The Regulatory Effect of Vitamin E on Follicular Development in Goose Out-of-Season Breeding and Research Status: Postprint

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Date: 2017-10-23T00:00:00+00:00

Abstract

Goose reproduction is characterized by distinct seasonal patterns, ultimately resulting in imbalanced annual production, market supply-demand deficiencies, and substantial price volatility. Vitamin E plays a pivotal role in maintaining normal reproductive function in poultry. However, research on the effects of vitamin E on expression of genes related to egg production, follicular development regulation, reproductive organs, as well as the apoptosis gene Dicer and candidate gene for egg production performance (CGLP) during follicular development in out-of-season breeding geese remains scarce. This paper presents a comprehensive review of current research status and future prospects regarding vitamin E' s role in regulating follicular development during out-of-season reproduction in breeding geese.

Full Text

Research Progress in Regulation of Vitamin E on Follicular Development of Geese in Counter-Season Production

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Abstract: Goose reproduction exhibits typical seasonal characteristics, resulting in uneven annual production, insufficient market supply, and significant price fluctuations. Vitamin E plays a crucial role in maintaining normal reproductive function in poultry. However, research on the effects of vitamin E on laying-related genes, follicular development regulation, reproductive organs,

and the expression of apoptotic gene Dicer and candidate gene for laying performance (CGLP) during counter-season breeding remains scarce. This review summarizes the current research status and future prospects of vitamin E in regulating follicular development in breeding geese during counter-season production.

Keywords: breeding geese; counter-season production; vitamin E; nutritional regulation; reproductive genes

Geese exhibit typical seasonal breeding patterns, leading to uneven annual production, market supply shortages, and substantial price volatility. Counter-season breeding technology artificially manipulates environmental factors such as photoperiod and temperature, combined with forced molting and nutritional regulation, to alter gonadal activity. This enables geese to cease egg production during their natural laying season and produce eggs during the off-season, thereby achieving continuous and efficient production year-round. While international research has primarily focused on wild geese and snow geese, domestic studies in China have examined counter-season breeding in breeds such as Magang geese, Yangzhou geese, and Xingguo Gray geese. These studies have primarily investigated the effects of photoperiod and temperature, yielding certain economic benefits. However, research on nutritional factors regulating counter-season breeding in geese remains limited. Therefore, investigating how nutritional factors can effectively regulate follicular development on the basis of existing counter-season breeding technologies holds significant practical value for improving egg production.

1. Regulation of Goose Reproductive Performance

Currently, both domestic and international literature on improving breeding goose reproductive rates is scarce, with even fewer studies on counter-season breeding. Domestic research typically employs three approaches: genetic selection, nutritional regulation, and biotechnology application. While breed improvement has enhanced egg production performance to some extent, genetic progress has become increasingly slow and fails to achieve balanced annual production. Consequently, researchers are now exploring counter-season breeding and nutritional regulation as means to further improve and achieve year-round balanced production.

Avian follicular development and hierarchical establishment represent a complex biological process regulated by multiple factors, dependent on the hypothalamic-pituitary-ovarian axis, though the molecular mechanisms remain unclear. Goose laying performance primarily depends on the growth and development level of ovarian follicles. Among the numerous follicles in poultry, only a small proportion—approximately 5%—develop into small yellow follicles. Follicles establish a strict hierarchical system through development, selection, and atresia mechanisms. The greater the number of follicles selected for hierarchical development, the longer the laying period and the higher the laying performance. Despite ex-

tensive research on follicle selection mechanisms, the precise regulatory network remains poorly understood due to the complex interplay of growth factor secretion, gene expression, and nutritional status. Particularly for geese, relevant research data is virtually nonexistent.

Since the 1980s, Xie Jinfang and colleagues have conducted extensive research on Xingguo Gray geese. To address the pronounced seasonal breeding characteristics of this breed, the research team employed counter-season breeding control technology using short photoperiod manipulation to resolve the natural cessation of egg production from May to August, significantly increasing egg numbers. However, these studies were limited to investigating photoperiod effects on hormones, fertilization rates, hatchability, and egg production. Research utilizing nutritional regulation measures to study follicular atresia and its regulation at physiological, biochemical, and molecular levels has not yet been initiated.

2. Regulatory Effects and Mechanisms of Vitamin E on Goose Follicular Development

Previous research on vitamin E' s effects on goose reproductive function has been limited to conventional reproductive indices, with few studies conducted. Apoptosis of follicular granulosa cells serves as a critical marker of follicular development. Key soluble signaling molecules facilitating follicular communication include the apoptosis "switch" Dicer gene and candidate genes for laying performance (CGLP). Goose ovaries contain tens of thousands of follicles, yet only a minority are selected for pre-ovulatory development and eventual ovulation, while the remainder undergo atresia. If vitamin E can reduce follicular atresia to promote increased ovulation, it may enhance goose reproductive capacity.

Egg formation involves estrogen (E2)-induced synthesis of yolk precursor proteins in the liver and their subsequent uptake by the ovary. Yolk precursor proteins (vg) are synthesized in the liver, and their release requires transport across cell membranes. As an antioxidant for cell membranes, vitamin E protects membrane integrity, ensuring normal transport function and enabling proper vg release to maintain high egg production. Studies have demonstrated that dietary vitamin E supplementation can improve goose egg production, fertilization rates, and hatchability. Furthermore, increasing vitamin E supplementation tends to increase oviduct weight, oviduct length, and ovarian weight in ducks. However, research on vitamin E' s effects and regulatory relationships with follicular development during counter-season breeding in geese remains unreported.

Dicer functions as a switch for follicular granulosa cell apoptosis and is essential for miRNA and siRNA synthesis. These small RNAs post-transcriptionally regulate mRNA expression, influencing cellular activities including proliferation, differentiation, and atresia. Recent studies using Dicer knockout mouse models have investigated its role in female reproductive tissues. Conditional inactivation of Dicer in granulosa cells leads to massive primordial follicle recruitment, promotes primary follicle replenishment, and generates more atretic follicles,

altering genes associated with follicular development. Conditional Dicer inactivation in ovarian granulosa cells, uterus, and oviduct stromal cells indeed results in decreased ovulation rates, increased atretic follicles, reduced embryonic integrity, delayed early embryonic development, significant bilateral oviduct cysts, impaired female reproductive tract development, and female infertility. Whether vitamin E can regulate Dicer function remains to be investigated, and if so, the regulatory relationship between vitamin E and Dicer in goose granulosa cells during counter-season breeding requires elucidation.

3. Regulation of CGLP by Vitamin E and Its Mechanisms

Studies have confirmed that vitamin E promotes proliferation and reduces apoptosis rates in chicken ovarian granulosa cells cultured in vitro. Investigating the dynamic expression patterns of CGLP holds significant importance for understanding the molecular regulatory mechanisms governing goose follicular development and egg production. Numerous candidate genes for livestock and poultry reproductive performance (CGLP) have been proposed, with most research focusing on pigs and relatively few studies on poultry CGLP genes. Research has confirmed that follicle-stimulating hormone (FSH), luteinizing hormone (LH), and prolactin (PRL) are the primary hormones regulating goose follicular development, with many other hormones exerting indirect regulatory effects by influencing the secretion of these three hormones. Hormone function is mediated through receptors including follicle-stimulating hormone receptor (FSHR), luteinizing hormone receptor (LHR), and prolactin receptor (PRLR). Scholars have successfully identified estrogen receptor 1 (ESR1) as a candidate gene for litter size in Meishan × Large White crossbred pigs and European synthetic pig populations. A single nucleotide polymorphism was identified in exon 5 of the ESR2 gene, with a methionine (Met)/valine (Val) substitution at position 949. However, no studies have investigated the effects of vitamin E regulating CGLP genes (FSHR, LHR, PRLR, and ESR) on follicular atresia in poultry. Therefore, research on vitamin E' s regulation of CGLP expression in goose follicles during counter-season breeding and its impact on follicular development and atresia is necessary to establish a foundation for future mechanistic studies.

Additionally, vitamin E protects reproductive organs and stimulates ovarian development to increase ovulation numbers in laying hens. Ovarian CGLP plays important regulatory roles in these processes. Studies investigating the effects of immunizing Magang and Landes geese with recombinant chicken inhibin (INH) fusion protein during the laying period demonstrated that immunized Magang geese showed a 6.43% increase in egg number over 120 days, while Landes geese exhibited a 23.29% increase over 90 days. FSH and LH play dominant roles in avian follicular development. FSH acts through FSHR on granulosa cells, with FSHR being virtually absent on all follicles in young poultry but gradually increasing on some follicles as birds age, while remaining absent on others. This differential expression determines the sequential development of follicles on the chicken ovary. LH also accelerates ovarian blood circulation, promoting matura-

tion of FSH-pretreated follicles and inducing ovulation. PRL inhibits follicular development, with elevated blood PRL levels during broodiness accompanied by cessation and atrophy of follicular development. Studies have shown that dietary vitamin E supplementation affects plasma LH, E2, and FSH levels in geese. These findings demonstrate that CGLP plays important roles in goose follicular development and can be regulated by external factors. However, the regulatory relationship between vitamin E and CGLP in follicular atresia during counter-season breeding remains unreported and requires further investigation.

4. Summary and Prospects

As described above, vitamin E plays important roles in poultry reproduction, while genes such as Dicer and CGLP in avian ovaries exert critical regulatory effects on follicular development. However, current reports on vitamin E' s regulatory effects on these factors during follicular development are scarce and incomplete, with no relevant research conducted in geese during counter-season breeding.

Addressing these gaps, research on vitamin E' s regulation of follicular development in geese during counter-season breeding is essential. With the ultimate goal of reducing follicular atresia to improve reproductive performance, future studies should adopt a comprehensive approach integrating whole-organism, molecular, and cellular in vivo and in vitro investigations. Through animal feeding trials and follicular granulosa cell culture models, researchers should explore the effects of vitamin E on Dicer and CGLP during follicular development in counter-season breeding and their interactions. Such systematic and comprehensive studies would elucidate the regulatory mechanisms of vitamin E on Dicer and CGLP during goose follicular development in counter-season breeding. These findings would establish a research foundation for exploring follicular development regulatory mechanisms and reducing atresia rates, holding important theoretical and practical significance for improving breeding goose reproductive performance and achieving balanced year-round production.

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(Executive editor: WU Hailong)

Note: Figure translations are in progress. See original paper for figures.