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Factors Influencing Fertility and Hatchability of Poultry

Nabiyu Tilahun Kuda
School of animal science and range science, Haramaya P.O. box 138, Dire Dawa Ethiopia
Email: nabiyutilahun@gmail.com

Abstract
Poultry production at all scales of operation is wholly dependent on the supply of day-old chicks. Two important factors that have a significant impact on the supply of day-old chicks are fertility and hatchability. Hatchability is the proportion of fertile eggs that actually hatch, whereas fertility refers to the proportion of fertile eggs that are incubated. Understanding the elements that affect the fertility and hatchability of eggs is important. Breeds, diet, age of the hens, environmental stress, egg weight, shell thickness, porosity, and form index are the most important variables that affect fertility and hatchability. The internal and exterior egg characteristics are diminished by heat stress. Heat illness has an impact on all stages of the breeder's semen production. The fertility and hatchability of eggs are impacted by various facilities, including storage crates, hatcheries, and incubators. As a result, offering the best management and developing intervention strategies for improvement can increase poultry fertility and hatchability.
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1. INTRODUCTION

Livestock is an important subsector of agriculture, and poultry is one of the most important subsectors of livestock, supplying a cheap source of good-quality animal protein in the form of meat and eggs (Tunsisa and Berihun, 2022). Poultry are among the most common livestock species in Ethiopia with an estimated of 57 million, of which total poultry regarding to breeds, 78.85%, 12.02% and 9.11% were indigenous, hybrid and exotic, respectively (CSA,2021). It is also expected that this number will increase because it tends to follow the rapid population growth and urbanization human, shortage of cultivating and grazing land, unemployed and high and unbalanced protein demand. Poultry is relatively become with the most preferred animal (Belay *et al.,* 2018).

Poultry production offers considerable opportunities in terms of generating employment opportunities, improving family nutrition, empowering women, and ensuring household food security (FAO, 2019). The sustainability of poultry production at all operational scales depends on a steady supply of day-old chicks, with egg fertility and hatchability serving as primary determinants of supply because they are important reproductive parameters. Fertility and hatchability are affected by environmental and genetic influences (Sapp *et al.,* 2004, Abdurrahman *et al.,* 2016).

The ability of male and female chickens to reproduce when they mate and have children is reflected by the parameter of fertility, which is significant in chickens. An egg is said to be infertile when it fails to show any evidence of a developing embryo and it depends on various factors such as breed, season, pre-incubation holding period, lighting, level of nutrition, mating, and time of mating (Miazi *et al*., 2012; *et al.,* 2015). The hen's capacity to reproduce successfully, store sperm, release an egg cell, and provide an environment favorable to the embryo's formation and growth all have an impact on an egg's fertility (Brillard, 2003). Moreover, effective mating of the hens as well as the quantity and caliber of semen they laid are key factors in fertility (Brillard, 2003). Similar to living beings, birds' fertility is influenced by both a female's and a male's age (Hocking and Bernard, 2000; Gumuka and Kapkowska, 2005).

Hatchability is the percentage of eggs that make it through incubation and hatch into chicks. Because of its significant impact on chick output, it is a characteristic of economic significance in the chicken industry (Khalid *et al.,* 2015). High egg hatchability is somewhat heritable but is influenced by a complex genetic makeup and the environment (Wolc *et al.,* 2010; Adedeji *et al.,* 2015). Inheritable features associated to fertility and hatchability differ between breeds, varieties, and individuals within a breed or variety (King'ori, 2011). Knowing key elements that affect egg fertility and hatchability at each stage is crucial for the poultry industry's success. Therefore, the first goal of this essay is to discuss the variables that affect the fertility and hatchability of chicken eggs.

2. FACTORS INFLUENCING FERTILITY and HATCHABILITY OF POULTRY

2.1 Effects of Breed on Fertility and Hatchability

Fertility and hatchability are interrelated heritable traits that vary among breeds. According to Abdurrahman and Urge (2016), local chicken genotypes exhibit higher levels of fertility and hatchability than exotic and crossbred chicken genotypes. This variation might come from the source of the eggs. This report is comparable to that of (Berhanu *et al*., 2022) on a study of indigenous chicken eggs collected from farmers that may experience reduced fertility and hatchability due to handling and stress during transport, as opposed to Sasso and crossed eggs produced in farms with careful handling, an appropriate male to female ratio, and minimal stress during transport. The hatchability of the pure normal feathered chicken is 86.36%, according to the study by Ajayi and Agaviezor (2016), while only 62.09 and 66.90% were recorded for the pure frizzle and naked neck strains of Nigeria. While analyzing reports from different sources, Ajayi and Agaviezor (2016) found that the hatchability % was greater for pure, normally feathered Nigerian chickens and comparable for pure frizzle and naked neck (Berhanu *et al.,* 2022). Desha *et al.* (2015) observed that native chickens in Bangladesh had a greater percentage of hatchability but a corresponding proportion of fertility.

The hatchability of fertile eggs for indigenous, Sasso, and crossbred was within the range (67.9%-89%) previously reported by (Alawi and Melesse 2013; Bamidele *et al.,* 2020) for indigenous, exotic and their crosses in Ethiopia. Moreover, the hatchability of fertile eggs for all three genotypes agreed with the reports under the study of Alabi *et al.* (2012) and Esatu *et al.,* (2011), who reported values ranging from 52.4-87.0% for indigenous and exotic and almost nearest even for crossbred (88%).

2.2 Effects Of Nutritional on Fertility and Hatchability

Quality and quantity-based nutrition is a vital aspect to increase fertility and hatchability of poultry eggs. The right quality and quantity of feed are essential for birds in providing energy to carry out the process of mating and invest some nutrients in the egg. In most poultry species like ostriches, egg size is an indicator of maternal investment in the egg (Dzoma, 2010). Egg size can be improved to increase the hatchability rate by manipulating fat levels, protein and enzymes addictive (Abiola *et al*., 2008).

Reproductive poultry should consume a diet that is sufficient in terms of both quality and quantity to maintain the necessary levels specified in the category's feed criteria. In the management of breeder poultry, feed is regulated to prevent excessive weight gain, a major cause of poor-quality ejaculate and ovulation and at extremes, early ovarian and testicular regression (Ogbu and Oguike 2018). This will ensure the production of good quality and the number of eggs and semen. However, new recommendations have been made over time from studies that have been carried out to address handicaps that producers have encountered in the industry (Ogbu and Oguike, 2018).

Conjugated linoleic acid caused 100% embryonic mortality in fertile chicken eggs, according to research by Aydin *et al.,* (2001). In Japanese quails, embryonic mortality occurs depending on the Conjugated linoleic acid dose and duration of feeding the diets supplemented with Conjugated linoleic acid (Ayidin and Cook, 2004). Embryonic mortality occurs in eggs because of the modification of the fatty acid composition of the egg yolk due to the low ratio of unsaturated to saturated fatty acids. Significant changes in the fatty acid composition of egg yolk have adverse side effects on embryo survival (King'ori *et al.,* 2011). Dietary Conjugated linoleic acid leads to a lower concentration of monounsaturated fatty acids and higher concentrations of saturated fatty acids in the egg (Park *et al.,* 2000; Ayidin and Cook, 2004). Javanka *et al.,* (2010) reported improved egg fertility and hatchability of fertile eggs of breeding layers fed brewery by-products. Brewery by-products have linoleic acid content of 4-5% which is responsible for increasing the fertility and hatchability of fertilized eggs. Supplementation of laying hen diets with organic selenium (Sel-PlexTM) improves the hatchability of fertile eggs (Hanafy *et al*., 2009).

Egg shell quality is an important economic factor in both hatching eggs and table eggs. Feed containing some mycotoxins, like ochratoxin A, can affect kidney function by impairing vitamin D3 production and consequently, calcium metabolism (Biomin, 2013). This can lead to poorer shell quality, more breakage, and reduced hatchability. In poultry diets, some nutrients are more essential than others, depending on the species of birds. Calcium and zinc have documented competition in gastrointestinal tract absorption in ostriches (Dzoma 2010). Also, an abnormal increase in some feed ingredients like conjugated linolenic acid (CLA) can harm hatchability by decreasing egg weight and yolk size, therefore causing embryo mortality among fertile eggs (Ayidin and Cook, 2004).

2.3 Effects of Age of Poultry on Fertility and Hatchability

The age of the laying hen influences the fertility and hatchability of eggs. The study reported by (Uni *et al.,* 2012) shows that the age of the hen has an influence on the size of the egg, as well as its yolk and albumen components. Hen age influences the fertility of eggs and there is a general tendency for fertility to decline with age. Also, there is greater variation in fertile egg percentage in the early production cycle than latter. Similar to the report of Othman and Rahman (2014) shows that there is a highly significant difference between the effects of the age of the hen on the fertility rate of eggs. They reported the largest fertility rate among the age of hen groups was found in middle-aged hens with an average of 98.94 percent, followed by 94.91 percent in the oldest age and 90.20 percent in the youngest group of hens.

The fertility decreased significantly with the increase in the hen's age. In this research Breeder factors that affect hatchability include strain, health, nutrition and **age of the flock**, egg size, weight and quality, egg storage duration, and conditions (Tona *et al*., 2005). Older breeder eggs tend to lose more weight in grams but less in percentage when compared to eggs from younger breeders. This is due to the associated increase in egg weight, as larger eggs have less shell area per unit of interior egg weight than smaller eggs Fertility generally declines after a peak (Brother stone *et al.,* 2000).

The study report of Othman and Rahman (2014) reveals that there was an insignificant difference between the effects of the age of the hen on the hatchability rate of eggs set based on fertile eggs. However, the eggs from hens of the middle age group had numerically the largest (76.96 %) hatchability among the age groups of hens and the oldest age group showed the smallest hatchability rate. In the same experiment, the hatchability rate was found to be reduced due to increasing age higher than 8 months and above. This finding was in agreement with an experiment conducted by Dudusola (2013) in Nigeria who noticed that the hatchability of fertile eggs was reduced due to increasing parental age. In his experiment, the hatchability of hens at 5.5 months and 9 months of age were 96.05 percent and 78.85 percent, respectively. There is more infertility and early embryonic mortality in eggs from Ross 308 compared with Cobb 500 broiler strains as the flock ages (Abudabos, 2010). Higher fertility has been recorded for light (White Leghorn) when compared with heavy breeds (Barred Plymouth Rock, Rhode Island Red, White Rock and New Hampshire) (Islam *et al.,* 2002). And he observed that the black Olympia and Hubbard and Nick strains (layer-type chicken) were 20% and 19%, respectively higher in egg fertility than the investigated Nigerian local chicken (King'ori (2004) reported lower hatchability of Kenyan local chicken eggs as compared to egg-type chicken hybrids. For a flock of the same breed difference in fertility has been reported for different batches of eggs laid at different periods (Islam *et al.,* 2002).

Considering the overall hatchability traits, the breed has little effect on the hatchability of poultry eggs (Islam *et al.,* 2002). The optimum cock; hen ratio to ensure the production of fertilized eggs should be maintained for the class of poultry under consideration. This ratio ranges from 1 cock for 5-10 hens, depending on the system (intensive or extensive) of production and size (light or heavy) of the breed. Heavy breed hens and extensive systems require more cocks. Inseminating a hen within 30 minutes after oviposition, the connective tissue around the vaginal wall is flaccid. This will result in venting and therefore bring about deep insemination which is associated with embryo mortality during hatching, which can lead to pathological polyspermy (Dymond, 2013).

2.4 Effect of Egg Factors on Fertility and Hatchability

Under normal circumstances, a fertile egg contains all the nutrients necessary for the development of the embryo to hatch. However, there are certain physical and chemical conditions of the egg that may lower or cause no hatchability at all. These may be due to the hen or environmental factors. Eggs usually become fertile about four days after the cock has been introduced to the hens. The physical characteristics of the egg play an important role in the processes of embryo development and successful hatching (Narushin and Romanov, 2002).

There are so many aspects of the egg that can either promote hatchability or mar it. These factors can be external or internal. The external properties include; eggshell thickness and porosity eggshell weight, eggshell breaking strength, eggshell chemical analysis eggshell color, and egg-specific gravity (Bramwell, 2009). These external traits of the egg are measurable to determine their level of influence on the rate at which the egg can hatch. Egg color is determined by a colorimeter, and specific gravity is checked with a salt solution or Archimedes' method (Diamond,2013). The shell weight (g scale) shell thickness is measured with a micrometer screw gauge (England *et al.,* 2012). The interior properties (yolk and albumen) can be evaluated by, checking the colour and strength of the perivitelline membrane with the aid of the Roche scale (Roberts 2004). The albumen is measured with haugh unit. (England *et al.,* 2012). Abiola *et al.,* (2008) have also stated that hatchability has a positive correlation with egg size. Washing eggs with liquid disinfectant before setting them in the incubators, possibly leads to disruption of the protective cuticles of the eggs shell, hence the use of fumigation should be routinely carried out before setting the eggs in the incubator (Markos S. *et al.,* 2017). The largest egg size group had significantly the reported highest hatchability (80.95%) followed by the other two groups with insignificant differences between the medium (60.45%) and smallest (66.73%) egg size groups. These results correspond with the result conducted by Sachdev *et al*. (1985) in India who noted that the hatchability of the fertile eggs was highest in heavy (10.1- 11.0 g) eggs.

Both thick shells and firm interiors, which are accepted as being higher than average, lead to an increase in egg weight, which probably results in the more successful hatching of embryos from heavier eggs. Best hatchability (97%) was reported for medium size eggs (50 g) of Anak broiler eggs (Abiola *et al.,* 2008). Large eggs (60 g) had the lowest hatchability (83%). As egg size increases, yolk size increases more than the quantity of albumen, ideal hatchability in broilers is achieved when the egg weight ranges between 55-65 g and 43-47 g in Kenyan indigenous chicken (King'ori *et al.,* 2010).

2.5 Effect of Storage of Eggs on Fertility and Hatchability

Eggs that have been in storage for more than a few days won't hatch, nor will eggs that have been laid after 10 to 14 days. Because the egg gets more alkaline as a result of CO2 loss via the shell, albumen becomes more translucent or watery (Ebenebe, 2014). The embryos that do survive early embryo mortality in stored eggs have a tendency to grow slowly and hatch slowly. Short periods of incubation during egg storage can remedy the issue whereby hatchability declines as egg age increases (Ogbu and oguike, 2018).

Eggs stored for more than a few days will not hatch, as well as eggs set when they are 10 - 14 days old. This occurs due to the loss of carbon dioxide (CO2) through the shell making the egg more alkaline thus, albumen becomes more transparent or watery (Ebenebe, 2014). Stored eggs have many early- embryo mortality, and the embryos that survive tend to develop slowly and are slow to hatch. Hatchability fails as the age of the egg increases, a situation which can be improved by introducing, short periods of incubation during egg storage (Ogbu and oguike, 2018).

Grochowlka (2019) reports egg storage time also differentiated eggs in terms of percentage of egg weight loss; however, optimal period lengths, resulting in a lower percentage of egg weight loss, were different concerning broiler breeder strain and setter or hatcher type. The detailed results for each subset were obtained in the present study in one analysis due to the application of the classification tree technique which agrees with those reported by Basha (2015), who observed progressive increment in egg weight loss during incubation after a prolonged pre-incubation period. Other studies considered the percentage of egg weight loss during pre-incubation time (among others Samli *et al.,* 2005; Alsobayel *et al.,* 2013). These authors observed that the level percentage of egg weight loss increased with the extension of pre-incubation time.

Moreover, Alsobayel *et al.* (2013) also reported that the interaction between breed and pre-incubation egg storage time was significant, which might drive to the conclusion that the genotype of each broiler breeder strain influences the regulation of expression of genes responsible for shaping this trait. Although ours and the other aforementioned studies show a negative effect of prolonged preincubation time on the percentage of egg weight loss both during storing and incubation, in practice storage of hatching eggs is an indispensable part of hatchery operation on breeder farms and at hatcheries aiming at reducing the transportation costs. Taking this fact into consideration, water loss is an important factor that influences the chick yield that is necessary for quality chicks. Water loss as well as chick weight and chick yield are closely related and have an impact on the post-hatch performance (Jabbar and Ditta 2017).

2.6 Effects of Equipment on Fertility and Hatchability

Facilities have constantly been used in the process of ensuring the continuous production of chicks via the hatching of fertile eggs. This equipment includes incubators, hatchers, storage crates, thermometers, barometers, etc. Factors that influence the incubator are egg-turning practice, humidity as well as sanitization. Incubation can be done naturally by the brooding hen or artificially with a modern incubator, designed to hatch eggs (Ogbu and oguike ,2018). In artificial incubation, a constant temperature of 38.6^{o} C accelerates embryonic growth, and utilization of nutrients and energy from the yolk and albumen reserves, but later decreases embryonic development due to limited metabolic process by insufficient exchange of oxygen (Louren *et al.,* 2005).

In the incubator, the hatchability of eggs stored for about 10-14 days before setting, reduces significantly (Roma *et al.,* 2008). The position of the egg in the incubating tray also influences hatchability. Tiwari and Maeda (2005) reported that eggs stored with a small end-up had higher hatchability rates than those with a large end-up. This could be due to reduced water loss from the exposed surface area. But in the incubating tray, it is ideal to set up the large end for if small ends are set up, hatchability is reduced by 17% in breeder boilers while it takes longer time in quail eggs (Mahdi *et al.,* 2010).

2.7 Effect of Artificial incubation on Fertility and Hatchability

The modern incubator is a simulated artificial design that mimics the mother-hen's role of providing fertile eggs with optimum environmental conditions (temperature, egg turning and humidity) to stimulate embryonic development until hatching. Hill (2001) and Lourens *et al.* (2005) showed that environmental temperature is the most important factor in incubation efficiency. A constant incubation chick embryo (Lourens, 2001) and gives the best embryo development and hatchability (Lourens *et al.,* 2007; Incubator temperature should be range is 36-38.9 C. Mortality is seen if the temperature drops below 35.6c^{0}or rises above 39.4 C^{0} for several hours. If the temperature stays at either extreme for several days, the eggs may not hatch. Overheating is more critical than underheating. Running the incubator during incubation initially accelerates embryonic growth, and utilization of nutrients and energy from the yolk and albumen reserves, but later decreases embryonic development as a result of the limited metabolic process by insufficient exchange of oxygen (Lourens *et al.,* 2007).

The hatchability for Meat and Egg type quail eggs is around 84% until 10 days of storage and then this rate decreased significantly (Romao *et al.,* 2008). Both types of quail eggs presented similar weight loss during storage and incubation. The research showed that quail eggs present great hatchability until 10 days of storage and that eggs submitted to storage present a reduced weight loss during incubation. Incubation procedures are important for successful hatching. Store fertile eggs in a clean place at 13-16^{o}C and 70-75% humidity. Never store eggs at temperatures about 24^{o}C and at humidity lower than 40%. These conditions can decrease hatchability dramatically in a very short period. Measures aimed at reducing the adverse effects of heat stress on embryo development are of great importance for profitable chick production in the tropics and sub-tropics.

Egg turning during incubation is important for successful hatching and influences hatchability. No turning of eggs during incubation results in low hatchability and delays hatching by a few days (Van Schalkwyk *et al.,* 2000; Yoshizaki and Saito, 2003). Improved management of eggs during incubation may therefore help to increase the hatchability. The optimum turning frequency is 96 times per day Elibol and Brake, 2003), although 24 times per day is accepted as the most practical under commercial circumstances, due to relatively small differences between 24 and 96 times (Elibol and Brake, 2008).

It is critical to turn the egg in the first week of incubation because at this time a large area of the chorion lies close to the shell membranes and the layer of albumen between the two has been greatly reduced by a loss of fluid from the albumen to the yolk. It is therefore possible to have adhesions between the chorion and shell membranes unless the shell and its membranes are particularly moved relative to the contents by turning the egg. Some causes and problems associated with poor hatchability are early embryonic death, egg rots, broken yolk, dead-in-shell chicks, prolonged pre-incubation storage, poor breeder nutrition, breeder age, contamination, incubator and hatcher malfunctions (Chabassi *et al.,* 2004; Ipek and Hassan, 2004; Hassan *et al.,* 2004; Malecki *et al*., 2005; Van Schalkwyk *et al.,* 2000).

2.8 Environmental factors on Fertility and Hatchability

According to King'ori (2010) temperature and photoperiod are two main environmental factors that influence the fertility and hatchability of eggs. It involves a lot more, temperature (37.2- 39.40c), relative humidity of 56-60 and ventilation (21%oxygen) (Oluyemi and Roberts 2000). The incubation temperature for hatching most poultry eggs (domestic birds and some wild species) is surprisingly uniform 99 – 100ºF (Msucaores, 2004). Laying hens subjected to abnormally high environmental temperatures (heat stress) typically have declines in egg production and in the shell quality of eggs that are produced. The decline in shell quality is associated with a reduction in the blood, as a result of hyperventilation induced by heat stress (Husvéth, 2011).

The two key parameters affecting fertility and hatchability are temperature and photoperiod. The testes of male turkeys exposed to a relatively short photoperiod (10.5 L) grow early and persistently throughout the entire reproductive cycle (Brillard,2007). However, as with other bird species, male turkeys who are photo refractory (a physiological response to light stimulation in which birds are initially stimulated by increasing and/or long photoperiods become progressively refractory to light stimulation) exhibit a progressive decline in plasma LH along with an irreversible regression of the testicles (Follet and Robinson, 1980). This lowers semen quality and quantity leading to poor fertility.

For poultry, a temperature range of 12-26 ºC is ideal. Feed intake was 20% lower in chickens under heat stress brought on by high ambient temperature and relative humidity. The internal and external egg characteristics are diminished by heat stress. High ambient temperatures reduce the egg's ideal calcium deposit, albumen consistency, and yolk size (Mahmoud *et al.,* 1996). The depression is brought on by an imbalance in the calcium-estrogen connection, a decreased albumen Haugh unit, and a decrease in the chickens' voluntary feed intake. The physiological reaction to heat stress, which aims to reduce excessive endogenous heat generated in the body due to feed metabolism, is blamed for the decrease in voluntary feed intake (Ayo *et al.,* 2010).

According to Banks *et al,* (2005), heat stress has an impact on every stage of the production of semen in breeder cocks. Due to a loss in somniferous epithelial cell differentiation caused by heat stress, reproductive capacity is reduced over time. This is seen in a drop in semen quality and quantity (Obidi *et al.,* 2008). Since heat stress inhibits intracellular ion exchange, it negatively affects testicular function. (Obidi *et al.,* 2008) In comparison to values obtained from males maintained at 21ºC, male fertility in broiler breeders exposed to 32oC decreased to 42% and in vivo sperm-egg penetration decreased to 52%. Environmental temperatures outside the thermal neutral zone reduced the volume, consistency, and spermatozoa concentration of semen (Obidi *et al.,* 2008). The lower number of spermatozoa stored in the sperm nest gland in the hen's reproductive tract may be the cause of the reduced in vivo sperm-egg penetration and fertility in heat-stressed roosters (Bakst *et al*., 1994; Bakst, 1998; Brillard, 2003). Due to heat stress, roosters in the natural mating breeding system are known to exhibit reduced mating activity and decreased libido, most likely as a result of dehydration and changes in sex hormone production. Heat stress-induced fertility in avian species has been linked to sperm defects such as micro-cephalic, bent head, broken mid-piece, and cytoplasmic droplets (Penfold *et al.,* 2000).

3. CONCLUSION

The sustainability of the modern poultry industry depends on a regular supply of day-old chickens, which are affected by two major reproductive performances; fertility and hatchability of chickens. Both fertility and hatchability are affected by different factors like breeds of chicken, nutrition, egg quality, age of chicken, environmental temperature, incubator, and different equipment. However, the level or degree and mechanism of action they affected are could vary. Of this fertility is highly affected by nutrients, breed, age of chickens, and environmental temperature. Whereas storage equipment, incubator, and egg quality highly affect the hatchability of poultry eggs. Therefore attention should have been given to the management's intervention and breed improvement to enhance the fertility and hatchability of poultry eggs.

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