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Advances in breeder nutrition: A Review

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Abstract
Over the past four decades, the poultry sector in India has transformed from a small-scale backyard enterprise into a large, organized, and commercially driven agro-industry. This progress has been fueled by the development of high-yielding layer strains (310-340 eggs) and fast-growing broilers (2.4-2.6 kg at 6 weeks), along with advancements in nutrition, housing, management, and health care practices. Breeder performance is central to sustaining chick supply in commercial production systems. While several factors such as genetics, age, management practices, reproductive health, microclimate, and biosecurity affect breeder productivity, nutritional status remains one of the most critical determinants. Fertility, a key driver of profitability, is strongly influenced by breeder nutrition. Balanced supplementation of energy, protein, essential fatty acids, vitamins (A, D, E), minerals (selenium, zinc), amino acids and their derivatives (L-carnitine, L-arginine, D-aspartic acid, guanidinoacetic acid), as well as functional additives like probiotics, phytochemicals (ginger, turmeric, lycopene, chrysin), and algae-based products has been shown to enhance reproductive efficiency. Ingredients such as dietary betaine (3 g/kg) improve egg production, semen quality, fertility, and hatchability while lowering embryonic mortality. Additionally, magnetized water has been reported to improve semen quality and hatchability in breeder flocks. In Conclusion, ensuring optimal quality and quantity of nutrients in breeder diets is essential for maximizing fertility, hatchability, and overall productivity in commercial poultry operations.

Keywords: Breeder nutrition, fertility, vitamin, mineral, reproductive performance

1. Introduction

The poultry sector in India has undergone a remarkable transformation over the last four decades, evolving from a traditional backyard activity into a highly organized and commercially significant agro-industry. This progress has largely been driven by the development of high-yielding layer strains (310-340 eggs per hen) and fast-growing broilers (2.4-2.6 kg at six weeks), coupled with advances in standardized practices for nutrition, housing, management, and disease control (Chatterjee and Rajkumar, 2015) [12]. According to BAHS (2023) [8], egg production in India registered an annual growth rate of 6.77%, while broiler production increased by 4.52% compared to 2021-22. Consequently, per capita availability has risen to 101 eggs and 7.1 kg of poultry meat, reflecting consistent improvements in productivity.

To meet the ever-increasing demand for eggs and poultry meat, it is essential to maintain the nutritional adequacy of breeder parents and grandparent flocks. This ensures the production of fertile eggs and robust chicks with enhanced immunity. Fertility in poultry is determined by both males and females; however, due to the smaller proportion of males used in natural mating or artificial insemination, the contribution of males is particularly critical. Since embryonic growth depends entirely on nutrients deposited in the egg, the nutritional status of the breeder hen directly influences chick size, vigor, and immunity at hatch. Importantly, breeder nutrition must be balanced with economic considerations across the entire production cycle, as apparent savings in feed costs may ultimately result in reduced broiler performance and higher overall losses (Kenny and Kemp, 2005) [33].

2. Fertility and Hatchability

Fertility and hatchability are key parameters that determine the supply of day-old chicks in the poultry industry.

Fertility refers to the proportion of incubated eggs that are fertilized, while hatchability represents the percentage of fertile eggs that successfully hatch. Although breed differences have limited impact on hatchability, light breeds are often reported to exhibit higher fertility and hatchability rates. Ensuring that breeder diets meet recommended nutrient levels in both quality and quantity is therefore critical (King'ori, 2011) [34].

Eggs are fertile only when hens are mated with roosters or inseminated artificially. Fertilization occurs through the union of spermatozoa with a matured ovum, either via natural mating or artificial insemination. Fertility remains one of the major determinants of profitability in commercial breeder operations and continues to be a limiting factor for productivity (Adegbenjo *et al*., 2020) [3].

3. Factors affecting breeder performance

3.1 Management

3.1.1 Restricted Feeding: Genetic selection for rapid growth in broiler stocks has resulted in parent lines that cannot regulate feed intake effectively to support reproduction. Hence, feed restriction is routinely practiced in modern broiler breeders to control body weight gain and reduce reproductive disorders (Renema and Robinson, 2004) [48].

3.1.2 Fibre diet: Despite equal nutrient intake, supplementing breeder diets with insoluble fiber can improve egg production, particularly during the early laying phase (Moradi *et al*., 2013) [40].

3.2 Reproductive Disorders

3.2.1 Multiple follicular hierarchy: Low egg production in ad libitum-fed broiler breeders during early lay is often linked to multiple ovulations resulting from the development of more than one hierarchy of yellow follicles. Feed restriction until 22 weeks of age has been shown to reduce follicular development and improve laying performance (Hocking and Robertson, 2000) [27].

3.2.2 Double yolk: The occurrence of double-yolked (DY) eggs is influenced by genetics, age, body weight, light stimulation, and nutrition. Multiple ovulations are most common during the first 10 weeks of lay, when follicular regulation is still immature. Restricted feeding has been shown to reduce the incidence of DY eggs (Salamon, 2020) [53].

3.2.3 Prolapse: Prolapse is characterized by eversion of the oviduct and rectum, often due to intestinal infections, overweight birds, early maturity, inappropriate photostimulation, double-yolked eggs, or imbalanced feed formulations (Ray *et al*., 2013) [46].

3.2.4 Internal oviposition: In some hens, follicles fail to reach oviposition due to atresia or internal ovulation into the peritoneal cavity. Stress and territorial challenges have been suggested as possible contributing factors (Navara *et al*., 2015) [42].

3.2.5 Oviduct impaction: This condition arises from egg or albumen accumulation in the oviduct, commonly due to chronic salpingitis, excessive mucin production, or cystic hyperplasia (Ritchie *et al*., 1994; Reisinho, 2008) [49, 47].

3.2.6 Egg yolk peritonitis: Often caused by coliform bacteria, this condition may arise from contaminated feed, water, or litter (Jordan *et al*., 2005) [31].

3.2.7 Refeeding syndrome: A metabolic condition characterized by severe electrolyte imbalances (low phosphate, magnesium, and potassium levels) during nutritional rehabilitation of underfed birds (Crook, 2014) [13].

3.2.8 Sudden death syndrome: This syndrome is observed in breeders around 24-26 weeks of age and is characterized by sudden collapse and death prior to or at the onset of lay (Pass, 1983) [43].

3.3 Genetic

Modern breeder hens represent a genetic balance between traits for rapid growth and efficient feed conversion on one hand, and high reproductive capacity on the other. This genetic compromise makes them more vulnerable to management and nutritional imbalances (Renema and Robinson, 2004) [47].

3.4 Biosecurity

The emergence and spread of infectious diseases can severely disrupt poultry production. Zoonotic and foodborne pathogens pose significant public health risks. Thus, strict biosecurity protocols are essential to minimize disease introduction and spread, with some measures targeting specific pathogens and others providing broad protection (Astill *et al*., 2018) [7].

3.5 Microclimate

Environmental conditions in poultry houses including temperature, humidity, ventilation, lighting, air composition (ammonia, CO_2, O_2), dust levels, and stocking density strongly influence breeder performance (Srankova *et al*., 2019) [54].

3.6 Age

Fertility in broiler breeders peaks between 30 and 40 weeks of age and subsequently declines. Male fertility decreases with reduced sperm output in older birds, while egg fertility also declines as hens age (Hocking and Bernard, 2000) [26].

3.7 Nutrition

Nutrition plays a central role in supporting growth, reproduction, and overall health. Optimal breeder performance requires balanced intake of energy, protein, vitamins, minerals, fats, and oils. Nutritional adequacy affects both male and female reproductive traits, including spermatogenesis, sperm motility and concentration, egg production, shell quality, hatchability, internal egg quality, and progeny performance (Jiwuba *et al*., 2020) [30].

3.7.1 Nutritional Aspects

In poultry males older than 45 weeks, fertility typically declines due to reductions in testicular weight, testosterone levels, semen volume, sperm concentration, viability, motility, and polyunsaturated fatty acids (PUFAs), particularly n-3 PUFAs, as well as decreased antioxidant activity. Nutritional interventions can counteract these age-related declines by improving reproductive organ health, semen quality, and overall fertility. For example, zinc supplementation has been shown to enhance sperm penetration into the egg yolk and improve fertility, likely due to improved semen quality and sexual efficiency (Lagares *et al*., 2017) [36].

3.7.1.1 Overfeeding
Erratic Oviposition and Defective Egg Syndrome (EODES) is characterized by the overproduction of large yellow follicles (LYFs), multiple follicular hierarchies, and oviposition disturbances. Effective control of EODES has been achieved through feed restriction during pullet growth and throughout the laying period (Eitan and Soller, 2009) [18].

3.7.1.2 Excess muscle Development
Intensive genetic selection has made broiler chickens highly efficient meat producers; however, the correlation between rapid muscle growth and reduced reproductive efficiency has created management challenges. This paradox fast growth versus reproductive health necessitates strict feed restriction to balance reproduction, welfare, and metabolic health (Decuypere *et al*., 2010) [15].

3.7.2 Fertility
Fertility aspects of breeder male and female depend on various nutritional factors such as.

3.7.2.1 Energy and Protein
Feeding high-energy diets with lower protein intake during the second laying phase has been shown to improve hatchability. However, excessive energy intake negatively affects both fertility and hatchability. Restricted feeding consistently yields higher fertility and hatchability compared to ad libitum feeding. Additionally, supplementation with inulin or cellulose has been shown to enhance hen performance, while higher dietary protein helps reduce obesity in broiler breeder hens (Asli *et al*., 2012) [6].

3.7.2.2 Fatty Acid
Avian spermatozoa contain high levels of PUFAs, such as docosatetraenoic acid (22:4n-6) and arachidonic acid (20:4n-6), making them susceptible to lipid peroxidation a major cause of male infertility (Surai *et al*., 2001) [56]. Dietary supplementation with oils can remodel sperm phospholipid profiles and improve quality. For instance, rosemary extract combined with PUFA improved sperm quality and hormonal profiles (Zadeh *et al*., 2020)[59], while corn oil, palmitic acid, oleic acid, or linoleic acid supplementation (2%) increased hatchability and reduced late embryonic mortality.

3.7.2.3 Vitamins
3.7.2.3.1 Vit A
Essential for epithelial integrity of the reproductive tract and gametogenesis signaling pathways (Hogarth and Griswold, 2010). Carotenoids such as canthaxanthin improve chick antioxidant status and hatchability, particularly in older breeders (Bonagurio *et al*., 2022) [11].

3.7.2.3.2 Vitamin D and calcium
Vitamin D is critical for calcium metabolism, shell quality, and embryo protection. Supplementation above 3,000 IU/kg has been shown to reduce early embryonic mortality and improve hatchability (Blades and Korver, 2014; Das *et al*., 2021) [10, 14].

3.7.2.3.3 Vitamin E
As a major antioxidant, vitamin E plays a central role in semen quality, embryo protection, and chick viability. Supplementation improves semen α-tocopherol levels, enhances resistance to oxidative stress, increases fertility, and supports antioxidant enzyme regulation (Surai *et al*., 2019; Lin *et al*., 2005; Biswas *et al*., 2007) [57, 37, 9].

3.7.2.4 Minerals
3.7.2.4.1 Selenium
Functions through selenoproteins with structural, enzymatic, and antioxidative roles. Organic selenium (SeMet) is efficiently transferred to eggs and embryos. Supplementation enhances semen quality, ejaculate volume, and fertility, especially when combined with vitamin E (Qazi *et al*., 2019; Surai and Fisinin, 2014) [45, 55].

3.7.2.4.2 Zinc
Zinc (Zn) Supports reproduction, immunity, antioxidant defense, and epigenetic processes, making it an essential mineral for breeder performance (Huang *et al*., 2019) [29].

3.7.2.5 Amino Acids and Their Metabolites
3.7.2.5.1 D-aspartic acid
Enhances testosterone synthesis, spermatogenesis, and fertility by improving sperm quality and steroidogenic gene expression (Di Fiore *et al*., 2008; Ansari *et al*., 2018) [16, 5].

3.7.2.5.2 L-carnitine
In poultry production, L-carnitine Improves semen quality, motility, and antioxidant activity while supporting growth and immunity (Adabi *et al*., 2011; Elokil *et al*., 2019) [2, 21].

3.7.2.5.3 Guanidinoacetic acid
Precursor of creatine, improves testis histology and spermatogenic markers (Nasirikhah *et al*., 2019) [41].

3.7.2.5.4 L-Arginine
Improves egg production, lipid metabolism, and antioxidant defenses. Supplementation restores testicular function and sperm motility in aged cocks (Fouad *et al*., 2012; Abbaspour *et al*., 2019) [22, 1].

3.7.2.2 Probiotics
Supplementation with Bacillus subtilis and Bacillus amyloliquefaciens strains improved sperm quality, egg fertilization, chick viability, and delayed reproductive aging, while reducing embryo mortality during early incubation (Prazdnova *et al*., 2019)[44].

3.7.2.7 Phytochemicals
3.7.2.7.1 Ginger (*Zingiber officinale*)
Enhances sperm motility, viability, and plasma membrane integrity in aged roosters (Akhlaghi *et al*., 2014; Herve *et al*., 2018) [4, 25].

3.7.2.7.2 Turmeric (*Curcuma longa*)
Improves sperm production, motility, and testicular function (Kazemizadeh *et al*., 2019) [32].

3.7.2.7.3 Lycopene
A potent antioxidant that improves semen viability, fertility, and DNA integrity of chilled/frozen spermatozoa (Mangiagalli *et al*., 2010; Rosato *et al*., 2012) [39, 51].

3.7.2.7.4 Chrysin
Chrysin is a bioflavonoid compound. Improves fertility and semen quality in male breeders (Zhandi *et al*., 2017) [61].

3.7.2.7.5 Other sources
Rosemary, dried apple pomace, cinnamon, flaxseed oil, fish oil, and moringa extract have been reported to enhance semen quality, fertility, and antioxidant capacity (Zanussi *et al*., 2019; Saber and Kutlu, 2020; Ghadimi *et al*., 2024) [60, 52, 23].

3.7.2.7.6 Betaine
At 3 g/kg diet, improves egg production, semen quality, fertility, and hatchability while reducing embryonic mortality (Rokade *et al*., 2020) [50].

3.7.2.8 Magnetic water
Magnetized water refers to water that has been exposed to a magnetic field, resulting in direct or indirect alterations in its physical, chemical, and electromagnetic characteristics, including boiling point, viscosity, surface tension, electrical conductivity, pH, and molecular energy (El Sabry *et al*., 2021; Wang *et al*., 2018) [20,58]. Magnetic treatment also influences the mineral composition of water, particularly the physical state of calcium carbonate (Kobe *et al*., 2001) [35]. These physicochemical changes depend on both the intensity of the magnetic field and the duration of exposure, with notable effects on properties such as surface tension and electrical conductivity (Hafizi *et al*., 2014; Ebrahim and Azab, 2017) [24, 17]. It has been suggested that magnetized drinking water (MDW) enhances dissolved oxygen levels and mineral solubility, thereby exerting beneficial effects at the cellular level (Hafizi *et al*., 2014)[24]. Moreover, these modified properties are thought to facilitate more efficient transport of water and nutrients across body compartments by improving cell membrane permeability (Lee and Kang, 2013) [37].
Magnetic water conditioners are capable of improving water quality, and their use in breeder flocks has shown promising results. Supplying MDW during the late laying phase was reported to enhance semen quality traits, which in turn improved fertility and hatchability rates. These findings highlight the potential of magnetized water as a novel approach for supporting reproductive performance in poultry (El Sabry *et al*., 2023) [19].

4. Conclusion
- Fertility and hatchability are critical determinants of economic success in poultry breeding; hence, genetic, nutritional, and management strategies must be optimized.
- Even a 1% improvement in hatchability can yield significant economic gains.
- In tropical developing countries like India, nutritional interventions are often the most feasible strategy for enhancing breeder performance.
- Dietary supplementation with antioxidants, vitamins, minerals, probiotics, and phytochemicals can rejuvenate reproductive function and improve fertility.
- Ensuring optimal parental nutrition is vital, as maternal nutrient transfer supports embryonic growth, hatchability, and early-life immunity in chicks.

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Financial Support: Not available

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