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Fertility and hatchability in duck eggs

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Ducks are waterfowl belonging to the *Anatidae* family of cosmopolitan distribution. In duck production systems, obtaining ducklings at one-day-old is determinant for the productive chain. The egg production in some species of ducks reaches about 250 to 300 eggs per year. Obtaining one-day-old ducklings can be done by natural incubation with a broody female duck or artificially in an incubator. During artificial incubation, fertility and hatchability are the most important indicators that must be controlled, because they influence the supply of ducklings to the farm. Many factors are related to fertility and hatching, such as environmental conditions, production system, season, nutrition, management of broodstock, storage time of egg and cleaning of eggs before the incubation. According to some reports, Pekin eggs have greater hatchability than Muscovy eggs. The eggs of Muscovy have presented values lower than 22.7% of hatchability. The hatchability of Pekin duck eggs was 78.0% in the spring, while in summer it was around 46.5%. The best hatchability is observed during the winter (57.68%), as in the summer it decreases to 54.14%. The reproductive characteristics of flocks, age, external and internal quality of the egg, male female relation, and presence of lethal genes are factors that directly involve breeders. Larger sexual ratios between males and females of 1:4.3 to 1: 10 cause reduced egg fertility from 75.9% down to 49.6%. Successful production of day-old ducklings starts with the proper selection and management of breeding stock, proper post-lay handling of fertile eggs and the correct incubation process. There are different methods used to improve the hatchability such as dipping eggs in nutrients during the incubation period.

Keywords: ducks; fertility; hatchability; eggs; incubation

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Introduction

Ducks are waterfowl that belong to the *Anatidae* family. Other waterfowl such as loons, grebes, gallinules and coots may be confused with this species (Idahor *et al.,* 2015; Ericson *et al.,* 2017; Farghly *et al.,* 2018a) but do not represent a monophyletic group; therefore, swans and geese are not considered ducks. They are distributed throughout the world, except in Antarctica (Idahor *et al.,* 2015), due to their adaptability to different environments. Because of the variable market demand for a one-day-old chick by the duck industry, fertility and hatchability are important economic factors which represent the major components of reproductive performance and are sensitive to environmental and genetic factors (Widiyaningrum *et al.,* 2016).

Fertility is defined as the percentage of embryonated eggs after three days placement in the incubator; meanwhile, hatchability is the percentage of fertile eggs that hatch (King'ori, 2011; Taplah *et al.,* 2018). Fertility and hatchability are affected by genetic and non-genetic factors. For a particular variety, non-genetic factors have a greater influence on fertility and hatchability in production (King'ori, 2011), Including management of the breeder, egg quality, and incubation processes. The management of breeding stock includes genetic selection (Drouilhet *et al.,* 2014), age of the breeders (King'ori, 2011), season and feeding (King'ori, 2011), breeding system and breeding technology (Weis *et al.,* 2011) and egg quality (Hester, 2017). The objective of the following review was to provide advanced information about the factors that affect fertility and hatchability of duck eggs and ways to improve them.

Fertility

Fertility can be affected by the quality of broodstock, male:female ratio, environmental temperature, storage time and housing systems. Brillard (2003) stated that fertility depends on the ability of females to ovulate, store sperm and provide an appropriate environment for the formation and development of the egg. Likewise, Brillard (2003) and Mohan *et al.* (2018) reported that the quality and quantity of semen deposited by the male were important to obtain good fertility. However, there are differences between duck breeds.

Muscovy ducks age influences the reproductive characteristics of both females and males (Yakubu, 2013). For flocks from the same breed, differences in fertility have been reported for different batches of eggs. In Muscovy ducks, the highest fertility is obtained at the peak of posture, compared to the moments before or after the peak of posture (Nickolova, 2005). Genitalia of waterfowl is more complicated than chickens, making the fertility issue more prevalent in ducks than in chickens, as well as the issue of sexual dimorphism in body size in some breeds of ducks and crossbreeding (Yakubu *et al.,* 2015).

The male:female ratio in all poultry species plays an important role in achieving greater fertility. For Muscovy ducks a ratio of one drake to five ducks is used according to Idahor *et al.* (2015) and one to four according to Nickolova (2005) and Alonso-Alvarez (2006). In Muscovy ducks, a ratio of one to six has been used satisfactorily where there is a shortage of males (Banerjee, 2013). However, larger sexual ratios of 1:4.3 to 1:10 cause a reduced egg fertility from 75.9% down to 49.6% (Nickolova, 2005), which corresponded with a loss in fertility from 97.09% to 93.41% when the sex ratio was increased from 1:5 to 1:8. In Khaki Campbell ducks, Giri *et al.* (2014) studies the ideal mating sex ratio for production of fertile eggs under intensive rearing and concluded that a 1:5 sex mating ratio was ideal for better fertility and hatchability.

An increase of the environmental temperature above the optimal ranges of thermal comfort in poultry affects productive performance of breeders. According to Chowdhury *et al.* (2004), heat stress causes a decrease in the number of germ cells, ovular release, fertilisation and survival capacity of the embryo and abnormalities in sperm of the Northern Pintail duck (Penfold *et al.,* 2000). The latter decreases deposition of sperm in the host gland in the reproductive system of female (Brillard, 2003; Abd El-Hack *et al.,* 2018). Fertility was significantly higher at months from January to May as compared to June to August months and was significantly lowered by 9.70%, 12.72% and 14.29% in Summer as compared to Autumn, Winter and Spring season, respectively (Awad, 2013)

The storage time before the incubation of Pekin duck eggs has a significant effect on their fertility, hatchability and early embryo mortality (Waehner *et al.,* 2015). Reyna and Burggren (2017) reported a decrease in the fertility of duck eggs stored for more than six days from laying to incubation.

Housing system influences the fertility of ducks, allows mass mating and provides access to swimming, which significantly increases the fertility rate as ducks are waterfowl by nature and prefer to mate in water (Ojewola, 2006). However, egg weight linearly improves fertility; in Khaki Campbell ducks, the egg weight increased from 60 g to 75 g when they had water access, which positively affected egg fertility (Giri *et al.,* 2014).

Hatchability

Factors attributed to the breeding birds, such as genetic selection, management and feeding, handling and storage of eggs and conditions inside the incubator can influence the hatchability of duck eggs. Archer *et al.* (2017) and Ramli *et al.* (2017) stated that the temperature, relative humidity, ventilation and turning of the eggs throughout incubation and hatching were environmental factors that can modify hatchability.

BREEDER MANAGEMENT

Breeders must use breeds with good genetic characteristics at optimal ages to obtain high fertility, hatchability and growth performance of progeny. The time of year and the feeding conditions play an important role in the development of the embryo, before and after incubation.

Genetic characteristics can influence the productive indicators of different breeds of ducks in varying ways. The Muscovy lineages, compared to the Pekin duck, show higher mortality due to adhesion to the egg shell and for normal ducklings, however, Pekin duck eggs have better hatchability than Muscovy eggs (Rashid *et al.,* 2009). The eggs of the Muscovy such have shown less than 22.7% of hatchability (Ali *et al.,* 1989). The fertility and hatchability of laying Brown Tsaiya ducks were increased when a genetic selection was made and one artificial insemination per week was combined with Muscovy semen (Cheng *et al.,* 2002).

AGE

The age of female ducks has more influence on fertility than age of males (Brommer and Rattiste, 2008). After 24 days of incubation, the relative weight of the yolk sac, with respect to total egg weight, increased in hens at 36 weeks compared with Pekin ducks at 26 and 31 weeks of age (Applegate *et al.,* 1998). On the other hand, increasing the age of the female decreases the functioning of the sperm storage tubules, leading to problems in the reproductive system which influences egg quality.

In addition, the age of ducks affects the external and internal quality of eggs, influencing both hatchability and fertility. The ratio between yolk and albumin decreased with increasing age of the birds (Peebles *et al.,* 2001). Larger eggs have comparatively less shell area per unit of interior weight than smaller ones, therefore, those from older broodstock have less weight when calculated in grams and more in percentage than the eggs of younger broodstock (Onasanya *et al.,* 2013). Age affects the deposition of calcium and minerals in the shell (Onbaşılar *et al.,* 2014). The shell allows gaseous exchange and loss of moisture from the egg, and poor shell quality results in excessive loss of relative humidity during incubation (Peebles *et al.,* 2001).

SEASON

The season when laying takes place affects fertility of ages and hatchability of ducklings, due to differences in temperature, wind speed, rainfall and relative humidity (Buhr, 1995; Farghly *et al.,* 2018b; Li *et al.,* 2018). Chowdhury *et al.* (2004) observed a high significance between the month and hatchability of Pekin duck eggs, where the hatchability in January was 59.54 ± 0.79%, but in July it decreased to 48.27 ± 0.79%. The best hatchability of Pekin duck eggs is observed during the winter (57.68 ± 0.59%), but during the summer it decreases to 54.14 ± 0.59%, and the lowest values are found in the monsoon or rainy season (49.13 ± 0.59%) (Chowdhury *et al.*, 2004). Hatchability of duck eggs showed the highest value in March (65.21%), but the lowest value (34.96%) was observed in August (Awad, 2013). Fertility and hatchability were lower in the summer months compared to other seasons due to high environmental temperature that causes a decrease in the reproductive efficiency in both male and female ducks.

NUTRITION

During egg formation, essential nutrients are deposited for the development of embryo during the incubation period and form reserves for the developing embryo until the first meal becomes available to the young birds (El-Kholy *et al.,* 2019; Saeed *et al.,* 2019). The nutrients are used for tissue formation, heat generation and muscle activity, and are stored in both albumin and yolk (Uni *et al.,* 2012; Onbaşılar *et al.,* 2014). Egg albumin from eggs from Pekin ducks is mainly water (85.7 to 88.1%) containing 10.9% to 13.1% water-soluble proteins and represents from 53.0% to 55.6% of the total egg content. Although the yolk only represents 31.3% to 33.9% of the egg content and 41.7% to 44.1% is water, it has higher protein reserves (17.3% to 17.8%), lipids (35% to 38.4%) and minerals (Yair and Uni, 2011).

Nutrient deficiencies impede the proper development of embryos, reduce hatchability and increase embryonic death, in addition to causing disorders of the musculoskeletal system, immune system and cardiovascular system (Uni *et al.,* 2012). The nutrients in the egg determine the weight of the duckling at birth, body size and hatchability. Therefore, feeding ducks correctly can increase deposition of nutrients in the egg, without causing any change in weight of the broodstock, which are important factors to consider to avoid low quality ejaculation and ovulation and, at an extreme, early ovarian and testicular regression (Brillard, 2003).

Certain nutrients and food ingredients have adverse effects on the quality and quantity of eggs produced by ducks. Anti-nutritional factors, such as gossypol from cotton seed meal, cause infertility in males manifested as immobility of sperm caused by damage to the mitochondria located in the tail of sperm, and extensive damage to the germinal epithelium (Randel *et al.,* 1992). Increased consumption of gossypol causes increased permeability of the yolk sac membrane which leads to excessive pigmentation of the albumin, known as 'pink disease' or white albumen which is mottled or gummy. It is necessary for producers to constantly update feeding standards and include new recommendations to ensure the quantity and quality of food necessary to the layer ducks.

Egg factors

Eggs are normally fertile four days after the deposition of the semen inside the female, and in this period all necessary components for the development of embryo until the birth should be present in the egg. Under normal circumstances, infertility is due to different factors related to the management of the broodstock and environmental conditions, since these are related to modifications in the physical and chemical characteristics that reduce embryonic development and hatching of good quality ducklings (Narushin and Romanov, 2002).

The management of broodstock plays an important role to ensure a good hatchability, breed used, season, health, and nutrition, also size, weight and quality of egg, in addition to the duration and storage conditions (Wilson, 1991; Onasanya *et al.,* 2013). The quality of eggs for incubation is determined by both external and internal characteristics, however, there are other factors that prevent hatching, such as the inheritance of lethal genes, lack of nutrients and sudden variations in incubation conditions (King'ori, 2011).

EGG QUALITY

Egg quality has a significant effect on hatchability, as conditions of the microenvironment during the storage process and early incubation modify both the external and internal quality of eggs (Narushin and Romanov, 2002). External characteristics such as weight, index form (described as maximum breadth to length ratio), shell thickness, porosity, surface quality of the shell and resistance to breakage have been measured (Toro *et al.,* 2015). Internal quality is determined by the height of the dense albumen and the yolk, in addition to Haugh Units. Haugh units are calculated as:

$$HU=100 \log (H+7.57-1.7W^{0.37})$$

where HU=Haugh units, H=albumin height and W=egg weight (Toro *et al.,* 2015).

Heavier eggs are more likely to hatch than those of low weight; however, there are contradictions about the weight of eggs that are not within the average values for incubation (King'ori, 2011). An increase in weight, shell thickness and internal contents of eggs leads to a higher total weight, which in turn reflects more reserves of nutrients and energy (Toro *et al.,* 2015). Light weight eggs have relatively shorter incubation times (Weis *et al.,* 2011) and the weight of hatchlings is higher from large eggs. It is important to note that, during incubation, larger embryos produce a greater amount of heat, which requires good ventilation to maintain the correct temperature (Jibrin *et al.,* 2011).

Likewise, egg size affects hatchability. Wilson (1991) and Weis *et al.* (2011) found that medium-sized eggs from Muscovy ducks had better hatchability than small eggs. In this sense Demirel and Kırıkçi (2009), found a greater increase in yolk compared to albumin as the egg size increased, which could be a major influence.

With longer storage time, HU decreases and pH of the albumin increases, apparently due to loss of water (Martínez *et al.,* 2014). Elibol *et al.* (2002) stated that the low pH in fresh eggs did not affect fertility and hatchability, however, other authors indicated the opposite, and perhaps this difference may be due to different flock age (Benton and Brake, 1994).

EMBRYO SURVIVAL

According to Kuurman *et al.* (2003), mortality describes a curved, diphasic Weibull distribution, due to the peaks of mortality in the first and last third of incubation. The survival of the embryo does not only depend on environmental conditions before and during incubation, factors related to the genotype of the dam and the sire, mainly the dam, affects the survival of the duckling within the egg. Chromosomal aberrations and lethal genes acquired from the sire and dam can cause high percentages of early embryonic mortality (Liptoi and Hidas, 2006). The stage of development decreases the heritability of the susceptibility to embryonic death, from 0.09 for early mortality to 0.05 for late mortality, based on the parent component and from 0.25 to 0.18 based on the dam component (Beaumont *et al.*, 1997). In this sense, Bennewitz *et al.* (2007) reported low direct heritability of hatchability, based on linear and threshold models respectively, with hatching capacity treated as a trait of the dam.

EGG STORAGE

The microenvironment conditions during storage, storage time and position of the eggs on the incubation tray are important to guarantee a profitable production of ducklings, especially for production in the tropics and subtropics. To avoid the effect of heat stress on the embryo during storage, temperature should be 13°C (55°F) and never higher than 24°C, and relative humidity should be less than 75% but higher than 40% (Buhr, 1995). Eggs stored under refrigeration should be placed for 4 h at room temperature before incubating (Onbaşılar *et al.,* 2007). Onbaşılar *et al.* (2007) reported that hatchability was lower and early embryonic death rate was the highest in eggs stored for 11 d. Saha *et al.* (1992) reported that hatchability of Khaki Campbell duck eggs was greatest in eggs stored for 3 d compared to 7 d pre-incubation.

It is advisable not to store eggs for more than two weeks, as hatchability decreases significantly after 14 d. Researcher have shown that storage period is related to both early and late embryonic deaths (Onbaşılar *et al.,* 2007). The hatchability of total and fertile eggs decreased with increasing storage period, since early and late embryonic death was higher due to loss of water and degradation of albumin during storage.

However, the optimal storage period is not fixed. It varies according to the age of the batch and the strain and species, due to the differences in the quality of the albumin. Keeping eggs with the small end down and the large end upwards can result in more successful hatching than when doing the opposite, perhaps because the incorrect orientation of the head of the embryo towards the larger pole prevents correct elimination of water. In this sense, Bauer *et al.* (1990) reported a 17% decrease in the hatchability of embryos of broilers located with the small pole up. Apparently, this happens because the embryo cannot find the air chamber that is located in the round pole, especially at the end of incubation (Bauer *et al.,* 1990).

Conclusions

Success of the duck sector at small or large scale depends on a regular supply of one-day-old chicks. The production of ducklings is influenced by the fertility and hatchability of the eggs, which are important economic factors representing the major components of reproductive performance. Fertility and hatchability are most sensitive to the environmental and genetic influences. There are many factors related to producers, breeders and environmental conditions during incubation that can influence these parameters, including managerial, nutritional and genetic factors as well as eggs quality and incubator factors. There are different methods used to improve the hatchability percentage of waterfowl eggs - cooling and periodic spraying with water are some of the most commonly used. Dipping eggs and *in ovo* injection with nutrients such as ascorbic acid and vitamin E during the incubation period is one of the tools used to improve hatchability percentage.

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