Chen 2015). However, when these products are used for long periods, it is necessary to use gloves to avoid burning, in addition, concentrations higher than those indicated on the labels can cause stains and have a significant residual effect. Other products such as cresol, cresylic acid and coal tar are used for the disinfection of poultry farms and pens, due to their corrosive effects and harmful and toxic gas emitters.

It is advisable to carry out exhaustive disinfection after emptying the hatchers, to guarantee between 95% and 99% antimicrobial effectiveness. The position of clean eggs to incubate and periodically clean equipment allows a decrease in the use of disinfectants. However, if the eggs are dirty and the system is quick to "give or receive", the machines are constantly filled with eggs, the emptying is complicated, and it is difficult to perform a proper disinfection, to counteract this situation the fumigation could be used to carry out cleaning.

Hatching duck eggs in simple steps

Figure 3 shows some simple steps to incubate duck eggs. It is necessary to incubate eggs with no more than 3 days of laying, the hatchability losses are less than 3% in eggs stored less than 7 days, place the eggs in the tray with the small end down (Elibol and Brake 2008), in addition, if the eggs are stored in refrigeration should be placed at room temperature for 4 h before incubation. The conditions of the incubator should be optimal for the development of the embryo, rotation every hour (Elibol and Brake 2008), constant ventilation, temperature 37.5°C (99.5°F on wet bulb thermometer) and RH 55% (84.5°F). Fertility controls will be carried out after 7 and 21 days of hatchability. Eggs of Pekin duck will be transferred to the hatcher at 25 days while those of Muscovy will move to 32 days. At the time of transfer, the temperature of the hatcher should be 37.2°C and the RH around 65%; however, in the final phase of hatching, the temperature should be reduced to 36.1°C, the RH increase up to 70% and increase the ventilation openings. The Pekin ducklings will be taken out of the hatchery at 28 days while the Muscovy ducklings will be removed at 35 days when the 90–95% ducklings are dry.

Ways to improve hatchability

Different methods are used to improve the hatchability of eggs from waterfowl; however, the physiological effects on the embryo are not known. Cooling and periodic spraying with water are some of the most commonly used procedures (Ghonim et al.

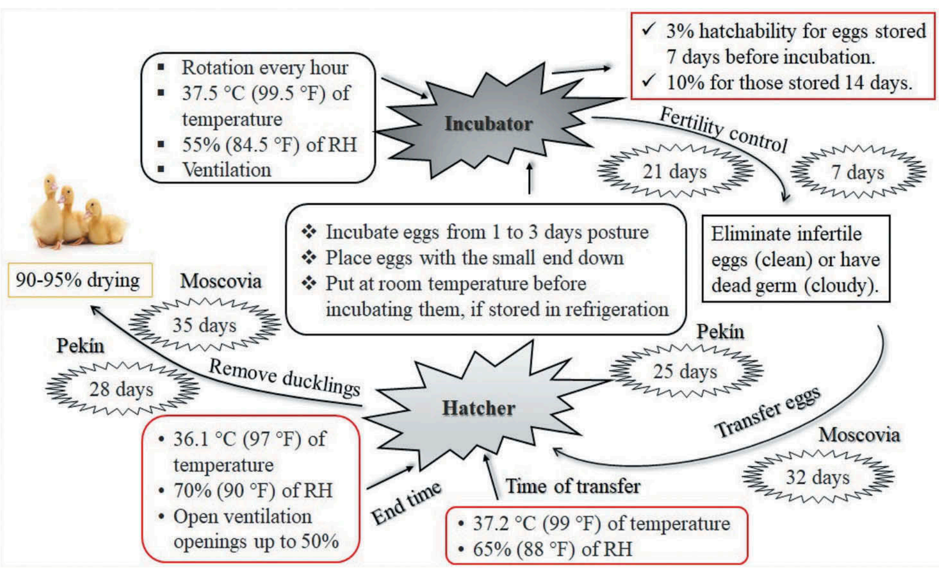

Figure 3. Steps to incubate duck eggs.

2008). In this sense, Harun et al. (2001) reported that Muscovy eggs hatch better when they are spraying than with nesting ducks, apparently because of a better simulation of natural incubation with the spraying.

The peak of the temperature of the metabolism (embryo peak metabolic rate) is 37.5°C, the optimum temperature for incubation; however, Nichelmann and Tzschentke (2003) found that between 39°C and 40.5°C is the thermoneutral zone of the Muscovy embryos according to age. The rate of oxygen consumption per gram of embryo mass can be modified when the incubation temperature is altered and the growth rate of the embryo changes. In the final incubation phase, the heat loss by evaporation is lower than the heat produced during the embryonic growth (Hoyt 1987). In this sense, Jibrin et al. (2011) found that the difference between the temperature of the embryo, and the temperature of the incubator is modified by an increase in the interior temperature of the egg with respect to the incubation environment.

According to the mathematical model of Meijerhof and van Beek (1993) for the temperature and moisture loss of the eggs to be incubated, the length is determinant during the incubation for the cooling and heating of the egg. In the early stages of incubation, the surface of the small eggs is warmer and more uniform than the surface of the large eggs; however, in the final incubation phase the opposite occurs, apparently due to surface heating due to the increase of blood flow in large eggs (Harun et al. 2001).

Dipping eggs during the incubation period is one of the tools used to improve hatchability percentage. In addition, it is considered the easiest method compared to the injecting eggs process (Ghonim et al. 2009). The addition of ascorbic acid (AA) may be beneficial for conditions of embryonic stress during incubation period (Awad and Abd El-Halim 2015). Eggs treatment with AA by dipping, injection or spraying may had positive effects on hatchability for any kind of poultry species. Dipping hatching eggs into AA solution (10 g/L) for 2 min had significantly improved hatchability and decreased embryonic mortality of eggs (Awad and Abd El-Halim 2015). Ghonim et al. (2008) informed that an important increase in hatchability and decrease in embryonic mortality due to dipping Muscovy duck eggs in different AA concentrations (10 up to 40.0 g/L) at the first day of incubation period. Also, El-Hanoun and Mossad (2008) suggested that immersion into liquid paraffin at 14th days of incubation or raising RH up to 80% from 14 to 28 days, could improve hatching percentage and birth weight of ducks Pekin. Moreover, Giri et al. (2012) concluded that dietary supplementation of vitamin E (0.5 g) and selenium (50 ppm) for 12 weeks to the laying native ducks improved egg production, fertility and hatchability.

Conclusion

This review compiled present and past information about the incubation factors that influence hatchability of duck eggs and also the new ways to improve the hatchability. This is because incubation conditions are the most important factors affecting the hatchability of duck eggs. And as is known, humidity, temperature, turning and ventilation during the incubation significantly affect the hatchability and quality of ducklings. It can be concluded that in the case of providing the appropriate conditions for hatching duck eggs, we will get a high hatchability and thus increase the production, but if any of these factors is disrupted, negative results will be given. Thus, there should be several studies to find new ways to improve the hatching rate in duck eggs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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