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THE IMPACT OF SUPPLEMENTING FEED WITH OMEGA-3 FATTY ACIDS ON THE NUTRITIONAL AND TECHNOLOGICAL CHARACTERISTICS OF POULTRY MEAT. A REVIEW

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Abstract

Supplementing feed with omega-3 fatty acid sources is a promising strategy for improving the lipid profile of poultry meat. The study analyzes the effect of diets enriched with flaxseed oil, fish oil and microalgae on the content of polyunsaturated fatty acids, oxidative stability and sensory characteristics of meat. The results indicate a significant increase in the content of EPA and DHA in meat, but oxidative stability was negatively affected, necessitating the use of natural antioxidants to prevent rancidity. These findings highlight the potential of nutritionally enhanced diets to produce healthier meat, but emphasize the need to balance nutritional benefits with product stability.

Key words: *poultry meat, omega-3, polyunsaturated fatty acids, oxidative stability, functional diet.*

INTRODUCTION

In recent years, interest in functional nutrition has increased significantly, as the connection between diet and health has become more evident. Among key nutrients, omega-3 fatty acids - particularly alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) - have attracted considerable attention due to their well-documented benefits on cardiovascular health, cognitive function, and inflammation reduction (Swanson et al., 2012).

Since poultry meat is an important protein source in the human diet, improving its lipid profile through omega-3 feed supplementation becomes a promising strategy for delivering healthier food to consumers. Given the steady yet suboptimal meat consumption in Romania, particularly among women in both urban and rural areas (Pogurschi et al., 2018), enriching poultry meat with omega-3 fatty acids could contribute to addressing common nutritional deficiencies. Nutritional supplementation of poultry feed with omega-3 sources (such as flaxseed, fish oil, or microalgae) has the potential to beneficially alter the fatty acid composition of chicken meat, enhancing its nutritional value (Kralik et al., 2021). Studies indicate that such practices do not negatively impact poultry performance and, in some cases, may even improve bird health via anti-inflammatory and immune-modulating effects (Zelenka et al., 2008).

Furthermore, omega-3 enrichment can contribute to reducing the high omega-6/omega-3 ratio found in modern Western diets, which is linked to an increased risk of chronic disease (Swanson et al., 2012).

MATERIALS AND METHODS

This article is a narrative review that synthesizes current scientific knowledge regarding the supplementation of poultry diets with omega-3 fatty acids and its effects on the nutritional, technological, and commercial characteristics of poultry meat.

The main objective of this review is to summarize and critically assess the current scientific literature regarding: main omega-3 sources used in poultry diets, effects of omega-3 supplementation on meat composition, impact on performance, health, and egg/meat quality, consumer acceptance and technological considerations and the potential of such interventions to contribute to public health via functional animal-based foods.

RESULTS AND DISCUSSIONS

Sources of omega-3 fatty acids in poultry nutrition

Omega-3 fatty acids can be introduced into poultry diets through a variety of sources, each differing in bioavailability, cost, sensory impact, and enrichment efficiency.

The most common plant sources include flaxseed, rapeseed, chia, and their oils. These ingredients are rich in alpha-linolenic acid (ALA), which can be partially converted into eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in poultry tissues (Zelenka et al., 2008).

Fish oil, fishmeal, and microalgae are more direct sources of EPA and DHA and generally offer higher enrichment efficiency compared to ALA-rich ingredients. These long-chain polyunsaturated fatty acids are more readily deposited in meat tissues, with microalgae offering a sustainable and odor-neutral alternative to fish-derived products (Kralik et al., 2021; Elkin & Harvatine, 2023).

In addition to traditional sources, commercial omega-3 supplements - such as encapsulated microalgae oils - are being developed. These formulations improve oxidative stability and allow precise omega-3 dosing in feed, reducing lipid oxidation in both the feed and final meat products (Mane et al., 2024).

A study by Sierżant et al. (2022) demonstrated that flaxseed oil combined with natural antioxidants such as quercetin significantly reduced lipid peroxidation in broiler meat. This combination not only enhanced meat oxidative stability but also preserved omega-3 content without compromising growth performance (Sierżant et al., 2022).

When comparing different plant and marine sources in laying hen diets, Coorey et al. (2015) found that while chia, flaxseed, and fish oil all increased omega-3 content in egg yolk, only fish oil supplementation resulted in measurable levels of EPA and DHA. Interestingly, chia seed supplementation produced a favorable omega-3 profile without altering the sensory quality of eggs, making it a suitable option for consumer-friendly enrichment (Coorey et al., 2015).

To improve the bioavailability of ALA-rich ingredients, recent research has explored nano-encapsulation technologies. Miraeez et al. (2024) showed that nano-encapsulated flaxseed oil led to significantly higher deposition of EPA and DHA in poultry tissues compared to conventional flaxseed oil. Additionally, it upregulated genes associated with fatty acid metabolism, enhancing the nutritional quality of the meat (Miraeez et al., 2024).

The duration of supplementation also plays a critical role. Konieczka et al. (2017) demonstrated that a feeding period of at least two to three weeks with flaxseed, rapeseed, or fish oil is sufficient to achieve meaningful omega-3 enrichment in meat. After three weeks, enrichment levels can meet nutritional labeling requirements in many regions, making short-term strategies cost-effective (Konieczka et al., 2017).

Finally, combining plant and marine-based omega-3 sources has emerged as an effective strategy. According to González-Esquerra & Leeson (2001), dietary blends of flaxseed, canola, and fish oil, along with antioxidant support (e.g., vitamin E), enhanced the omega-3 profile of poultry meat without negatively affecting growth performance or product palatability (González-Esquerra & Leeson, 2001).

Factors influencing the efficiency of omega-3 enrichment

The incorporation of omega-3 fatty acids into poultry meat is influenced by several biological and nutritional variables, including bird species, age, duration of supplementation, and the chemical form of fatty acids. However, genetic background is also a critical determinant.

Recent research emphasizes that genotype plays a key role in how birds respond to dietary interventions. For instance, Tudorache et al. (2022) showed that both genotype and feed composition significantly affect growth performance, carcass yield, and blood biochemical parameters in slow-growing hybrids derived from crosses between local breeds and commercial lines. These findings support the idea that omega-3 supplementation strategies should be tailored to specific genetic profiles to optimize both nutritional benefits and production efficiency.

This highlights the need for genotype-specific nutritional strategies, especially when applying functional feeds aimed at improving meat quality and health-promoting properties.

Furthermore, fatty acid profile of the supplement determines enrichment efficiency. Long-chain omega-3 sources like fish oil and DHA Gold outperform alpha-linolenic acid (ALA) sources like flaxseed in enriching EPA and DHA in meat tissues (Lemahieu et al., 2015).

In addition, gene expression patterns such as *L-FABP* (fatty acid binding protein), *PPARA*, and *LPL* have been shown to respond significantly to dietary levels and durations of omega-3 supplementation. Higher DHA intake (4.5% tuna oil) over longer periods increases EPA and DHA tissue levels while reducing the n-6/n-3 ratio (Khosinklang et al., 2023).

Another derivative namely nano-encapsulated flaxseed oil showed significantly better tissue deposition of omega-3 compared to its conventional form, due to enhanced intestinal absorption (Miraeez et al., 2024).

A minimum of 2-3 weeks of supplementation is required to see meaningful deposition of omega-3 in tissues, with optimal outcomes around 4-6 weeks before slaughter (Konieczka et al., 2017).

High levels of dietary linoleic acid (omega-6) reduce conversion of ALA to longer-chain omega-3s by competing for desaturase and elongase enzymes (El-Zenary et al., 2020).

Vitamin E plays a critical role in preventing lipid oxidation and preserving omega-3 integrity in enriched meat products (Roux et al., 2011).

Slow-growing chicken genotypes have shown higher deposition of long-chain omega-3 fatty acids compared to fast-growing commercial lines, suggesting species-specific enrichment efficiency (Costa et al., 2017).

Poultry reared under enriched environments (light modulation, perches, tactile stimuli) exhibit improved physiological status and better nutrient assimilation, which can enhance the effectiveness of omega-3 incorporation (Campbell et al., 2019).

Effects of omega-3 fatty acid supplementation on the nutritional composition of poultry meat

Poultry diets can be supplemented with omega-3 fatty acids from plant sources (such as flaxseed or rapeseed oil), marine sources (fish oil, fishmeal), or microalgae. Studies show that flaxseed significantly increases the level of alpha-linolenic acid (ALA), with a partial conversion into EPA and DHA in the meat (Oliveira et al., 2021). However, marine sources are superior in directly increasing DHA levels in poultry tissues (Rymer & Givens, 2005). Baseline differences in fatty acid composition and nutritional value between poultry species have also been reported, suggesting that species-specific considerations may influence the extent of nutritional enhancement through dietary strategies (Costache et al., 2019).

Omega-3 supplementation leads to a significant increase in the content of unsaturated fatty acids in poultry meat. Several studies report a dose-dependent relationship between dietary omega-3 levels and the concentration of EPA and DHA in breast and thigh muscles (Lakshani et al., 2016). The use of microalgae-based feed ingredients is particularly effective in increasing DHA levels in meat without compromising animal performance (Moran et al., 2018).

The impact of dietary interventions on meat quality and bird physiology is often influenced by genotype. For example, Tudorache et al. (2022) demonstrated that both genotype and diet significantly affect performance traits, carcass characteristics, and blood profiles in slow-growing hybrids derived from local and commercial poultry lines. This suggests that omega-3 supplementation strategies may need to be tailored based on the genetic background of the birds.

The efficiency of omega-3 incorporation into poultry meat is influenced by several factors: the type of omega-3 source, bird species, age, duration of supplementation, and the chemical form of the fatty acids. Plant-based sources tend to be less efficient than marine sources in elevating DHA content in meat, mainly due to limited enzymatic conversion from ALA to long-chain PUFAs (Rymer & Givens, 2005; Custură et al., 2024). Baseline differences in fatty acid profiles between poultry species may also influence the potential for omega-3 enrichment, as shown by comparative analyses on eggs and egg products from various bird species (Usturoi et al., 2021).

Omega-3 enrichment may increase the susceptibility of meat to lipid oxidation, which can negatively impact flavor, odor, and shelf life. To mitigate this, antioxidants - either natural (e.g., tocopherols, rosemary extract) or synthetic - are commonly added to the diet to preserve product quality during processing and storage (Fraeye et al., 2012).

The typical omega-6 to omega-3 ratio in conventional poultry meat is often higher than ideal. Enrichment can lower this ratio from 15:1 to below 4:1, aligning better with nutritional guidelines and contributing to reduced inflammation risks in humans body (Qi et al., 2010).

Most studies show that omega-3 enrichment does not significantly alter the protein, vitamin (e.g., B-complex), or mineral (e.g., iron, zinc) content of poultry meat (González-Esquerra & Leeson, 2001).

However, some variations in antioxidant levels, especially vitamin E (used to prevent lipid oxidation), may occur depending on the enrichment method. Studies show that as the dietary PUFA level increases, vitamin E concentration in tissues decreases unless supplementation is adjusted accordingly. For every gram of dietary PUFA, 2.5–3.7 mg of extra vitamin E may be required to maintain oxidative stability (Barroeta, 2007).

Despite higher feed costs, omega-3 enriched poultry has market potential, particularly in health-conscious consumer segments. Clear labeling and consumer education improve acceptance and willingness to pay a premium price (Barroeta, 2007).

Omega-3 enrichment enhances the nutritional quality of poultry meat while maintaining bioavailability and acceptable sensory traits, offering health benefits and commercial appeal (Gheorghe et al., 2022).

In addition to omega-3 fatty acids, other dietary strategies such as probiotic supplementation have been explored to support gut health and improve performance in broiler production systems (Custură et al., 2019). Such complementary approaches may act synergistically to enhance both animal welfare and product quality.

Technological and Physicochemical Properties of Omega-3 Enriched Meat

The enrichment of poultry meat with omega-3 fatty acids influences several technological parameters, including meat color, pH, and water-holding capacity. The inclusion of omega-3 sources such as fish oil, flaxseed, or microalgae often leads to paler meat due to increased myoglobin oxidation, which affects consumer appeal (Le et al., 2018).

The pH of omega-3 enriched meat may be slightly reduced, altering protein structure and reducing water-holding capacity. These changes can result in drier meat with lower juiciness and reduced yield during processing (Zhi et al., 2023).

Omega-3 enrichment can alter meat texture by softening the muscle fibers and reducing firmness. These effects are dependent on the source and form of omega-3 fatty acids used. Pre-emulsification of oils before incorporation helps maintain a better texture and more uniform structure in processed meat products (Zhi et al., 2023).

Meat products enriched with omega-3 tend to have lower cooking yields if not properly stabilized. Emulsification techniques improve the distribution and retention of omega-3 oils during thermal processing. Pre-emulsification of plant oils helps reduce water and fat losses and improves the structural integrity of products like sausages or meatballs (Zhi et al., 2023).

The enrichment of poultry meat with omega-3 fatty acids significantly influences its sensory profile. Although omega-3 fats are beneficial for health, they can produce unpleasant fishy odors and flavors due to lipid oxidation, especially when fish oil is used (Lee et al., 2023).

Vegetable sources of omega-3, such as flaxseed or canola oil, tend to have a more neutral impact on flavor while maintaining desirable meat juiciness and texture (Le et al., 2018).

Omega-3 fatty acid oxidation leads to the development of volatile compounds that negatively affect taste and odor. This remains a major limitation in the promotion of omega-3 enriched poultry products, as metallic and rancid flavors may appear, especially with prolonged storage (Tura et al., 2024).

Natural antioxidants and microencapsulation technologies can help minimize these sensory issues.

Consumer acceptance is largely influenced by the balance between health benefits and sensory appeal. Studies show that while many consumers are interested in omega-3 enriched foods, taste and odor are critical determinants of purchasing decisions (Lee et al., 2023).

Health benefits of consuming omega-3 enriched poultry meat

Omega-3 fatty acids, particularly EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), are essential for maintaining cardiovascular, cognitive, and anti-inflammatory health. Given the decline in fish consumption and the need for alternative sources, omega-3 enriched poultry meat is emerging as a promising dietary option.

Omega-3 enriched poultry meat offers an effective way to supplement essential fatty acids, especially for individuals who do not regularly consume fish. This meat can provide enhanced levels of EPA and DHA, helping to meet daily intake recommendations (Konieczka et al., 2017).

Regular consumption of omega-3 enriched poultry meat may support cardiovascular health by lowering blood triglyceride levels and reducing the risk of heart disease (Brennan et al., 2016).

DHA plays a critical role in brain development and cognitive function. Increased intake through enriched poultry meat may positively impact memory, learning capacity, and help prevent cognitive decline (Brennan et al., 2016).

Omega-3 fatty acids are well-known for their anti-inflammatory effects. Their incorporation into poultry meat may help reduce chronic inflammation and support overall health (Konieczka et al., 2017).

Omega-3 enriched products are generally well accepted by consumers, especially when the meat retains good sensory quality and freshness. Many consumers are drawn to these products for their perceived health benefits (Rymer & Givens, 2005).

Although multiple omega-3 sources have been used in poultry diets (flaxseed, fish oil, microalgae), their efficiency varies significantly depending on the chemical form of the fatty acids and the supplementation duration. A recent study showed that supplementing with the DHA-rich microalga *Aurantiochytrium limacinum* during only the finishing period (21 days) was just as effective as feeding it throughout the entire lifespan, opening the door to more cost-effective strategies (Keegan et al., 2019).

Recent studies have examined how tuna oil supplementation affects the expression of genes involved in lipid metabolism (e.g., L-FABP, PPARA, LPL), showing a clear link between dietary composition and the genetic regulation of omega-3 deposition in meat (Khosinklang et al., 2023). More research is needed to fully understand these mechanisms and their implications for meat quality.

While omega-3 enrichment is nutritionally effective, it may lead to undesirable sensory changes and oxidation. Advanced technologies such as nano-encapsulation of flaxseed oil have shown promise in improving oxidative stability and bioavailability without negatively affecting flavor (Miraeez et al., 2024). Future research should focus on scaling up these technologies for industrial use.

CONCLUSIONS

This review highlights the considerable potential of omega-3 fatty acid supplementation to enhance the nutritional and functional quality of poultry meat. Numerous sources, including flaxseed, fish oil, microalgae, and chia, offer varying levels of effectiveness depending on their chemical structure, bioavailability, and the length of supplementation. Among them, marine sources such as fish oil and microalgae consistently show superior enrichment of EPA and DHA in poultry tissues, while novel delivery methods like nano-encapsulation improve the stability and absorption of plant-based omega-3 sources.

The enrichment process is highly multifactorial. Biological factors such as bird genotype, age, and sex interact with nutritional components - including the type and combination of omega-3 sources, the omega-6/omega-3 dietary ratio, and antioxidant support (e.g., vitamin E) - to influence enrichment efficiency. Environmental conditions and animal welfare also play a role, as enriched rearing systems improve physiological responses and nutrient assimilation.

From a nutritional perspective, omega-3 enriched poultry meat presents improved fatty acid profiles with lowered omega-6/omega-3 ratios, aligning better with dietary guidelines and potentially reducing inflammation risks in consumers. Importantly, protein, vitamin, and mineral contents remain largely unaffected, preserving the meat's baseline nutritional value. Technological and sensory challenges persist. Omega-3 enrichment may negatively impact meat texture, water-holding capacity, and flavour - particularly when fish oil is used - due to increased lipid oxidation. However, these effects can be mitigated through pre-emulsification techniques, dietary antioxidants, and the strategic use of more neutral sources like flaxseed or canola oil.

Consumer acceptance of omega-3 enriched poultry meat hinges on sensory appeal, clear health communication, and proper labeling. While omega-3 products can command premium prices, success depends on delivering both health benefits and acceptable eating quality.

Overall, omega-3 enrichment in poultry diets is a scientifically validated strategy for producing functional meat products. It offers a sustainable, accessible way to improve public intake of essential fatty acids, particularly in populations with low fish consumption. Future research should focus on optimizing enrichment protocols by considering genetic responses, improving sensory outcomes, and expanding scalable technologies like microencapsulation for commercial implementation.

Recent trends in poultry meat production emphasize both technological innovation and alignment with consumer expectations for healthier products, which supports the development of omega-3 enriched meat (Moise et al., 2024). Economic feasibility and environmental impact assessments are needed to ensure large-scale adoption (González-Esquerra & Leeson, 2001).

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