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Dietary Flaxseed Supplementation to Enhance Productivity and Omega-3 Enrichment in Laying Hens

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ABSTRACT

Flaxseed is increasingly recognized as an effective functional dietary supplement in poultry nutrition due to its high content of alpha-linolenic acid (ALA) and various bioactive components. Current evidence demonstrates that incorporating flaxseed into poultry diets markedly improves the nutritional profile of animal products by significantly reducing the omega-6 to omega-3 fatty acids ratio, thereby enhancing lipid balance and contributing to potential health benefits for consumers. Moreover, studies have shown that flaxseed supplementation does not impair production performance; instead, it may enhance key indicators such as egg production rate, egg weight, and internal egg quality. These improvements are attributed to its antioxidant and immunomodulatory effects, as well as its positive regulation of genes involved in lipid metabolism. Collectively, the findings underscore the value of flaxseed as a sustainable nutritional intervention capable of enriching poultry products, supporting animal performance, and contributing to improved public health outcomes.

Keywords: Flaxseed, omega-3, omega-6, performance, poultry.

INTRODUCTION

In recent times, attention has intensely increased in consuming animal-derived food products to improve human health and wellbeing (Wood, et al., 2024). The enrichment of poultry products with biological active compound, mainly *n*-3 polyunsaturated fatty acids (PUFAs), has becoming more prominent, mostly attributable to **amplifying consumer understanding** of the connection between nourishment and health (Usturoi et al., 2025). The fatty acid (FA) structure of animal-derived foods products, such as egg yolks, accurately represents the lipid content of the animals' ration (Lanza et al., 2025). Flaxseed (*Linum usitatissimum L.*) are slight with a flat to oval shape and are almost 2.5-3.1 mm wide and 3.5-4.5 mm long (Moghadam and Cherian, 2017). Flaxseed are frequently used in poultry diet for enriching eggs with fatty acid due to its high content of α-linolenic acid (>50%) (Szmek, et al., 2025). Based on proximate analysis, flaxseed contain 20 - 30% protein, around 30% nitrogen-free extract and flax oilseed contains 41-42% crude fat, with apparent metabolizable energy value of 3,957 kcal/kg. This review goes to bring together the usage of flaxseed in poultry ration and its impact on final product to meet the human necessity of fatty acid (Singh et al., 2011).

Role of flaxseed

Recent research has shown increasing interest in studying the effects of including flaxseed (Figure 1) in animal diets, particularly regarding productive performance and improving the omega-6 to omega-3 fatty acid ratio. Various studies indicate a complex understanding of the role of flaxseed, which contains high levels of α-linolenic acid and phytoestrogens, in

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influencing growth and reproductive parameters across various animal species.

Figure 1. Dried flaxseed

Omega-3 and omega-6 fatty acids are considered essential polyunsaturated fatty acids, playing vital roles in numerous biological processes (Lee et al., 2021). Omega-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), Omega-3 fatty acids play a fundamental role in maintaining cardiovascular, circulatory, and nervous system health (Banaszak et al., 2024). Several dietary sources of these fatty acids are presented in Figure 2.

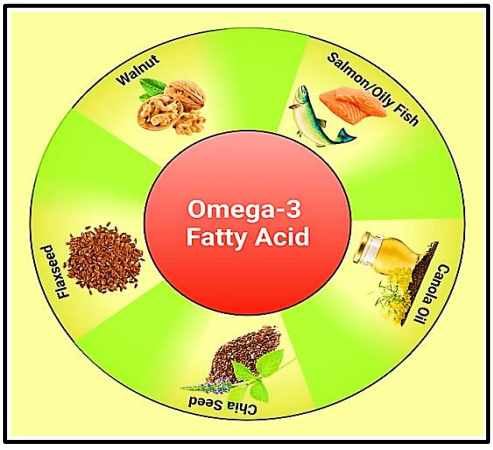
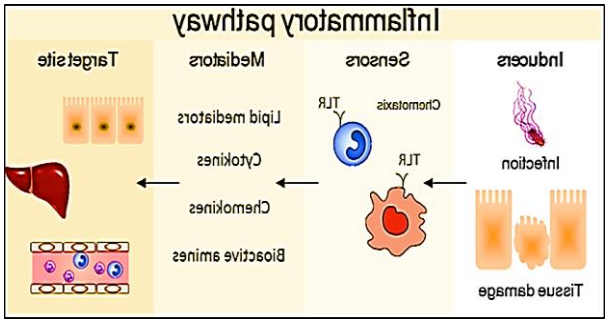


Figure 2. Major Dietary Sources of Omega-3 Fatty Acids

Omega-6 fatty acids are also essential components of the diet, but they are typically present in greater quantities than omega-3 fatty acids. This underscores the importance of achieving a proper balance between omega-3 and omega-6 fatty acids, as a high omega-6 to omega-3 ratio has been associated with several health problems, including inflammation (Figure 3), as well as an increased risk of chronic diseases. Flaxseed is a rich plant source of alpha-linolenic acid (ALA), a type of omega-3 that can be converted in the body into EPA and DHA (Zárate et al., 2017).



TLR: toll-like receptor in the immune system

Figure 3. Diagrammatic illustration of the molecular mechanisms underlying the inflammatory pathway.

The ideal healthy ratio of omega-6 to omega-3 fatty acids in the diet typically ranges from 1:1 to 2:1, indicating that the body requires a delicate balance between these two fatty acids to achieve the desired health benefits. In eggs produced by layers fed flaxseed, the omega-6 to omega-3 ratio was close to 1:1 (Kartikasari et al., 2024), which contributes to enhancing the nutritional value of the eggs and reducing the negative effects of excessive omega-6 consumption. Studies indicate that nutritional supplements such as flaxseed effectively contribute to improving this ratio, due to its rich content of alpha-linolenic acid (ALA) (Simopoulos, 2010).

Polyunsaturated fatty acids (PUFAs) are classified into two main groups: omega-3 and omega-6, based on the position of the first double bond in the carbon chain, calculated from the methyl end (CH_3). Among these categories are essential fatty acids, which the body cannot synthesize on its own and must be supplied in the diet.

These include alpha-linolenic acid (ALA), which belongs to the omega-3 family, and linoleic acid (LA). These acids play vital roles in numerous biochemical and physiological functions, highlighting the importance of balance in the diet to maintain optimal health.

In chickens, omega-3 fatty acids cannot be converted to omega-6 and vice versa due to different metabolic pathways and the absence of the required enzymes. Once in the body, essential omega-3 fatty acids, such as alpha-linolenic acid (ALA), are converted by elongases and desaturases into more biologically active compounds such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Similarly, linoleic acid (LA), an omega-6, is converted to arachidonic acid (AA) via similar pathways. These polyunsaturated fatty acids (PUFAs) are key substrates for membrane-bound enzymes, including cytochrome P450 (CYP450) enzymes, cyclooxygenases (COXs), and lipoxygenases (LOXs). These enzymes convert fatty acids into a wide range of bioactive lipid intermediates that play regulatory roles in various cellular processes, particularly in inflammatory and immune responses (Greene et al., 2011). Omega-6 and omega-3 fatty acids are vital precursors that determine the systemic properties of lipid mediators, which are known for their dual role in inducing or reducing inflammation (Serhan et al., 2014). While omega-6-derived lipid mediators are often associated with pro-inflammatory effects, omega-3-derived mediators have anti-inflammatory properties (Shearer & Walker, 2018). Cytokines play a key regulatory role in the body's immune response to various conditions, including inflammation. Some cytokines, such as interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor (TNF), are classified as pro-inflammatory cytokines due to their role in promoting the inflammatory response (Dinarello, 2000). Mattioli et al. (2017) reported 10% flaxseed in chicken diets significantly increased the egg content of omega-3 polyunsaturated fatty acids (n-3 PUFAs) and lignans, without negatively affecting the productive performance of laying hens. This suggests the potential for improving the nutritional value of eggs through dietary modification.

In a related study, Parveen et al., (2016) examined the effect of flaxseed supplementation on broiler chickens, showing that the inclusion of 10% flaxseed in the diet led to qualitative changes in the lipid composition of tissues, in addition to altering the expression of genes associated with lipid metabolism pathways. A significant increase in the concentration of alpha-linolenic acid (ALA) was observed, accompanied by a marked decrease in the levels of both palmitic acid and linoleic acid, leading to an overall improvement in the qualitative composition of fatty acids, particularly those belonging to the omega-3 family. These results highlight the nutritional potential of flaxseed in modifying the lipid composition of poultry products, which positively affects public health through the consumption of functional foods rich in healthy fatty acids (Head et al., 2019). Studies have shown that the inclusion of flaxseed in the diet led to significant improvements in several egg quality indicators, demonstrating the positive effects of functional nutrition on the physicochemical properties of animal products. One of the most notable findings was a significant increase in the concentration of secoisolariciresinol (SECO) in treated chicken eggs, reaching three times its level in eggs produced from conventional diets (Zaki et al., 2022). SECO is one of the most important bioactive plant lignans, belonging to the phytoestrogen group, known for its potential protective effects against several hormonal and immune disorders.

In addition, flaxseed supplements contributed to enhancing the egg content of alpha-linolenic acid (ALA), one of the most important omega-3 essential fatty acids, known for its role in supporting heart and brain function. These results suggest that using flaxseed as a functional food source could be an effective strategy for improving the nutritional properties of eggs, enhancing their health value for consumers, and linking animal production with preventive nutrition within the framework of farming for health (Antruejo et al., 2011). Several recent studies have indicated a growing trend toward enhancing the nutritional value of animal products, particularly beef products, by enriching them with omega-3 fatty acids. This can be achieved by including food sources rich in

these acids, such as flaxseed, in animal feed (Gjerlaug-Enger et al., 2015). In this context, the addition of flaxseed to laying hens' diets was studied to examine its impact on both the chemical composition of eggs and the physiological and health functions of the animal, with a particular focus on analyzing the levels of nutritionally mediated lipid mediators. These studies demonstrated that the addition of flaxseed to laying hens' feed contributes to improving the omega-6 to omega-3 ratio in eggs, reflecting a positive modification in lipid composition, in addition to its potential effects in reducing the inflammatory response. It is suggested that omega-3 fatty acid supplements may improve the productive performance of birds by reducing levels of inflammation and stress associated with the production period, through regulatory mechanisms linked to the role of lipid mediators and cytokines in inflammatory responses (Zachut et al., 2010).

To evaluate this hypothesis, studies included monitoring a number of physiological and inflammatory indicators in laying hens following dietary treatment, including production performance, serum lipid composition, serum levels of typical inflammatory cytokines, corticosterone concentrations, and the heterophil/lymphocyte ratio (H/L ratio) as a biomarker of physiological stress. The results indicate that using flaxseed as a nutritional source rich in omega-3 fatty acids represents an effective strategy for improving both overall health and production performance in poultry by regulating inflammatory pathways and stress-related responses. The action mechanisms of lipid mediators derived from omega-3 and omega-6 fatty acids are too complex to simplify in the physiological regulation of inflammation and its resolution (Serhan et al., 2015). Different lipid mediators, on the other hand, usually act as signaling molecules that mainly use G-protein-coupled receptors (including GPR32, GPR18, ChemR23, GPR37, and LGR6) to mediate their anti-inflammatory and pro-resolution activities (Shearer & Walker, 2018).

Omega-3 fatty acid-derived lipid mediators, particularly those known to promote inflammation resolution (pro-resolving lipid mediators), are a major focus of recent studies due to their physiological role in effectively regulating and terminating the inflammatory response without causing tissue damage (Hallisey et al., 2020). The importance of these mediators lies in their contribution to restoring immune balance after the inflammatory stimulus has ended, distinguishing them from traditional lipid mediators that only stimulate inflammation. Cytokines, on the other hand, play a central role in regulating immune responses, acting dually to either activate or inhibit inflammation, depending on their type and the context in which they are secreted. Several cytokines, such as tumor necrosis factor (TNF), interleukin-1 (IL-1), and interleukin-6 (IL-6), are classified as pro-inflammatory cytokines, as they directly contribute to stimulating and amplifying the inflammatory response (Arnardottir et al., 2021).

Flaxseed Effect on Laying Hens

Cyanogenic glycosides, mucilage, trypsin inhibitors, and other anti-nutritional substances found in flaxseed may affect performance and digestibility. To mitigate these adverse effects, various detoxification and processing techniques can be applied. These include thermal treatments such as roasting, extrusion, or autoclaving, which denature trypsin inhibitors and reduce cyanogenic compounds. Additionally, enzymatic treatment and microbial fermentation have been shown to degrade mucilage and improve nutrient availability. Mechanical processing methods, including milling or dehulling, can further enhance digestibility by reducing fiber content and improving access to nutrients. These approaches collectively improve the safety and nutritional efficiency of flaxseed when used in poultry diets (Takatoshi Yamashita et al. 2007). The integration of flaxseed into the diet of laying hens can lead to notable changes in egg composition, health benefits for the birds, and even potential alterations in hen behavior. The presence of flaxseed in the diet of laying hens has been observed to positively affect egg production. Hens fed flaxseed may produce eggs with elevated omega-3 fatty acid levels, improving the omega-3 to omega-6 ratio, which is essential for human health (Usturoi et al., 2025).

However, the specific impact on the quantity of egg production can vary. Some studies report a neutral or slight decrease in egg production due to the energy content of flaxseed, whereas others report sustained or improved laying rates. The balance of such outcomes can be influenced by factors such as the proportion of flaxseed in the diet and the adaptive responses of the hens' metabolism. Furthermore, the inclusion of flaxseed in poultry diets has been shown to enhance egg quality, reflected in improved shell strength and more intense yolk pigmentation—traits of both nutritional and aesthetic significance (Kazempoor et al., 2021). In addition to their impact on egg production parameters, flaxseed supplements confer important health benefits to laying hens. The high levels of ALA in flaxseed may help reduce systemic inflammation and enhance the immune response, fostering improved overall health among the birds (Kartikasari et al., 2024). Additionally, flaxseed contains lignans with antioxidant properties that may protect cellular structures and functions, potentially leading to a longer productive lifespan for the hens. Improved plumage condition and better fertility rates have also been documented, reflecting the holistic impact of a flaxseed-enriched diet. Moreover, dietary flaxseed can influence the behavior of laying hens, though this aspect is less frequently studied. This could be linked to the physiological benefits provided by omega-3 fatty acids, impacting neurotransmitter function and reducing stress susceptibility. Understanding these behavioral shifts is essential, as they can affect the welfare and productivity of the flock. Thus, incorporating flaxseed into the diet of laying hens presents a multifaceted intervention with promising benefits for egg quality, hen health, and behavior, aligning with contemporary goals for sustainable and health-focused poultry farming practices (Alagawany et al., 2022).

Effects of Flaxseed on Egg Production

Investigations into nutritional interventions for laying hens often focus on enhancing egg quality and yield, and the inclusion of flaxseed into their diets has gained significant interest. Flaxseed, which is rich in alpha-linolenic acid (ALA), is proposed to improve the fatty acid profiles of eggs. When incorporated into layer diets, ALA from flaxseed is efficiently deposited in the yolk, resulting in eggs with elevated omega-3 polyunsaturated fatty acids (PUFAs) and a markedly improved omega-6 to omega-3 ratio. This dietary strategy not only enhances the nutritional value of eggs but also produces a functional food product that supports human cardiovascular and metabolic health, which can significantly affect their nutritional value and market appeal. The inclusion of flaxseed in laying hen diets has been shown to modify egg production in several beneficial ways while also affecting the overall nutritive composition of the eggs. The seed's omega-3 fatty acids contribute not only to improved omega-3 content in the eggs but can also influence the production parameters, such as egg size, shell strength, and yolk consistency (Sepehr et al., 2021). Studies demonstrate that integrating flaxseed into laying hens' diets often results in an uptick in egg production metrics. The essential fatty acids found in flax can enhance reproductive efficiency and overall health, which are instrumental in maintaining or boosting the egg-laying frequency and consistency. Flaxseed is primarily used because of its elevated levels of ALA content, which has been linked to improved cardiovascular health in humans who consume these eggs. Moreover, this dietary intervention can alter yolk lipid profiles, thereby contributing to increased omega-3 content. Such enrichment renders the eggs more attractive for consumers seeking heart-healthy dietary options, further increasing product demand and economic return for producers (El-Zenary et al., 2023). However, it is important to balance flaxseed inclusion within hen diets, as excessive amounts might lead to gastrointestinal distress and reduced nutrient absorption. This can inadvertently lower egg production if not adequately managed. For optimal impacts, the appropriate proportion of flaxseed must be identified and monitored, ensuring hens receive sufficient nutrients without adverse effects. Therefore, integrating flaxseed into laying hens' diets has emerged not only as a strategy to enhance egg quality but also as a means to refine production efficiencies,

underpinning a growing imperative to align agricultural practices with evolving consumer health trends (Attia et al., 2024).

Health Benefits for Laying Hens

Incorporating flaxseed into laying hen diets not only influences the nutritional quality of eggs but also provides several health benefits for the hens. The primary advantage is derived from the high content of omega-3 fatty acids present in flaxseed. Omega-3 fatty acids are essential, as they are involved in numerous physiological processes that can enhance the overall health and well-being of hens (Gao et al., 2021). These fatty acids contribute to anti-inflammatory effects, which help mitigate chronic low-grade inflammation that can hinder egg production and contribute to various avian disorders. Moreover, flaxseed is a rich source of lignans and fiber, both of which play crucial roles in digestive health (Vlaicu et al., 2021). The lignans in flaxseed possess antioxidant properties that help reduce oxidative stress. This stress, when left unchecked, can have adverse effects on cellular components, potentially leading to compromised health. Furthermore, the fiber content from flaxseed promotes efficient digestive function, facilitating better nutrient absorption and enhancing gut health. A balanced gut microbiota, supported by dietary fiber, can improve immune responses and lower susceptibility to disease (Teneva et al., 2025). Additional benefits of flaxseed in hen diets include improved bone health, attributed to its mineral content, particularly phosphorus and magnesium. These minerals are vital for maintaining a robust skeletal structure, which is crucial given the physical demands of egg production (Kopacz et al., 2021). Flaxseed may also positively influence hen lipid profiles by altering fat metabolism, which may reduce fat deposition in non-essential areas and support a healthier body weight. By integrating flaxseed into their diet, not only is there potential for improved egg quality with enhanced omega-3 levels, but hens can also experience improved health outcomes, optimizing their productivity and longevity within egg-producing cycles (Fabro et al., 2021).

The inclusion of flaxseed in the diet of laying hens is not only significant for their nutritional benefits but also manifests pronounced behavioral changes within the flock. Such dietary adjustments influence the hens' neurological pathways, potentially altering their general demeanor and activity levels. Notably, dietary omega-3 fatty acids from flaxseed are implicated in modulating behavior due to their roles in brain health and cognitive function. Omega-3s have been linked to improved mental well-being, exhibiting effects similar to those observed in other animal studies, where increased omega-3 intake leads to reduced aggression and enhanced sociability (Nemeth et al., 2021). Observations reveal a noticeable shift in hens' social interactions and responsiveness when flaxseed is introduced. Furthermore, there have been accounts of increased exploratory behavior, where hens exhibit heightened curiosity and engagement with their environment. This burgeoning inquisitiveness could be associated with improved neurologic function, as omega-3 fatty acids support neurotransmission and cognitive performance, thus fostering a more dynamic behavioral repertoire (Al-Madhagy et al., 2023). Interestingly, altered energy metabolism resulting from flaxseed consumption also contributes to behavioral changes. Enhanced dietary fiber can lead to prolonged satiety, thus potentially decreasing frantic foraging behaviors often observed in hens under nutritional stress. As hens experience a more balanced energy state, their overall activity levels tend to stabilize, reflecting an enhanced well-being (Kumar et al., 2025). Beyond the immediate health implications, such behavioral shifts emphasize the holistic impact of integrating flaxseed into the diet, illustrating how nuanced nutritional strategies can effectively dovetail into broader animal welfare frameworks. Thus, flaxseed supplementation emerges not only as beneficial in the biological matrix but also as influential in fostering a tranquil and productive flock environment (Nakandakari et al., 2023).

Analysis of Omega-3 to Omega-6 Ratio in Eggs

Moghadam and Cherian (2017) showed in their review the chemical composition and nutrient profile of

flaxseed (Table 1). The analysis of the omega-3 to omega-6 ratio in eggs provides critical insights into the nutritional value of eggs, particularly when laying hens are fed flaxseed, known for their high omega-3 content. Omega-3 and omega-6 fatty acids are essential nutrients for humans and play a significant role in maintaining health. They cannot be synthesized by the body and must be obtained through diet. Their proper balance is crucial, as it influences inflammation and cardiovascular health, among other bodily processes. A higher proportion of omega-3s relative to omega-6s is often associated with numerous health benefits, including reduced risk of chronic diseases (Zhang et al., 2024). To accurately assess the effect of flaxseed supplementation on these fatty acid ratios, a systematic methodology is essential. Laboratory analyses typically employ gas chromatography to measure the specific concentrations of these fats within egg yolks. This technique allows for precise quantification of individual fatty acids, thereby enabling a detailed comparison between eggs produced by flaxseed-fed hens and those fed conventional diets. The subsequent data often reveal a marked increase in the omega-3 fatty acid content, accompanied by an improved omega-3 to omega-6 ratio. This shift not only enhances the nutritional profile of the eggs but also aligns with dietary recommendations aimed at promoting optimal health (Fox-Skelly, 2024). Various studies underscore the relationship between diet modifications and the resultant fatty acid composition in eggs. Consistent findings show that while omega-6 levels remain relatively stable, the omega-3 content significantly rises when hens' diets are enriched with flaxseed. Comparative analyses further highlight that the balance of omega-3 to omega-6 in flaxseed-fed eggs closely mimics the ideal physiological ratio targeted by nutritionists. This improvement underscores the potential of dietary interventions in altering food composition and, consequently, influencing human health outcomes in a positive direction. By understanding these changes, producers, nutritionists, and consumers all equally can make informed decisions, benefiting both animal welfare and human health alike (Nayda et al., 2023).

Numerous studies have investigated the impact of incorporating flaxseed into the diet of laying hens, particularly examining how these seeds influence the omega-3 to omega-6 fatty acid ratios in the resultant eggs. These studies generally align in their findings: flaxseed supplementation prominently enhances the omega-3 fatty acid content, notably alpha-linolenic acid (ALA), in eggs. This shift is primarily attributable to the high ALA content in flaxseed, which, upon digestion by hens, is deposited into the yolk (Whittle, 2023). Consequently, this dietary modification results in eggs enriched with omega-3s, providing significant nutritional benefits for consumers aiming to balance their intake of these essential fatty acids. Al-Nasser et al. (2011) focused on laying hens' diets enriched with different concentration levels of flaxseed, finding a marked increase in the omega-3 content, ranging from 2-3 times higher than in eggs from hens on standard feeds. This enhanced omega-3 concentration contributes to achieving a more favorable omega-3 to omega-6 ratio, a metric increasingly important in human nutrition for its role in reducing inflammation and associated chronic diseases (Ponnampalam et al., 2021). Furthermore, the enriched omega-3 profile in these eggs does not compromise the hens' overall health; rather, studies consistently report neutral or even positive effects on laying performance and health metrics. Beyond omega-3 enhancement, the inclusion of flaxseed has been linked to improved quality in other egg parameters. Javed et al., (2025) indicates potential benefits in yolk color intensity and shell strength, factors that indirectly correlate with bird health and dietary adequacy. Importantly, these findings are consistent across various subspecies of chickens and geographical locations, suggesting that flaxseed diets' capacity to improve egg omega-3 content is robust and broadly applicable (Antony et al., 2024).

Table 1. The nutritional composition of flaxseed*.

Nutrient composition	Flaxseed
AME, kcal/kg	3800-3960
TMEn, kcal/kg	3788
Crude protein, %	19.0-21.9

Crude fat, %	41.70- 42.0
Fatty acid (%)	
Palmitic (16:0)	5.81
Stearic (18:0)	3.47
Oleic acid (18:1)	15.61
Linoleic (18:2 n-6)	14.52
α-Linolenic (18:3 n-3)	60.08
Amino acid (%)	
Aspartic acid	1.74-2.05
Threonine	0.63-0.80
Serine	0.66-0.95
Glutamic acid	3.32-4.08
Glycine	1.17-1.31
Alanine	0.85-1.02
Valine	0.81-1.11
Isoleucine	0.81-0.94
Leucine	1.10-1.28
Tyrosine	0.40-0.50
Tryptophan	0.22-0.24
Phenylalanine	0.88-1.02
Lysine	0.77-0.94
Histidine	0.39-0.46
Arginine	1.35- 1.67
Cystine	0.36-0.39
Methionine	0.42-0.47
Minerals (ppm)	
P	6449
K	7025
Ca	2022
Mg	3439
S	1828
Na	168
Fe	61.3
Mn	41.7
Zn	53.4
Cu	8.97
Vitamin	
Vitamin E (mg/kg)	18.9
Thiamine (mg/kg)	7.0
Riboflavin (mg/kg)	4.5
Choline (mg/kg)	3150
Niacin	41.0

*Adapted from Lee et al., 1995; Cherian and Quezada, 2016.

Future Research Directions

To further understand the nuances of dietary impacts on hens' health and egg composition, future research should delve into the long-term effects of incorporating flaxseed into poultry diets. While short-term studies provide valuable insights into the immediate changes in omega-3 and omega-6 ratios in eggs and corresponding health indicators in laying hens, the chronic influences remain largely unexplored. Research should investigate how sustained flaxseed diets might affect the hens' overall physiological and reproductive health, including potential implications on their longevity and disease resistance (Ngo Njembe et al., 2021). Additionally, exploring potential shifts in egg production metrics, such as size, shell integrity, and nutritional profile, could offer further evidence of flaxseed's role in optimizing both poultry welfare and consumer nutritional benefits. Parallel to this, an avenue ripe for exploration is the comparative efficacy of other omega-rich dietary sources alongside flaxseed (Xu et al., 2022). Given the increasing interest in enhancing nutritional content in eggs, alternative sources like chia seeds, fish oil, and algae could be examined for their viability in poultry diets. Comparing the omega-3 conversion efficiency and health impacts of various supplements may shed light on balanced nutritional strategies that could complement or exceed flaxseed's benefits. This could also include studying genetic variations among hen populations to understand the differential impacts of these supplements. A multifaceted approach analyzing both direct and indirect outcomes through advanced biochemical and genomic techniques could pave the way for innovative dietary formulations, thus enhancing the nutritional value of eggs and overall poultry health. By extending research in these directions, we can aim to establish comprehensive dietary regulations that optimize not only the quality of egg products but also contribute to sustainable poultry farming practices (Garbowska. Et al., 2023; Rizzo et al., 2023; Jiang et al., 2024).

Conclusion

This review demonstrates that flaxseed supplementation in laying hen diets effectively enhances the fatty acid profile of eggs by increasing omega-3 levels and improving the omega-3/omega-6 ratio, thereby elevating their nutritional value. The enrichment of eggs with alpha-linolenic acid occurs without compromising hen health or production performance, as egg output and shell quality remain stable under appropriate inclusion levels. Although higher polyunsaturated fatty acids may raise oxidative stress concerns, these can be mitigated through antioxidant supplementation. The findings highlight flaxseed as a practical and sustainable feed additive for producing nutritionally enhanced eggs that support improved cardiovascular and anti-inflammatory health benefits in consumers. Future research should focus on long-term impacts of flaxseed use, the stability of enriched fatty acids during storage, and potential synergistic effects with other functional feed ingredients to further advance poultry nutrition and human health outcomes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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إضافة بذور الكتان إلى العلف لتعزيز الإنتاجية وإثراء أحماض أوميغا–3 الدهنية في الدجاج البياض

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ملخص

تعرف بذور الكتان بشكل متزايد كمكمل غذائي وظيفي فعال في تغذية الدواجن، وذلك لاحتوائه على نسبة عالية من حمض ألفا لينولينيك (ALA) ومكونات حيوية نشطة متنوعة. تشير الأدلة الحالية إلى أن إضافة بذور الكتان إلى علائق الدواجن تُحسّن بشكل ملحوظ القيمة الغذائية للمنتجات الحيوانية، وذلك عن طريق خفض نسبة أحماض أوميغا–6 إلى أوميغا–3 الدهنية بشكل كبير، مما يُحسّن توازن الدهون ويُساهم في فوائد صحية محتملة للمستهلكين. علاوة على ذلك، أظهرت الدراسات أن إضافة بذور الكتان لا تُؤثر سلبًا على أداء الإنتاج؛ بل قد تُحسّن مؤشرات رئيسية مثل معدل إنتاج البيض، ووزن البيض، وجودة البيض الداخلية. تُعزى هذه التحسينات إلى تأثيراته المضادة للأكسدة والمُعدِّلة للمناعة، بالإضافة إلى تنظيمه الإيجابي للجينات المُشاركة في استقلاب الدهون. تؤكد النتائج مجتمعةً على أهمية بذور الكتان كعنصر غذائي مستدام قادر على إثراء منتجات الدواجن، ودعم أداء الحيوانات، والمساهمة في تحسين الصحة العامة.

الكلمات الدالة: بذور الكتان، أوميغا–3، أوميغا–6، الأداء، الدواجن.

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