Impact of Vitamin E on the Morphometry of Reproductive Organs in Avian Species across Breeding Cycles

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Abstract

Vitamin E is a fat soluble antioxidant and is very important for birds' health, breeding, and ability to scavenge the oxidative stress. The avian reproduction shows how reproductive organs change with variation in seasons. It focuses on the male testicular cycles and looks at how things like photoperiod and diet affect them. A lot of research has been done on how taking extra vitamin E can help with fertility, sperm health, and eliminating oxidative stress. Vitamin E deficits have been linked to problems with reproduction, including infertility and the death of embryos. The changes in the testes of different bird species are also histological and morphometric, which shows how important diet, especially Vitamin E, is for maintaining reproductive health. Pollutants in the atmosphere, especially toxic substances, can hurt reproductive systems, which show how important Vitamin E is as a protective agent. This chapter aims to summarize the changes in mophometry of reproductive organs in breeding and beneficial effects of vitamin E on these organs.

Keywords: Birds, Effect of vitamin E, Reproduction, Physiology, Breeding season

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Introduction

The breeding season of avian species is influenced by certain environmental factors like photoperiod, temperature and availability of food as well as timing of egg-laying. Avian testes show seasonal variations in testicular size and hormoneduring the various months of breeding seasons; the level of testosterone rises to peak in yellow-necked sparrow and span January, March and April (breeding season), and fall from May forward (Bhat & Maiti, 2000; Hayat et al., 2022). Testes of rose-ringed parakeets undergo five distinct phases annually from prebreeding to regression; Leydig cell activity peaks during breeding (Krishnaprasadan et al., 1988).

Vitamin E acts as a fat-soluble antioxidant that is essential for several physiological functions, including reproduction (Koutsos et al., 2001) It is observed that vitamin E deficiency can lead to various reproductive problems, such as infertility and embryonic mortality, in several species of birds (Nawab et al., 2019).

Morphometric Dynamics of Reproductive Organs with Season

Generally, the bird testes have thinner capsules than mammals; interspecies differences show that some birds like turkeys and quails have bigger hilums (Aire & Ozegbe, 2007). While interstitial Leydig cells generate testosterone, seminiferous tubules within the testes host Sertoli cells for sperm generation (Yadav & Mali, 2024).

In most avian species, testes reach their maximum size during peak breeding season, followed by a quiescent period when sperm production ceases (Dawson & Sharp, 2007; Leska & Dusza, 2007; Rasheed et al., 2025). Long days stimulate gonadal growth and increase plasma sex steroids by promoting gonadotropin production (Busso et al., 2013). In budgies, gonadal samples have been categorized into three reproductive phases; active, intermediate, and non-active-based on testicular weight and tubular measurements. Lipid presence in non-active tubules was confirmed through staining and fluorescence imaging (Reitemeier et al., 2011). Testosterone levels peak during the breeding season and decrease as testes regress, although testosterone has a limited effect on testicular weight.

Testosterone, converted to estradiol in the brain, plays a significant role in regulating behavior. In males, peak spermatogenic activity occurs between 110 and 130 days of age, with tunica albuginea thickness, seminiferous tubule diameter, and germinal epithelium height reaching their highest values in late summer (Amoroso et al., 2008).

Research has also focused on how different lighting conditions affect male reproductive performance. In Muscovy ducks, continuous light exposure resulted in increased testicular weight and testosterone levels (El-Badry et al., 2009). Seasonal changes in testosterone, luteinizing hormone (LH), and testicular activity in house sparrows showed significant fluctuations, with testosterone levels peaking during the breeding phase (Bharucha & Padate, 2009).

Asymmetry in testicular size is common in birds, and compensatory mechanisms allow one testis to take over if the other underperforms, supporting the notion of natural compensation in reproductive investment (Calhim & Birkhead, 2009).

A study examined the annual testicular cycle of the yellow-necked sparrow, focusing on variations in the male reproductive system, including the rete testis, tubular vasa differentia, vas deferens, seminal glomus, and epididymis. The seminal glomus and all segments of the reproductive tract increased in size from January to March (progressive stage), reaching their peak in April (breeding season), before shrinking from May to June (regression stage), and becoming most regressed during the non-breeding period (July to December). The seminal glomus content peaked during the progressive phase, remained high during breeding, and began to decline afterward. Thus, the male accessory reproductive functions closely follow the annual testicular cycle, likely due to changes in testicular androgen production in the yellow-throated sparrow (Bhat and Maiti, 2000).

The main environmental signal regulating seasonal avian reproduction is photoperiod. Longer days activate the hypothalamic-pituitary-gonadal (HPG) axis, which releases gonadotropin-releasing hormone (GnRH), therefore activating the luteinizing hormone (LH) and follicle-stimulating hormone (FSH) from the pituitary gland (Ball & Ketterson, 2007). These hormones advance ovulation, maturation, and follicular development. In species such as the woodpigeon (*Columba palumbus*), exposure to summer photoperiods causes fast gonadal recurrences; artificially reduced photoperiods postpone ovarian activation (hUllachain and Dunne, 2013).

In tropical species, such as the rufous-collared sparrow (*Zonotrichia capensis*), photoperiod has a less influence and additional elements including temperature and food availability control breeding. Ovarian development is affected by seasonal fluctuations in environmental signals even if GnRH expression is stable over seasons (Stevenson et al., 2012).

Avian oviducts and ovaries grow quickly and functionally activate during the breeding season. The ovary stays dormant in non-breeding seasons and consists just of primordial follicles. But once the breeding season gets underway, follicles grow hierarchically, getting larger and yolk-filled to support egg output (Needham et al., 2019). For example, female zebra finches undergo fast oviduct hypertrophy in preparation for egg laying, and their metabolic costs show themselves in higher resting metabolic rates (Vézina & Salvante, 2010).

During the breeding season, the liver also is quite important since it synthesizes vitellogenin, a yolk precursor protein controlled by estrogen. Liver sensitivity to oestrogen peaks during egg formation in female dark-eyed juncos (*Junco hyemalis*), hence boosting yolk output to satisfy reproductive needs (Needham et al., 2019).

Reproductive success throughout the breeding season can be much influenced by environmental elements including noise pollution, food availability, and temperature variations. For example, traffic noise disturbs avian vocal communication, hence lowering clutch size and fledgling success in great tits (*Parus major*). In species living in temperate regions with shorter growing seasons especially, resource shortages might delay clutch initiation and lower egg quality (Liu et al., 2021).

Effects of Vitamin E on Ovarian Morphometry

In several findings, vitamin E supplements have shown the rise in ovarian growth. Yin et al. (2019) reported that Vit E with dose of 80 mg/kg greatly raised follicle-stimulating hormone (FSH) and estradiol levels in Xingguo grey geese, therefore fostering follicular development during the reproductive cycle.

Significant increases in α-tocopherol content in semen linked with an increased resistance to oxidative stress imposed by different external stressors were revealed to be linked with increasing vitamin E supplementation of poultry males. Similarly, higher α-tocopherol concentration in the tissues of the developing embryos and newly hatched chicks resulting in enhanced antioxidant defenses and lower lipid peroxidation was shown to be correlated with increased vitamin E concentration in the egg yolk owing to dietary supplementation. Furthermore revealed to be linked with elevation of antioxidant enzymes reflecting antioxidant system control and adaptation was increased vitamin E transport from the diet to egg yolk and subsequently to the developing embryo. A summarized view of vitamin E effects on various poultry production parameters has been shown in figure 1.

Vitamin E dose also increased the expression of hormone receptor genes including FSHR and LHR in ovarian tissues, therefore improving general fertility, In the comparison to this study, Japanese quails treated with 120 mg/kg Vitamin E showed higher oviduct and ovary weights as well as higher estrogen concentrations, which is an indication that better egg production and embryonic viability due to this vitamin (Abedi et al., 2017).

In male Japanese quails, vitamin E has been demonstrated to improve reproductive success by raising cloacal foam generation and hence improving fertility rates (Biswas et al., 2007). Though it did not greatly alter their athletic performance, a meal high in antioxidants has been shown to lower oxidative stress in budgies during flight (Larcombe et al., 2008).

Avian health suffers from environmental pollution including TE contamination of harmful substances. Emphasizing the significance of preserving animals from environmental threats, a research on budgies subjected to contaminated water revealed displacement of cellular nuclei (de Souza et al., 2017).

Free-living budgies have shown seasonal fluctuations in testosterone, LH, and testicular activity; notable differences in testicular size and activity across the year (Krishnaprasadan et al., 1988). Furthermore, supporting testicular function during breeding seasons is vitamin

E's positive influence on testicular morphometry and testosterone levels in male Japanese quails (Ali et al., 2015).The effect of vitamin E supplementation on reproductive performance in quails underlines its function in increasing fertility and sperm quality, therefore supporting the relevance of this nutrient in avian reproductive health (Biswas et al., 2007).

High levels of dietary antioxidants include carotenoids and vitamin E (tocopherol) are thought to help animals. Most studies have concentrated on the individual impacts of these substances on animal physiology and phenotype, including elements of coloration, health, development, and eyesight. Still, there is an increasing need to look at the possible interactions and synergistic effects among these lipid-soluble compounds. This work investigated how dietary Evion influences the accumulation of these compounds in the body using the house sparrow (*Haemorhous mexicanus*), a species with well-established relationships between carotenoids and fitness. Using a 2x2 factorial approach including birds in shedding and non-shedding circumstances, the study also evaluated oxidative damage and plumage color development. Lutein supplements raised circulating carotenoid levels and improved the pigmentation of recently molted plumage as predicted. These results confirm the theory that combined actions of carotenoids and vitamin E may surpass their respective functions (Giraudeau et al., 2013).

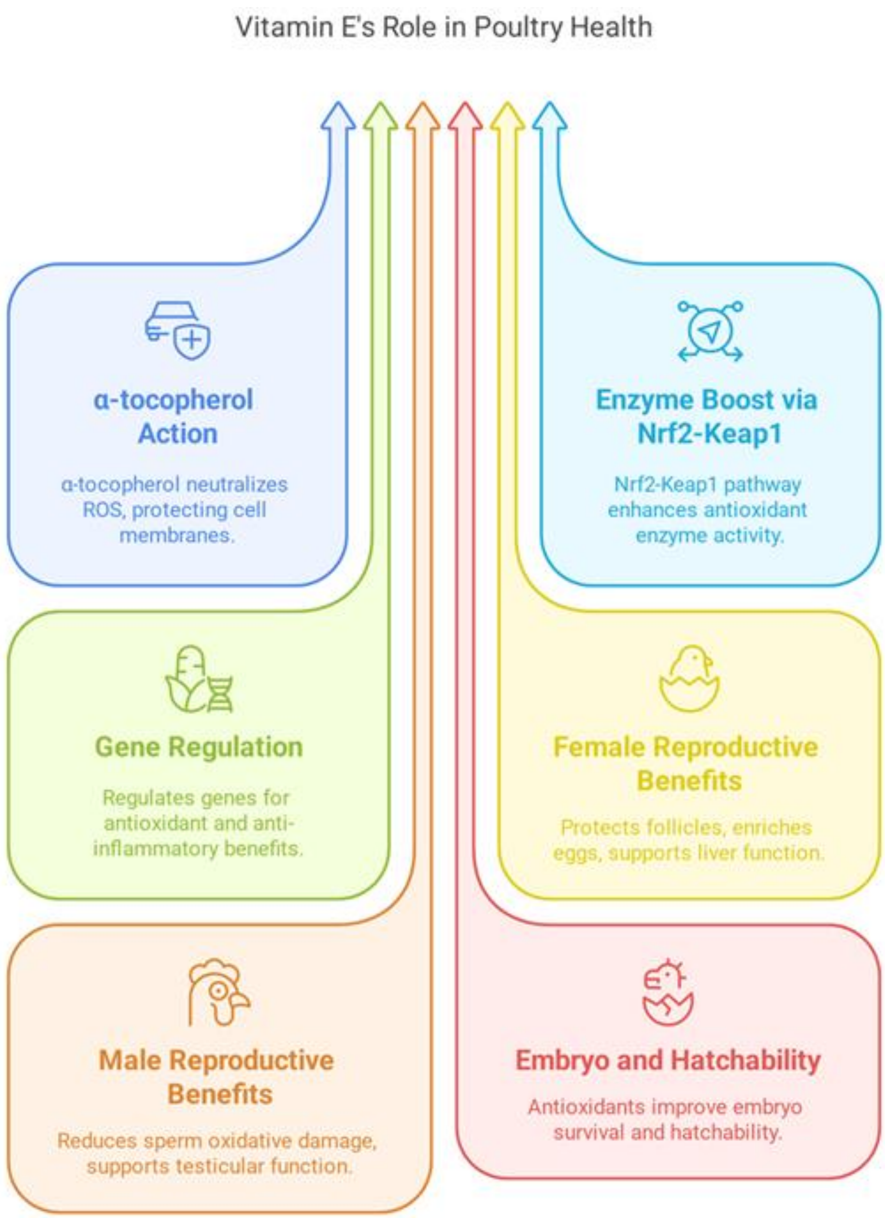

Fig. 1: Summary of vitamin E effects in poultry health and reproduction.

The effects of vitamin E on the reproductive organs of budgies (*Melopsittacus undulatus*) were investigated in a recent study together with diet type and immunological function. These results imply that, in budgies, mixed seed and pellet-based diets produce equivalent short-term health effects. This study emphasizes the importance of reevaluating food recommendations for companion birds in view of species-specific nutritional needs. (Eggleston et al., 2019).

Effects of Vitamin E on immunity in various animal species have extensively been reported (Ralla et al., 2024). Dietary changes of vitamin E at 100–300 mg/kg levels of feed in monogastric animals and 1-4 g/head/ day in dairy cows have shown to improve humoral immune and cell-mediated immune responses. Vitamin E supplements have been associated with higher lymphocyte proliferation, immunoglobulin levels, antibody responses, natural killer cell activity and immunological and inflammatory mediators IL-6 and IL-2 production (Lewis et al., 2019), as illustrated in figure 2. A summary of findings, about antioxidant and immunomodulatory effects of vitamin E in different species has been mentioned in Table 1.

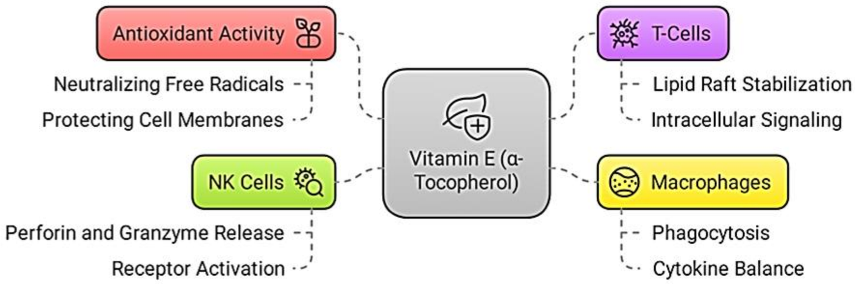

Fig. 2: Impact of vitamin E on immune cells and immunity

In birds and other animals, vitamin E is well known to affect development of tissues, reproduction, growth, and disease resistance. Acting as an antioxidant, it preserves sperm and egg quality so improving fertility and so decreasing the damage caused by infectious agents. Conversely, vitamin E shortages have been connected to lower fertility in birds as well as animals. In this regard, vitamin E is absolutely important for postnatal development, sperm motility, and egg production. Moreover, it preserves the integrity of sperm membranes and egg quality, so it is a vital determinant of the reproductive success of humans and animals (Nawab et al., 2019).

Common in birds, particularly under stress from fast development, sickness, or poor diet, oxidative stress results from an imbalance between pro-oxidants and antioxidants. Vitamins among other antioxidants are quite important in reducing oxidative stress, enhancing general health, and enabling sustainable economic results in chicken raising. Appropriate antioxidant balance stimulates development, increases nutrition, and improves bird welfare, therefore helping them to be resilient against environmental stresses (Panda and Cherian, 2014).

Vitamin E, commonly found in vegetable oils, is essential for various physiological functions in both humans and animals. One of its primary roles is protecting cells from oxidative damage. A deficiency in vitamin E can lead to reduced fertility in both humans and domestic animals. In birds, vitamin E plays a significant role in improving egg quality and production. In females, it prevents lipid peroxidation, protecting reproductive cells, while in males, it helps maintain sperm quality (Rengaraj and Hong, 2015).

In breeding geese, a study investigated the effects of vitamin E supplementation on various physiological aspects, including egg production, egg quality, antioxidant capacity, and immune function. Four treatments and four replicates were used, covering both male and female geese. The results showed that vitamin E improved several key factors, such as the egg-laying rate, gosling health, egg quality, hatching success, and the spleen index. It also enhanced the concentration of reproductive hormones, follicle development, and antioxidant enzyme levels, suggesting that vitamin E positively affects reproductive success and overall health in geese (Fu et al., 2022).

In Hubbard grandparent roosters the effects of nutritional supplementation of certain degrees of soybean lecithin and vitamin E on semen quality measures and some reproductive hormones were evaluated. Two levels of vitamin E, 120 (base diet) and 600 mg/kg feed; three levels of soybean lecithin, 0%, 1% and 2%; Including 1% soybean lecithin and vitamin E into the diet raised sperm concentration, membrane integrity and viability ($p<0.05$), semen volume, The amplitude of lateral head displacement of sperm ($p = 0.05$) was much raised by vitamin E. In all three treatments with vitamin E, malondialdehyde content was much reduced ($p < 0.05$). The researchers found that adding vitamin E and 1% lecithin to rooster meals increases fertility related measures in Hubbard grandparent roosters (Shabani et al., 2022).

Table 1: Summary of findings about anti-oxidant and immune-modulatory effects of vitamin E in various species.

Effects/ dose of vitamin E	Findings	References
Powerful antioxidant	For free radical molecules, vitamin E functions as a quenching agent.	(Forman et al., 2014)
	Oxidation of PUFAs in the membrane is prevented	(Traber, 2007)
	Deposition of α-tocopherol in the animal tissues, as well as in the egg, increases in direct proportion to supply in the diet, accompanied by high oxidative stability	Galobart et al., 2001; (Cortinas et al., 2006; Villaverde et al., 2008)
Immunity and inflammation	Stimulated the proliferation of T-cells (CD4+ and CD8+)	(Lee and Han, 2018)
	Increased lymphocyte proliferation, immunoglobulin levels, antibody responses, natural killer cell activity and immune and inflammatory mediators-IL-2 and IL-6 production	(Lewis et al., 2019)
	Improved immune response and reduced mortality in birds facing an *Escherichia coli* challenge	(Shojadoost et al., 2021)
	Inclusion of 100 mg/kg vitamin E with 0.3 mg/kg organic-Selinium, in broilers from day 1 to 42 days, effectively supported the immune system	(Dalia et al., 2018; Pompeu et al., 2018)
	Expression of IFN and TNF-α were reduced, cytokine TGF-β1) was upregulated as the in the broilers	(Khatun & Das, 2020)
0.2 g/kg	Improved count of sperm, testosterone level, follicle and leutinizing hormone and antioxidant level	(Amevor et al., 2022)

A study assessed the impact of vitamin E on semen quality under conditions of induced oxidative stress using dexamethasone, a synthetic glucocorticoid. Four concentrations of oxidative stress, along with vitamin E supplementation, were administered over seven days. Oxidative stress reduced sperm count, motility, and the percentage of live sperm. But vitamin E supplements enhanced sperm count, motility, and viability, therefore proving their protective action in preserving sperm health under stress (Eid et al., 2006). Vitamin E deficiency manifests in various clinical symptoms across the animal species, influenced by factors like dietary composition, environmental contaminants, stress, and seasonality. Studies showed that circulating levels of vitamin E vary significantly among reptiles, birds, and mammals, with plasma concentrations ranging from 0.1- 2 µg/mL in most mammals and 1- 26 µg/mL in birds (Machlin & Bendich, 2022). In birds, these variations are associated with diet, season, life history strategy, and species-specific differences (Surai, 2019). Monitoring vitamin E levels through blood testing in zoo animals is essential for early detection and intervention before appearance of clinical symptoms of deficiency. This proactive approach is crucial for maintaining animal health and preventing conditions such as reproductive failure, muscular weakness, and neurological disorders linked to inadequate vitamin E levels (Bendich, 2020).

Vitamin E often works synergistically with selenium to enhance reproductive outcomes. Studies on Japanese quails indicate that combining Vitamin E with selenium significantly increased villi height and crypt depth in the intestinal mucosa, improving nutrient absorption essential for reproductive health (Adamnezhad & Ghiasi-Ghalehkandi, 2018). Furthermore, Vitamin E-selenium combinations have been linked to higher hatchability and chick viability, demonstrating their effectiveness in supporting avian reproduction (Urso et al., 2015).

The effects of sunflower oil (as an omega-6 fatty acid source) and pumpkin seed oil (as a source of omega-3 fatty acids) along with 200 mg/kg feed of vitamin E (vs. a baseline diet containing 30 mg/kg) on the reproductive characteristics of aged roosters at 45 weeks of age, (showing reduced reproductive function), were investigated. Along with the higher percentage of sperm concentration, overall motility, progressive motility, viability and membrane integrity, the roosters fed pumpkin seed oil with 200 mg/kg feed of vitamin E had reduced lipid peroxidation ($p \leq 0.05$.). Thus vitamin E along with a source of omega-3 fatty acids like pumpkin oil is a good strategy to preserve the reproductive activity of aged roosters (Lotfi et al., 2021).

Feeding vitamin E causes the improvement in male reproductive system of Japanese quail (Biswas et al., 2007). Similarly, Hooda et al. (2007) found that supplementation of 75 and 150 IU/kg to quails improved weight of testes and testosterone levels.

Conclusion

Vitamin E plays a crucial role in maintaining the structural and functional integrity of reproductive organs in bird species. Being a potent antioxidant, it protects reproductive tissues from oxidative stress, enhances follicular development, and improves sperm quality. Additionally, it supports hormonal stability, ensuring optimal reproductive performance. Numerous studies indicate that moderate supplementation (80–200 mg/kg) benefits most avian species by promoting reproductive success and overall health. However, excessive doses may have adverse effects, potentially disrupting hormonal balance and reducing fertility. Seasonal variations in reproductive organ morphometry and hormonal activity have been observed across various avian species, highlighting the importance of vitamin E in regulating these changes. The synergistic effects of vitamin E with other essential nutrients, especially selenium, further enhance its protective and reproductive benefits. Investigating optimal dosages and interactions with other dietary components will help refine feeding strategies to maximize reproductive efficiency in both wild and captive bird populations. Understanding these mechanisms is essential for improving avian breeding programs, conservation efforts, and poultry production management. Future research should focus on the long-term impacts of vitamin E supplementation, evaluating its precise role in reproductive physiology across different environmental conditions.

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