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Reproduction in Guinea Fowl: A review

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Abstract

This work is aimed to provide relevant information required for effective management of reproductive traits in guinea fowl. Sexing in guinea fowl is difficult to practice because of the similarity of sex indicators that occur between males and females, yet sexing can be done at all stages of development in guinea fowls. Mating ratio in guinea fowl differs within breeds and systems of production. Pubertal traits varied within breeds and also depend on management. In extensive rearing system, puberty of guinea fowl cock and hen may be delayed up to a year and consequently reduced the quantity and quality of semen and egg production respectively. In intensive system, guinea hen may attain puberty at 16 to 17 weeks and improved its egg production to about 100 - 180 eggs/bird/year. Fertility of guinea fowl egg is about 53% in hens mated naturally but can be improved to 80% when the hens are inseminated. Hatchability of guinea fowl egg is about 80% in first clutch and slightly decreased in second clutch of 12 to 15 eggs in natural incubation. Hatchability is about 70% in manual incubation and above 80% in automated incubation of guinea fowl eggs. Keet mortality is between 33.1 to 68.9% in free range system while about 5% keet mortality may occur in keets raised under intensive management. Poultry farmers should therefore adopt the advisory practices reviewed in this work for effective management of guinea cocks, hens, eggs and keets in small and large scale of production.

Keywords: Local guinea fowl, exotic guinea fowl, free range system, intensive system and hormone

Introduction

Guinea fowl (*Numida meleagris*) originated from Africa but has ubiquitous distribution in America, Europe and Asian (Moreki and Radikara 2013). Its attractive plumage and value as a table bird with game-type flavour and high meat to bone ratio has led to its worldwide acceptance (Moreki, 2005). Guinea fowl meat and egg are cheap and are nutritionally superior to chicken products (Moreki and Seabo 2012) and serve as buffer to shortages of poultry products in many African countries including Nigeria (Onyeanusi, 2007; Ocheja *et al*. 2010). The bird is not only reared for income but also for socio-cultural purposes (Yildirim 2012). Guinea fowl production requires less capital, labour and management than chicken. This is because the fowl has greater capacity to scavenge for insects, grains and forage; better ability to protect itself against predators; and better resistance to common poultry parasites and diseases (Microlivestock 1991). According to Ikani and Dafwang (2004), guinea fowls perform better in tropical areas like Nigeria where their hardiness and scavenging ability have enable them to survive and produce under harsh conditions.

Despite the above mentioned qualities, guinea fowl production is still at a low level in Nigeria (Dougnon *et al.* 2012) and this level of production is unable to meet the demand of consumers in Nigeria (Ayorinde, 2004). This may be because of their seasonal breeding behaviour with many limitations associated with it. It has been reported that guinea fowl, unlike chicken, naturally has low egg producing ability (Adeyinka *et al*., 2007), with low percentage of egg fertility and hatchability (Kabera, 1997; Yildirim 2012), and high keets mortality (Dougnon *et al*., 2012). Currently, there are a lot of fragmented information on various aspects of guinea fowl production. This manuscript is deliberately designed to review and compile relevant works on guinea fowl reproduction and hence present it as a practical guide required to improve production of guinea fowl.

Sexing

Sexing is the ability to identify the gender of animals. Sexing aids farmers to appropriately house, feed, breed and adopt other practices required for effective parent-stocking (eHow, 2008). Sexing is ambiguous in guinea fowl stocking, because of the difficulties in identifying the slight differences in the physical appearance of guinea cocks and hens. Indicators for sexing of guinea fowls are fewer than most avian species but uniquely their eggs and some phenotypic attributes can be sexed as shown in Table 1 below.

Table 1: Sex indicators of guinea fowl at different stages of development

Stage of Development	Indicator	Sex	Reference
Eggs	Eggs with narrow end more pointed	male	Avornyo*et al*., 2007
	Eggs with narrow end slightly round	female	
2weeks keets	Pelvic inlet is ≈4.6mm	male	Awotwi, 1987
	Pelvic inlet is ≈5.8mm	female	
4weeks keets	Longer necks and bigger keets in the clutch	male	Avornyo*et al*., 2007
	Shorter necks and smaller keets in the clutch	female	
	Rudimentary phallus is fully developed	male	Teye and Gyawu, 2002
	Rudimentary phallus is not development	female	
9weeks and above	More elongated and larger head, higher body frame, more pronounced and more concave wattles, more protruding helmet, and monosyllable sound	male	Avornyo*et al*., 2007 eHow, 2008
	More rounded and smaller head, lower body frame, less pronounced and flatter wattles, less protruding helmet, and disyllabic sound	female	

Sex-ratio and sexual behaviour

Sex-ratio is the number of male courting with a number of females and it is preferably termed mating-ratio or cock/hen ratio. In the wild, guinea fowls exhibit a monogamous behavior. USDA (1976) suggested that under free range conditions, it is not necessary to mate the birds in pairs before fertile eggs can be produced, rather different sex-ratios should be adopted depending on the management and season. Sex ratio of guinea fowl reared under extensive and confined system is one guinea fowl cock to 4-5 guinea fowl hens and one guinea fowl cock to 6-8 guinea fowl hens respectively. Also, the recommended sex-ratio for guinea fowl during the rainy season is one cock to five hens (Nwagu *et al*., 1997; Apiiga, 2007), while in the dry season it is a cock to three hens (Avornyo *et al*., 2007). For guinea fowl breeders (i.e. parent-stock), one cock to five hens is recommended (Bell and Smith, 2003). The aim of these recommended sex-ratios in guinea fowl production is to ensure that high fertility and hatchability of eggs are achieved.

During the early period of breeding season, wild guinea fowl hens do search for hidden places to prepare their nests, (Elile *et al*., 2021a), while the domesticated guinea fowl hens may use available nests of local hen (Nwagu *et al*., 1997; Platt, 1997). Ikani and Dafwang (2004) observed that, guinea fowl cock prepares a nest for his flocked group of hens. This may be the reason 20 to 30 eggs or more eggs are usually found in a single nest during breeding season. Elile *et al.* (2021a) explained that nests are usually located in well hidden places especially when many cocks are kept. More so, once nest is found, farmers are advised to leave at least three newly marked or dummy eggs in the nest each time egg collected. This will encourage the guinea fowl hens to continue using the same nest during the next breeding season. Significantly, more infertile eggs are observed in free housing system due to the monogamous tendency of guinea fowl cocks (Bell and Smith, 2003). In the wild, pairs of guinea fowls are established during the rainy season, the pairs and their off-springs merge together with others to form larger groups at the end of the breeding season (Leach, 2009). Guinea fowls form stable pair bonds after two to three-week “dating” period of temporary courtship (Leach, 2009). Elile *et al.* (2021a) reported that guinea fowl cocks may show mate preferences and court some individual hens more than others within a flock. Efforts should be made to ensure that the pairing behavior between reproductive adults is eliminated. More so, guinea fowl hens are usually less accessible to copulate by guinea fowl cocks. This is because of the natural aggressiveness of guinea fowl cocks during mating which usually causes injuries to the hens (Elile *et al*., 2021a).

Reproduction in guinea cock

The breeding soundness of male guinea fowl is an important prerequisite for effective reproduction. This is because of his genetic influence on the breeder progeny through fertilization.

Testicular development

Generally, avian testes are larger than those of mammals in relation to body weight (Lake, 1957). Guinea fowl cocks have smaller testicular size (1-9 g) than chicken cocks (14-16 g) (Nwagu and Alawa, 1995). In many species of avian, including guinea fowl cocks, the testes are bilateral asymmetry, with the left testis being larger than the right (Mohan *et al*, 2016). Mohan *et al*, (2016) reported that irrespective of seasons, the left testicular weight is lightly higher than the right. The mechanisms that are responsible for testicular asymmetry in cocks may be the same as those that cause ovarian asymmetry in hens (Mohan *et al*, 2016) or, may be due to unequal number of primordial germ cells incorporated into the embryonic gonads (Tyler and Gous, 2008). Quresh *et al*. (2016) reported that right and left testes showed a non-significant difference in all morphological variations. Quresh *et al*. (2016) also revealed that season initiates the reproductive phases which in turn affected the testicular morphology of guinea fowl cocks (see Table 2). Quresh *et al*. (2016) concluded that development of seminiferous tubules and regression of interstitial cells are under the control of increased secretion of gonadotropins releasing hormone (GnRH) and a mechanism of timing in brain influenced mostly by photoperiod. Similar findings were observed in Japanese quail (Akbar *et al*., 2012; Shil *et al*., 2015) and in Jungle crow (Islam *et al*., 2010). However, increase in weight of testes is due to an increase in number and volume of Leydig and Sertoli cells (Gonzalez- Moran and Soria-Castro 2010).

Spermatogenesis and sperm fertility

Romanoff (1960) has described the processes of spermatogenesis (i.e. spermatozoa production) in fowl. Spermatogenesis is a continuous phenomenon, since each region of the seminiferous tubule of the testes contains spermatozoa in a different stage of differentiation. Spermatogenesis occur at the internal body temperature of 41ºC in birds as opposed to scrotal temperature of 24-26ºC in mammals (Etches, 1996). The post-abdominal air sacs, where air movements occurs are close to the testes which reduce testicular temperature to about 3 or 4ºC lower than body temperature (Lake, 1971). Rekwot *et al*. (2005) observed that spermatogenesis is more intense during the night, when the activity of the fowl is lowest and body temperature is reduced. This shows that spermatogenesis may be interfered with high temperature in birds. A sexually active cock may produce about 3 billion spermatozoa daily (Etches, 1996).

Epididymis is a site of sperm maturation and fertility. Structural differentiation of spermatozoa is complete before it leaves the rete tubules. Early studies indicate that sperm cells, taken from the testis or epididymis of the cock, were capable of producing fertility at a very low level because sperm motility is achieved in the vas deferens (Munro, 1938a). The time it takes for transit of spermatozoon from testes to the terminal region of the vasa deferentia range from 1 to 4 days (Munro, 1938a). There is evidence that Sertoli and epithelial cells of the epididymis may reabsorb spermatozoa in order to eliminate unejaculated sperm cells (Tingari and Lake, 1972).

Semen quality

Semen quality gives excellent information of male animal's reproductive potential and this quality has been a major determinant of fertility and subsequent hatchability of eggs in birds. Much work has been done on semen quality of chicken and turkey (Mohan *et al*., 2011; Ogbu *et al*., 2014) which are useful for artificial insemination (A.I) technique. Elile *et al.* (2019) reported that literatures on semen quality of guinea cock are scanty. However, semen quality is often determined by four main characteristics via: semen volume, sperm concentration, sperm motility and sperm mobility (i.e. sperm abnormality and livability) and these characteristics are discussed thereof.

i. **Semen volume:** Mohan *et al.* (2016) reported that the average semen volume of pearl, lavender and white guinea fowl cocks is 0.055 ml, 0.051 ml and 0.035 ml respectively. They also discovered that semen volume of pearl and lavender is nearly 50% higher than white variety of guinea fowl. This may be due to variation in variety. Nwakalor *et al*. (1988) reported an average semen volume of 0.032 ml for local guinea fowl cocks while Pal *et al*. (1999) noticed 0.073 ml as an average semen volume for improved guinea fowl cocks. These volumes of guinea fowl cock ejaculate are less than 0.50 to 1.00 ml of local chicken ejaculates observed by Machebe and Ezekwe (2002). Brown and McCartney (1983) found that volume of semen obtained has no effect on fertility and hatchability of eggs.

ii. **Sperm motility:** Nwakalor *et al*. (1988) reported average sperm motility of 91.60 % with a range of 87% to 96% in guinea fowl. Whereas, Mohan *et al.* (2016) recorded 89.52%, 90.71% and 86.19% as the average sperm motility in pearl, lavender and white guinea fowl respectively. High percentage of sperm motility is positively correlated with fertility and hatchability of eggs (Mohan *et al., (*2016).

iii. **Sperm concentration:** In chicken, average concentration of spermatozoa is 3.5 million per ml (Sturkie and Opel, 1976) or 7.0 to 8.2 billion per ejaculate (Lake, 1957). Elile *et al*. (2020) estimated 3.60 x 10^9 as mean value of sperm concentration per ejaculate in guinea fowl cock. Mohan *et al*. (2016) reported that sperm concentration of pearl, lavender and white guinea fowl is 3.51 x 10^9, 3.67 x 10^9 and 3.05 x 10^9 per ejaculate respectively. Bratte and Ibe, (1989) recommended 50 x 10^6 sperm cells per ml as adequate dose for better percentage rate of fertility during AI in domestic birds like guinea fowl.

iv. **Abnormal and live spermatozoa:** Every ejaculate contains dead and abnormal sperm cells which may not interfere with fertility but high proportion of these cells show either impaired fertility or may cause sterility in avian cocks (Mohan *et al*., 2016). The types of abnormality found in sperm cells of birds are mostly micro-cephalic, bent head, broken mid-piece and cytoplasmic droplets. The percentage of abnormal spermatozoa of guinea fowl cocks ranges from 3% to 5% (Mohan *et al*., 2016). In guinea fowl, percentage of dead spermatozoa ranges from 5% to 7% (Nwakalor *et al*., 1988) or slightly higher (8.4%) (Mohan *et al*., 2016). Mohan *et al*. (2016) suggested that higher percentages of dead and abnormal sperm cells associated with lower sperm concentration may cause poor fertility in guinea fowl cocks. Percentages of dead and abnormal sperm cells have been found to be negatively correlated with fertility because only 1% increase of dead sperm may significantly decrease the percentage of fertility (Mohan *et al*., 2016). Wilson *et al*. (1969) found that 10% or more number of dead sperm cells may cause/sterility in guinea fowl cocks. Heat-stress have been reported as the major contributing factors to high number of abnormal and dead spermatozoa which may induced infertility in avian male species (Penfold *et al*., 2000). Other factors that may cause high rate of abnormality and dead sperm cells are poor nutrition, photoperiods and bad management (Quresh *et al*., 2016).

Reproduction in guinea hen

Guinea hens are viviparous and produce oocytes that express her genetic traits on the breeder progeny through fertilization and therefore reproduction in hens are paramount in breeding management of birds.

Egg formation

Egg formation is a continuous process that occurs on the left side of the ovary and oviduct of birds, while the right oviduct is regressed. Ovary is situated between left lung and left kidney with weight ranges from 18 g to 35g which is smaller than that of the domestic hen of 40 g to 60g (Ayorinde, 2004). The ovary contains a number of follicles at different stages of development. Large follicles contain yolk which is source of nutrients and water for the developing chick during incubation. It takes 9 to 11days for a follicle to develop enough and ready for ovulation. After ovulation, the oocyte is transported from ovary to magnum, through infundibulum. Albumen is formed in the magnum which synthesizes proteins. Progesterone and oestrogens stimulate secretions of proteins that are deposited around the oocyte. Two shell membranes are formed around the albumen in the isthmus, which is next segment of the oviduct. Thereafter, the egg moves to the shell gland (uterus) where eggshell and cuticle are formed. The uterus and magnum of guinea hen are quite small when compared to chicken (Ayorinde*et al.*, 1989). The size of the magnum is positively related to egg size which may be responsible for the low efficiency of egg production in the guinea fowl hens (Ayorinde, 2004). However, guinea fowl hens have larger uterine size, when compared to chicken, which may be responsible for the thickness, hardness and well-formed guinea eggs (Ayorinde, 2004). Rose (1997) reported that it takes at least 25 hours for an egg to complete its formation before moving to vagina for the cloaca to finally push out (lay) the egg.

First lay

Most farmers do not know the age at which their guinea fowl hens lay their first egg because of lack of records or interest. Early attainment of puberty is a desirable trait which may result to smaller eggs being produced, while late pubertal birds may produce bigger eggs (Oke*et al*., 2003). However, it has been reported that wild guinea fowl hens commence egg production at 9 to 12 months old (Ayorinde and Okaeme, 1984). Also, it has been observed that local and exotic guinea fowl hens may lay their first eggs at the age of 6 months (Avornyo *et al*, 2007, Apiiga, 2007) and 18 weeks (NRC, 1991) respectively, depending on the feeding and other management practices provided. The point of lay of local guinea fowl hens reared under free range and intensive system is 30 to 32 weeks and 22 weeks respectively (Apiiga, 2007). Guinea hens subjected to long photoperiod may drop their first egg at 17th week of age (Teye and Gyawu, 2002). According to Oke *et al*. (2004), average body weight at first lay is about 1163 g. The weight of point-of-lay of guinea fowl hens ranges from 800 g to 1.5 kg depending on geographical location (Apiiga, 2007). Weight and age of guinea fowl hens may be directly correlated, depending on the nutrition, health, and genetics among other factors. For instance, Oke *et al*. (2003) reported that the correlation of age at first egg and body weight of pearl, lavender and white guinea fowl hens were 231 d, 219 d, 220 d and 1126.40 g, 1137.45 g, 1128.61 g respectively. These records show that certain body composition must be attained before eggs are produced. Oke *et al*. (2004) suggested that, the selection of heavier individuals in a population may cause early attainment of puberty in hens.

Laying performance

Moreki (2005) found out that guinea fowl hens may attain puberty as early as 16 weeks under good management and may continue to lay for about 8 months producing 150 to160 eggs during the first laying period and/or 180 eggs during the second laying period in the tropics. In temperate region, Bell and Smith (2003) stated that guinea hens may start to lay in the spring (a season of increased daylight) and continue to lay for 9 months or more. In Nigeria, the laying period only occurs during the rainy season i.e. late March to early October (Moreki, 2005; Elile *et al*., 2020). Platt (1997) reported that guinea fowl hens that start to lay during the early phase of breeding (April – May) may not become broody. A guinea fowl hen may lay 36 to 60 eggs (Platt, 1997), or about100 eggs (Elile *et al*., 2021b), or about 120 eggs (Apiiga, 2007) per annum depending on the management and breed. Moreki (2005) also suggested that good breed of guinea fowl hen subjected to good management may lay more than 120 eggs per annum in Africa. According to USDA (1976), caged guinea fowl hen may lay 170 to 180 eggs per year, while guinea fowl hen reared extensively may lay 70 to100 eggs per year.

Guinea fowl hens generally maintain good level of egg-production for about two to three years but rapidly declined when exceeding four years in stock (Moreki, 2005). In extensive rearing, a guinea fowl hen may lay about 30 eggs and then go broody, or may continue to lay throughout the breeding season, if broodiness is discouraged (USDA, 1976). Local guinea fowl hens may lay 70 to 100 eggs per year, while exotic guinea fowl hens lay on the average of 200 eggs per year (Teye and Gyawu, 2002). Adeyinka *et al*. (2007) observed 14, 25, 85, 105, 250, 200 and 14 eggs from twenty native guinea fowl hens reared intensively in the month of April, May, June, July, August, September and October respectively, while no egg was lay in the rest five months of the year. It may be deducted that, January to March is the early resting phase when the hens are seasonally unfertile; May to June is early breeding phase when egg production is at increasing order; August is peak breeding phase with the highest number of eggs laid; September to October is the late breeding phase when egg production is on the decline and December to March is late resting or unfertile phase.

In the wild, guinea fowl hens may lay 12 to 20 eggs per bird per breeding season and their eggs are laid in well-concealed nests (Ayorinde and Okaeme, 1984). A nest may serve more than one guinea hen (Elile *et al*., 2020a). Broodiness may be delayed in guinea fowl hen by removing eggs from her nest and leaving two or three eggs which may increase egg production from 15 eggs to a range of 60 to 80 eggs (Elile *et al*., 2020a). The laying period of guinea fowl hen may be extended by increasing day-length by 3-5 hours using artificial lighting a long side with adequate provision of diet and cool water during dry season (Apiiga, 2007; Elile *et al*., 2020b). In addition, water should be systematically sprayed on guinea fowl hens to regulate their body temperature which will increase the number, size and fertility of eggs produced (Bell and Smith, 2003).

A clutch of eggs refers to all the eggs produced by a bird or birds in a nest at a single laying period (Wikipedia, 2010). Clutch size of a guinea fowl hen is 12 to 15 eggs (Moreki, 2005) or 15 to 20 eggs (NRC, 1991) or 20 to 30 eggs in a well-hidden lined scrape (Wikipedia, 2008). Clutch size depends on size of hen, size of eggs, time of lay and nesting materials used by hen or farmer (Moreki, 2005). However, under proper management of systematic removal of eggs from the nest, guinea hens may keep on laying up to 200 eggs per laying season. Complete removal of eggs or leaving only one egg in the nest may discourage guinea hen from laying and abandon the nest (Maganga and Haule, 1994). Nests may be provided for caged guinea hens to enhance egg production (Nwagu *et al*., 1997). Guinea hens that are about to lay make a peculiar monosyllabic sound like ‘kien kien kien’ which is similar to the sound produced after laying (Avornyo *et al*., 2007). Most guinea hens lay from 9:00 a.m. to 2:00 p.m.

Egg quality

Guinea fowl egg has a distinctive pyriform shape of one end pointed and the other end rounded. Guinea fowl eggs are smaller than chicken eggs with average length, diameter, surface area and area: weight ratio of 4.78 cm, 3.80 cm, 52 $cm^2$and 1.37 respectively (Ayorinde, 1987). The shell of guinea fowl egg varies in shades and appears in brown or white colour. The brown eggs are usually laid by pearl, lavender and black guinea fowl hens while white eggs are laid by white guinea fowl hens. Local and exotic guinea fowl egg weight ranges from 35 to 40 g (Ikani and Dafwang, 2004) and 40 to 45g (Fani *et al*., 2004) respectively which is about 60 to 70 percent of the weight of chicken egg. Egg weight of the first lay of guinea fowl hen is about 28 g which increases to about 39 g by the end of the first breeding season (Ayorinde*et al*, 1989). These authors further observed slightly increase of guinea fowl egg weight in the second and third breeding seasons. Ayorinde, (2004) also reported that yolk weight and albumen weight of guinea eggs is averagely 15 g and 30 g respectively.

Handling and storage of fertile guinea fowl eggs

Fertile guinea fowl eggs should be collected four times a day under temperature condition of 20^{o}C or more frequently under extreme temperatures of ≥ 28^{0}C (warm) or ≤ 5^{0}C (cold) to prevent deterioration of shell quality (Khairunnesa, 2013). Fertile guinea fowl eggs should be collected by 10 a.m, 2 p.m, 4 p.m and 6 p.m on daily basis and should be incubated the same day of collection to increase the level of hatchability.

Storage conditions for guinea fowl eggs are temperatures of 10ºC to18ºC with relative humidity of 70% to 80% (Kanengoni, 1998). Belshaw (1985) suggested that the best storage conditions for guinea fowl eggs are temperature and relative humidity ranges of 13^{0}C to 16^{0}C and 70% to 80% respectively in proper ventilated store-room. The storage period of guinea fowl eggs should not be more than 7days (Binali and Kanengoni, 1998), because hatchability of fertile eggs drops by 1% in every four days of storage (Khairunnesa, 2013). Hence, four days storage period of guinea eggs is recommended, if stored within the required storage conditions. Other factors to be examined before and during storage of fertile eggs are egg size, egg shape, shell quality and shell porosity (Khairunnesa, 2013). These factors may also affects hatchability of guinea fowl eggs.

Fertility of guinea fowl eggs

Fertility among other reproductive trait constitutes important yardsticks in evaluating the economic efficiency of parent stocks. In guinea fowl, average percentage of fertility in guinea fowl egg is 53% (Ayorinde *et al*., 1988) or 49% to 58% (Galor, 1983) in naturally mated stock or 70% to 88% (Ayorinde *et al*., 1989) when inseminated artificially.

Incubation

Incubation is the process of providing fertile eggs with optimum environmental conditions to stimulate embryonic development until hatching is achieved. These environmental conditions include temperature, egg turning and humidity which may be provided naturally (i.e. natural incubation) or artificially (i.e. artificial incubation) depending on the scale of production.

Natural incubation: A brooding guinea fowl hen provides optimum conditions to stimulate embryonic development of her fertile eggs for a period of 26 to 28days when the eggs are hatched into keets. A good brooding hen should be healthy with mothering records which include the ability to: incubate her eggs properly throughout the incubation period; ruffles her feathers and spreads her winds; make distinctive clucking sound; stop laying at her clutch size and should be large enough to incubate an optimum clutch size of 12 to 15 eggs (King'ori, 2011). King'ori (2011) confirmed that hatchability often declines among guinea fowl hens of large clutch size of more than 15eggs.

A brooding hen requires farmer's assistance to optimally maintain the incubation conditions in order to reduce the level of embryonic damage. High embryonic damage is usually caused by the cooling of the eggs because mother hen frequently leaves her nest to search for food and water. According to King'ori, (2011), a good brooding guinea fowl hen needs water to splashes on her eggs with her beak to maintain humidity. Therefore, provision of feed and water is required for brooding hen to maintain optimum temperature, tuning and humidity (King'ori, 2011). In dry regions or season, slightly damp soil may be made under the nesting material to retain humidity (King'ori, 2011). Fertile eggs from other guinea fowl hens may be added to eggs of brooding hen of small clutch size within the first-four days of incubation (King'ori, 2011). Anonymous (2001) reported that most small scale farmers prefer to use chicken and turkey hens to hatch guinea fowl eggs because guinea fowl hen may leave the nest after the hatch of few keets. King'ori (2011) also reported that local chicken hens may brood and hatch first and second clutch of eggs but this may causes severe loss of their body weight and drop in hatchability of the second clutch of eggs due to prolong physiological and nutritional stress.

Artificial incubation: An incubator is an artificial device that mimics the mother-hen's brooding potentials of providing required environmental conditions to stimulate embryonic development of fertile eggs to hatch into chicks. Among all the conditions required for incubation efficiency, temperature is the most important factor (Lourens *et al*., 2007). High embryo mortality may be observed, if the incubator temperature drops below 35.6^{o}C or rises above 39.4^{o}C for 3 to 5 hours or may not hatch at these extremes temperatures for several days (Lourens *et al*., 2007). King'ori, (2011) reported that over-heating may be more critical than under-heating. Wilson (1991b) suggested that temperature of 37.2^{o}C to 38.4^{o}C is preferable but should not exceed the range of 36.1^{o}C to 38.9^{o}C to prevent high embryo mortality. A constant incubation temperature of 37.8^{o}C is the best thermal homeostasis in embryo development and hatchability (Lourens *et al*., 2007).

The position (i.e. large end up or small end up) of eggs during the period of storage and incubation may influence hatchability. Broiler eggs set with the small end up reduced hatchability by 17% (Bauer *et al*., 1990). Mahdi *et al*. (2010) observed lower hatchability and longer incubation time to hatch in Japanese quail eggs incubated with the small end up. Physiologically, this may be the location of embryo that made it difficult to locate the air-cell when positioned small end up (King'ori, 2011). Also, Bauer *et al*. (1990) reported that poor turning of fertile eggs during incubation increases the number of dead embryos. Other problems associated with poor turning of eggs during incubation are egg rots, broken yolk, dead-in-shell chicks and prolonged pre-incubation. King'ori (2011) also reported that increase in embryonic size may cause an increase in heat expired by embryo which will need cooling especially after 18 days of incubation. Therefore, moisture levels of 60 to 80% relative humidity are vital in later period of incubation in order to balance the excess moisture loss from the egg contents through the porous egg shell and membranes (King'ori, 2011).

Embryonic mortality

A process by which egg is held against a light source to determine certain qualitative characteristics of the internal parts of egg without breaking the shell is called candling. Candling may be established prior to incubation (Wilson, 1995b) or during early, mid or late phase of incubation to determine infertile, dead and living eggs. In guinea fowl, candling is best done at 7 to 18 days to determine embryonic mortality (Khairunnesa, 2013). Embryonic mortality is usually categorized into three types, viz: early embryonic mortality; mid embryonic mortality; and late embryonic mortality (Wilson, 1995a).

Early embryonic mortality: This is embryo that died during the first-seven days of incubation which is more difficult to determine (Leeson and Summers, 2000). The yolk of early dead embryo is pale and may have a mottled appearance and a blood ring or network of blood vessels, while live embryos may have more advanced stage of development (Wilson, 1995a). In addition, the blood vessels in early dead embryo are dark-red color than the live embryos due to pigment oxidation (Wilson, 1995a). Early dead embryos may adhere to shell when the egg is rotated (Wilson, 1995a). However, early embryonic mortality may be caused by improper pre-incubation, poor egg handling and storage conditions (Leeson and Summers, 2000). A survey analysis indicated that average of 2.5% early embryonic mortality usually occur in conventional hatcheries (Wilson, 1995a).

Mid embryonic mortality: Mid-dead embryos are identified by a hard beak with a well-defined egg tooth on the upper side of the beak (Wilson, 1995a). Mid-embryonic mortality is induced by poor nutrition (Leeson and Summers, 2000) and this type of embryonic mortality is averagely 0.5% in hatchery industries (Wilson, 1995a).

Late embryonic mortality: A fully feathered embryo covering the entire space within the egg indicates late embryonic death (Wilson, 1995a). This type of embryonic mortality is induced by incubation conditions, breeder management or nutrition (Leeson and Summers, 2000). A survey analysis reported by Wilson (1995a) indicated that late embryonic mortality is the commonest type and the rate of occurrence in hatchery industries is averagely 2.75%. Breeders should therefore adopt good management practices in handling, storing and incubating fertile eggs as well as ensuring proper nutrition and good health conditions of parent-stock. These will reduce the rate of embryonic mortality of guinea fowl eggs during incubation.

Hatchability

Hatchability is the ability of embryo to survive and successfully escape from eggshell. Hatchability is an important reproductive trait of birds which highly influence the production of day-old-chicks. However, genetic and environmental factors may affect hatchability of sized eggs. Genetically, lethal and semi-lethal genes affect the hatchability of eggs (Khairunnesa, 2013). Moreki and Mothei (2013) discovered that the number of medium sized eggs hatched was more than the number of small and big eggs and this observation shows that size of egg is a factor that affects hatchability. Guinea fowl eggs exhibit low hatchability than chicken eggs because of their thick eggshells (Yildirim, 2012).

Environmental factors like handling of eggs before incubation greatly affects hatchability. Hatchability decreases rapidly in eggs stored for more than 10 days (King'ori, 2011). Eggs stored for two weeks or more may extend the normal incubation time by one day (Janet, 1975). Nwagu and Alawa (1995) reported that, hatchability deteriorated by nearly 4% per day of storage. The level of hatchability in guinea fowl eggs under natural incubation is higher than manual artificial incubation (Moreki 2009). Kabera (1997) observed higher percentage hatchability of about 80% in automated incubators than manual incubators that hatchet 70% to 75% of fertile eggs. This may be due to automatic turning facility installed in automated incubators. The time an egg is laid has an effect on hatchability. According to Khairunnesa, 2013, fertile eggs laid early in the morning have lower hatchability than those laid later in the day. The author suggested that the high hatchability rate of eggs laid in the afternoon/evening may be the positive effect of light during egg formation. King'ori, (2011) reported that poor semen quality reduces egg fertility and hatchability. Khairunnesa (2013) reported that during heat stress, feed intake drops causing decline in fertility and hatchability. Other factors affecting hatchability are egg shape, excessive shell porosity, age of birds, egg production rate, preferential mating, male-female ratio and pre-incubation temperature and humidity (King'ori, 2011; Khairunnesa, 2013). Average rate of 67% (Kabera, 1997) or range of 70% to 75% (Galor, 1983) hatchability has been achieved under manual artificial incubation. Therefore, farmers should adopt good management in breeders' stock as well as in the management of pre-incubation and incubation of fertile eggs.

Keet survival and management

Keet survival is essential for successful guinea fowl production. Keets are commonly raised under extensive system by most rural farmers. Embury (2001) reported that this system may cause colossal losses like stealing of mother-hen and her keets, poor mothering by guinea hen, exposure to bad weather, poor feeding, worm infection and attacks from rodents. Furthermore, Houndonougbo *et al*. (2017) carried out a survey work on the various causes of keet mortality in extensive system and they find out that 28% of mortalities were due to various illnesses, 19% to straying of agro-chemicals, 17% to various accidents, 7% to drowning in run-off water during heavy rain, 5% to predators, 5% to food poisoning and 18% to other causes. Sanfo *et al*. (2007b) suggested that keet mortality may also be related to weight of incubated eggs. They reported that the 40% keet mortality obtained from eggs that weighed 25 g to 35 g is higher than 6% mortality rate of keets hatched from eggs that weighed 45 g to 50g. Sanfo *et al*. (2007a) reported that mortality rate of keets ranges from 33.1% to 68.9%. Nwagu and Alawa (1995) observed an average of 50% keets mortality when exposed to free housing system.

Anonymous (1998) suggested that brood chicken and turkey hens may be the best mothers for keets since they are used for natural incubation of guinea fowl eggs. He also reported that 1 to 4 days old keets may be introduced at hatching of local or turkey chicks because of their inherent wild-like characters. Bell and Smith (2003) advised that keets should not be hatched or brood on smooth surfaces as they have a tendency to go "straddled legged" in a short time which may causes them lameness, starvation and subsequently death. Proper brooding management of keets under intensive system for the first-fourth weeks may reduce mortality to approximately5% (Embury, 2001). The author also observed high survival rates of exotic keets reared in confined environment by commercial farmers. This is because nutrition, health care, and clean cool water were served in intensive environment of moderate temperature, humidity and ventilation which are the requisite for good performance of keets.

Roles of reproductive hormones in guinea fowl

Reproductive hormones play multiple roles in the reproduction of male and female animals and these hormones include mostly luteinizing hormone (LH), follicle-stimulating hormone (FSH), testosterone, oestrogen and progesterone. However, based on complex interactions of hormones and the scope of this review, specific physiological roles of sex hormones on the reproductive traits of guinea fowl are reviewed thereof.

Guinea fowl cocks: Testosterone is pivotal for reproductive activities in guinea cocks. It stimulates testicular growth (Biswas *et al*., 2007), spermatogenesis (i.e. sperm production) (Boon *et al*., 2000; Kirby and Froman, 2000), variability in testicular biometrics (Boon *et. al*, 2000), and sexual behaviours (Garamszegi *et al*., 2005). Testosterone supports the transformation of secondary spermatocytes to spermatids while FSH is required for the production of earlier stages of spermatocytes (Lake and Furr, 1971). Testosterone is secreted by the Leydig cells and these cells are controlled by LH. Thus, high secretion of gonadotropic hormones (LH and FSH) leads to high testosterone production (Degen *et al*., 1994; Yang *et al*., 2005) which holistically mediates the reproductive traits of guinea cocks. However, low production of these hormones (LH, FSH and testosterone) causes reduction of Leydig and Sertoli cell population (Ubuka *et al*., 2006), and regression of testicular biometrics which include testicular weight, length, height, width, volume and phallus thickness (Abdul-Rahan *et al*., 2015).

Testosterone profile of guinea cock is seasonal. The high levels of testosterone suggest the impact of season on gonadal activity of seasonal breeds (Jalmee*et al.*, 1996). The testicular involution that takes place at the end of the reproductive season in guinea cocks is attributed to tissue necrosis (i.e. the temporary inactiveness of testicular cells like Leydig and Sertoli cells) (Thurston and Korn, 2000). This necrosis is cause by the low or/and failure of testosterone to maintain the integrity of the seminiferous tubules (Thurston and Korn, 2000). The regression of the excurrent ducts (Kirby and Froman, 2000) and phallic structures (Lake and Furr, 1971) may be attributed to low testosterone level observed in non-breeding cocks when compared to breeding cocks with high testosterone levels. Therefore, proper administration of exogenous testosterone in guinea cocks during their non-breeding season is recommended to improve their reproductive status to all year round or to a desirable period.

Guinea fowl hen: Oestrogen stimulates growth, development, maturation and the functioning of reproductive tract, as well as the sexual differentiation and the behavior of female animals (Lien *et al*., 1985; Laugier *et al*., 1988; Balthazart *et al*., 2009). Oestrogen is associated with ovarian recrudescence and promotion of the synthesis of hepatic yolk precursors (vitellogenin) and oocyte size during vitellogenesis (Schulz, 1984). Oestrogen affects the function of hypothalamus, pituitary, liver, skeleton and calcium (Ca) homeostasis (Connolly and Callard, 1987; Williams *et al*. 1991; Turner *et al*., 1994). It also enhances growth of the oviduct, formation of tubular secretory glands, epithelial cell differentiation, increased body weight, early sexual maturation (Lien *et al*. , 1985; Forgo *et al*., 1996) and improve laying performance (Berg *et al*., 2001).

Progesterone is another female reproductive hormone first demonstrated in the blood of laying and non-laying hens by Fraps *et al*. (1948, 1949). Progesterone influences the development of follicles and ovulation, synthesis of lipid and protein in birds (Johnson and van Tienhoven 1984). Synergistically, progesterone and estrogen control the albumin formation and secretion in magnum (Silver *et al*., 1974). Seasonal variation of progesterone had been reported by Adeyinka *et.al*. (2007) to be a good estimator of egg production in guinea fowl hens, as shown in figure 1 below.

Figure 1: Progesterone profile of native guinea fowls reared in deep litter system
Source: Adeyinka et.al, 2007

Adeyinka *et.al*. (2007) observed that guinea fowl hens cease to lay when progesterone level drops during heat or dry season. These findings also support the suggestion of Bluhm *et al*. (1983) who noted that the cessation of egg laying induced by stress is associated with low levels of progesterone and estrogen in seasonal breeds. Mashaly and Wentworth (1974) concluded that egg production appears to be more strongly associated with circulatory progesterone than oestrogen. Therefore, exogenous progesterone-base drugs are preferable and should be properly administered to guinea fowl hens during heat season. This will go a long way in improving laying period and egg production performance of guinea fowl hens.

Table 2: Summarized chart of some reproductive traits of guinea fowl

Reproductive traits	Reference
Sex-ratio	
Free range system: 1 cock:4 to5 hens	Elile *et al*., 2021b
Intensive system: 1cock:6-8 hens	Elile *et al*., 2021b
Raining season: 1 cock:5 hens	Nwagu*et al*., 1997;
Dry season:1 cock:3 hens	Avornyo *et al*., 2007
Parent stocking: 1 cock:5 hens	Bell and Smith, 2003
Testicular development and sex behavior	
Body weight of breeding guinea fowl cock:1195 g ^{a};≈1190 g^{b}	Abdul-Rahma *et al*., 2016
TM :- Weight: 695 mg to 955.0 mg^{a}; 238 mg to 416.0 mg^{b}	Abdul-Rahma *et al*., 2016
Length:≈18.2 mm^{a}; ≈13.2 mm^{b}	Abdul-Rahma *et al*., 2016
Height: ≈7.6 mm^{a}; ≈6.0 mm^{b}	Abdul-Rahma *et al*., 2016
Width: ≈9.8 mm^{a}; ≈7.2 mm^{b}	Abdul-Rahma *et al*., 2016
Volume: 0.8 $cm^{3}$to 1.1 cm^{3a}; 0.3 cm^{3} to 0.4 cm^{3b}	Abdul-Rahma *et al*., 2016
Semen quality	
Semen volume:- Local breed: ≈0.032 ml	Nwakalor *et al*., 1988
Exotic breed: ≈0.073 ml	Pal *et al*.,1999
Sperm motility: ≈ 91.0%	Nwakalor *et al*., 1988
Sperm concentration per ml: ≈2.35 x10^{6}	Elile *et al*., 2019
Sperm concentration per ejaculate: ≈3.60x10^{9}	Ayorinde, 2004
Abnormal sperm cells: 3% to 5%	Mohan *et al*., 2016
Dead sperm cells: 5% to 7%	Nwakalor *et al*., 1988
First lay	
weight: ≈1163 g	Oke *et al*., 2004
Wild guinea fowl hen: 9 to 12 months	Ayorinde and Okaema, 1984
Exotic guinea fowl hen: ≈18 weeks	NRC, 1991
Local breed: free range system: 30 to 32 weeks	Apiiga, 2007
Intensive system: ≈22 weeks	Apiiga, 2007
Under continuous lighting ≈ 17 weeks	Teye and Gyawu, 2002
Laying performance	
wild guinea hen: 12 to 20 eggs per year	Ayorinde and Okaema, 1984
Local breed: 90 to 120 eggs per year	Apiiga, 2007
Exotic breed: ≥ 200 eggs per year	Teye and Gyawu, 2000
Laying period (under natural day-length of 11 to 12 h): 20 to 30 weeks	Moreki, 2005
Laying period (under extended day length of 14 to 16 h): ≥ 40 weeks	Apiiga 2007
Egg quality	
weight (local guinea fowl): 35 g to 40 g	Ikani and Dafwang, 2004
weight (exotic guinea fowl): 40 g to 45 g	Fani*et al*., 2004
Egg storage and handling	
Duration: ≤ 7 days	Biali and Kanengoni, 1998
Temperature: 13 to 16°C	Belshaw, 1985
Humidity: 70 to 80%	Biali and Kanengoni, 1998
Egg fertility	
Natural mated stock:49 to 58%	Galor, 1983
Artificial insemination practice:70 to 88%	Ayorinde *et al*., 1989
Incubation and embryonic mortality of egg	
Period: 26 to 28 days	Ayorinde *et al*., 1989
Clutch size per hen: 12 eggs to 15eggs	Fani *et al*., 2004
Temperature: 37.2 to 38.4°C	Wilson,1991
Humidity: 60 to 80%	King'ori, 2011
Early embryonic mortality: ≈ 2.50%	Wilson, 1995a
Mid embryonic mortality :≈ 50%	Wilson, 1995a
Late embryonic mortality: ≈ 2.75%	Wilson, 1995a
Hatchability:-Natural incubation: >75%	Moreki, 2005
Artificial incubation (manual incubator): ≈ 70% to 75%	Galor, 1983
Artificial incubation (automated incubator): ≈ 80%	kabera, 1997
Day-old keet weight: ≈24.62g	Fani*et al*.,2004
Keet mortality:- Free range system:33 to 68.9%	Sanfo*et al*., 2007a
Intensive system: ≤ 5%	Embury, 2001

Note: [a]=Breeding season; [b]= Non-breeding season

Conclusion

Guinea fowl is a bird that is generally accepted for socio-cultural and economic purposes. The meat and egg of guinea fowl are nutritive with the meat having high proportion of yield. The birds are resistance to parasites, rodents and diseases with better capacities to survive and scavenge for food in free range environment and thus require less labour in management. These advantages have encouraged farmers into guinea fowl production but yet were unable to meet the demand of consumers in Africa. This shortage of guinea fowl products is caused by poor management of reproductive activities of guinea fowl. These activities include sexing, mating-ratio, sex behavior and seasonality in reproduction. These activities may cause poor egg production, decreased rate of hatchability and increased keet mortality which today are challenges to guinea fowl producers. However, this study has pooled established facts of relevant aspects of guinea fowl reproduction that will mitigate these challenges.

In this study, sex-indicators of guinea eggs are essential for day-old keet production while other indicators at various stages of development are relevant for mating-ratio in parent-stocking. The aim of various recommended mating-ratios of guinea fowl is to achieve effective natural mating by eliminating the behavior of pairing among guinea fowls at all systems or seasons. Naturally, during rainy or breeding season guinea cocks becomes fertile with increased testicular morphological traits with resultant semen quality of high sperm concentration, high sperm mobility rate, low number of abnormal and dead sperm cells. However, these qualities decline during dry or non-breeding season. In guinea fowl hen, first lay may occurs at the age of 9 months and 18 weeks in wild and exotic guinea fowl hens; or at the age of 22 weeks and 30 weeks in local guinea fowl hens raised under intensive and free range management respectively. The average body weight at which first lay occurs in guinea fowl hens is about 1163 g. Exotic breed of guinea fowl lay highest number of egg of about 200 eggs per hen per year followed by local guinea fowl hen that lay 90 to 120 eggs per hen per year. Wild guinea fowl hen exhibit the poorest laying performance of 12 to 20 eggs per hen per year within 30 weeks of laying period in tropics. Laying period can be extended to 40 weeks or more by increasing day-length to 16-18 hours on daily bases with adequate water and feeding. Testosterone and progesterone can be administered to manipulate the seasonality of reproduction in guinea fowl cocks and hens respectively. The extension of daylight and the administration of testosterone and progesterone will also improve semen and egg quantity, fertility and hatchability. Egg fertility is higher (≈ 80%) in AI practice than natural mated flock (≈55%) and hatchability of guinea fowl egg is 75 to 90%. In natural incubation, healthy brooding chicken hen with good mothering abilities is preferable to brood and hatch first and second clutch size of 12 to 15 eggs at proximity of feed and water. In artificial incubation, precautions in storage, handling and candling of eggs should be ensured and recommended conditions for effective incubation should also be adopted as well. Keets performance is better in intensive system where keet mortality is approximately 5% when compare 50% mortality rate or more that is usually obtained in free rage system. This is because of the adequate diets and medical services given to keets and growing guinea fowl at comfortable environment which trigger early attainment of puberty and subsequently production of guinea fowls.

Future scope

This set of information would serve as a practical guide for hatchery industries to go into the production of day-old keets. This work will also guide all scale of poultry farmers to engage and enhance the production of guinea fowl production. The prospects of the work will therefore go a long way to improve the production of guinea fowl meat and eggs in Africa.

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