The Impact of Intensive and Alternative Rearing Systems on the Nutritional Composition of Poultry Meat

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Abstract
Poultry rearing systems significantly influence the nutritional composition of meat, with major implications for consumer health. This study compares the nutritional parameters of meat from intensive and alternative systems (free-range, organic), analyzing the content of protein, fat, essential fatty acids, minerals, and vitamins. The results show that birds reared in alternative systems have a higher content of omega-3 fatty acids and a more favorable omega-6/omega-3 ratio, while intensive systems ensure rapid growth and high economic yield. These findings suggest that alternative rearing methods can offer superior nutritional advantages, but require optimization of production costs and yield.

Keywords: free-range, intensive system, nutritional profile, omega-3 fatty acids, poultry meat

1. Introduction

Poultry meat is among the most consumed sources of animal protein worldwide due to its high nutritional value, affordability, and production efficiency [1]. However, the nutritional composition and overall quality of poultry meat can vary considerably depending on the rearing system. In recent years, growing consumer awareness regarding animal welfare, food safety, and environmental sustainability has increased the demand for alternative rearing systems, such as free-range and organic farming. These systems have been shown to positively influence the fatty acid profile, micronutrient content, and sensory quality of poultry meat, particularly by increasing omega-3 fatty acid concentrations and improving the omega-6/omega-3 ratio [2, 3].

Beyond nutritional aspects, the environmental footprint of rearing systems is an increasingly relevant consideration in assessing their overall sustainability. Intensive industrial systems, while economically advantageous due to higher stocking densities and growth rates, are often associated with higher greenhouse gas emissions, greater waste output, and limited biodiversity. In contrast, alternative systems may offer ecological benefits such as improved soil health and lower environmental impact, but often at the expense of increased land use and production costs [4].

This study aims to: (1) compare the nutritional quality of poultry meat from intensive and alternative rearing systems; (2) analyze crude protein, fat, essential fatty acids (omega-3 and omega-6), vitamins, and minerals; (3) assess the nutritional and economic trade-offs between systems; and (4) emphasize the need to integrate sustainability including environmental impact into the evaluation of modern poultry production strategies.

2. Materials and methods

This study was designed as a comparative nutritional evaluation of poultry meat obtained

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from two distinct rearing systems: intensive (commercial indoor) and alternative (free-range/organic). A total of 60 Ross 308 broiler chickens were used and evenly allocated into two experimental groups (n = 30 per group).

In the intensive system group chickens were raised in a closed housing system with a high stocking density (~35 kg/m²), on fully slatted floors. Environmental conditions were controlled automatically: temperature was maintained between 32°C (at placement) and 20°C (towards slaughter), relative humidity between 55–65%, air velocity between 0.2–0.5 m/s, and light intensity was kept at 20 lux during the photoperiod (18 h light/6 h dark). Feed consisted of a standard commercial corn-soybean diet with vitamin-mineral premix, synthetic amino acids, and coccidiostats.

On the other hands in alternative system group birds were reared under organic-certified protocols on pasture with access to outdoor areas (4 m²/bird), lower stocking density (~15 kg/m²), and received a diet free of synthetic additives. The feed was composed of 50% maize, 25% wheat, 15% sunflower meal, and 10% peas, supplemented with certified organic vitamin-mineral premix. No antibiotics or growth promoters were used. Birds had access to daylight and natural ventilation, and lighting inside the shelter was limited to 12 h/day at 15 lux.

All birds were slaughtered at 70 days of age in a licensed slaughterhouse following standard humane slaughter procedures. Sanitary-veterinary interventions included vaccination against Newcastle Disease and Infectious Bronchitis (on days 1 and 14), and clinical monitoring was conducted weekly. No therapeutic treatments were applied.

Regarding the sample collection breast (Pectoralis major) and thigh (Biceps femoris) muscle samples were collected from the left side of 10 randomly selected carcasses per group (n=10 per muscle type per system). Samples were vacuum-sealed and stored at –20°C until analysis.

Crude protein content in meat samples was determined using the Kjeldahl method with a Foss Tecator Kjeltec 8400 Analyzer (Foss, Denmark), while crude fat was quantified by Soxhlet extraction using petroleum ether in a Buchi B-811 extractor (Buchi Labortechnik, Switzerland). The fatty acid profile, including omega-3 and omega-6 fatty acids, was analyzed by gas chromatography on a Perkin Elmer Clarus 500 GC system equipped with a flame ionization detector (FID). Prior to analysis, fatty acids were transesterified to methyl esters (FAMEs) using a methanol–sulfuric acid protocol, and separation was achieved on a 100 m SP-2560 capillary column with helium as the carrier gas. The oven temperature was programmed from 140°C to 240°C at a rate of 4°C/min. The omega-6/omega-3 ratio was calculated based on the relative concentrations of linoleic acid (C18:2 n-6) and alpha-linolenic acid (C18:3 n-3). For mineral content, concentrations of iron (Fe), zinc (Zn), and magnesium (Mg) were determined using atomic absorption spectrometry (AAS) with a Thermo Scientific iCE 3500 instrument. Additionally, the levels of vitamins B1, B6, B12, and E were measured using high-performance liquid chromatography (HPLC) with UV detection, performed on a Shimadzu Prominence system equipped with a C18 column and appropriate mobile phases specific for each vitamin.

Data were expressed as mean ± standard deviation. The normality of distributions was tested using the Shapiro–Wilk test. An independent sample t-test was applied to compare the means between the two rearing systems. When required, ANOVA followed by Tukey's post-hoc test was applied for multiple comparisons. Statistical significance was set at $p<0.05$. Analyses were performed using SPSS software, version 25.0 (IBM Corp., Armonk, NY, USA).

All animal procedures were conducted in accordance with Directive 2010/63/EU on the protection of animals used for scientific purposes.

3. Results and discussion

Poultry rearing systems are broadly categorized into intensive, free-range, and organic systems. These approaches differ significantly in terms of housing conditions, feed composition, animal density, access to outdoor space, and welfare practices, all of which can influence the nutritional and qualitative properties of the resulting meat.

In intensive systems, birds are housed in confined indoor spaces with high stocking densities and are typically fed standardized commercial diets optimized for rapid growth. While this method ensures high productivity and economic efficiency, it may lead to increased stress levels, metabolic disorders, and reduced opportunities for natural behavior [4].

In contrast, free-range and organic systems emphasize animal welfare by allowing birds access to outdoor environments, reduced stocking densities, and the use of organic or natural feed sources. These systems are associated with higher physical activity, which can lead to leaner meat and altered lipid metabolism, improving the fatty acid profile of the meat [5].

Scientific reviews show that chickens raised in alternative systems such as free-range or organic often have meat with higher protein content, lower total fat, and an improved omega-6/omega-3 ratio, along with better sensory properties [6].

Moreover, these systems stimulate positive metabolic adaptations in birds, influencing not only carcass composition but also the expression of genes related to energy metabolism and muscle development [7]. This underlines the multifactorial impact of housing conditions beyond productivity on meat nutritional quality and biological value.

Consumer trends are also shifting in favor of alternative systems, driven by perceptions of improved welfare, sustainability, and meat quality. These preferences highlight the importance of rearing system labeling and transparent production practices as part of the marketing and value chain strategies [8].

The composition of poultry meat is influenced not only by genetic background and diet, but also by rearing conditions such as physical activity, access to pasture, environmental enrichment, and stress levels. These factors significantly modulate the metabolic, oxidative, and hormonal pathways that control muscle growth and nutrient deposition.

Birds raised in free-range or organic systems typically engage in more movement, which stimulates muscle development, enhances protein synthesis, and reduces fat accumulation in tissues [4]. Increased locomotor activity has also been linked with improved meat tenderness and reduced intramuscular fat deposition, as reported by comparative studies in indigenous and commercial breeds [9].

One of the key mechanistic insights revealed by transcriptomic studies is the upregulation of genes involved in lipid metabolism, mitochondrial activity, and muscle differentiation in birds reared under extensive systems. For example, genes such as fibromodulin, acetyl-L-carnitine, and PPARα were more expressed in free-range birds, which correlated with leaner meat and better oxidative stability [9].

In addition, oxidative stress levels tend to be lower in birds reared with outdoor access due to improved antioxidant intake from natural feeds (e.g., forage rich in vitamin E and carotenoids), which contributes to enhanced meat shelf life and lipid stability [10]. Reduced oxidative stress also limits lipid peroxidation and maintains a healthier fatty acid profile in the meat.

Stress-induced hormonal responses, such as elevated corticosterone levels in intensive systems, negatively impact muscle metabolism, immune status, and feed efficiency, potentially reducing meat quality [11].

Chickens reared in alternative systems showed a significantly higher crude protein content (22.9±0.4%) compared to those from intensive systems (22.3±0.5%) ($p=0.03$) (Table 1). This increase is largely attributed to higher physical activity, which stimulates muscle development and protein synthesis [3, 4]. At the same time, total fat content was significantly lower in birds from alternative systems (4.9±0.3%) versus intensive ones (5.61±0.42%) ($p=0.01$) (Table 1), suggesting a leaner meat profile that aligns with dietary recommendations for low-fat consumption [6, 1].

The most striking differences were observed in the fatty acid profile. Broilers reared under alternative systems had significantly higher omega-3 fatty acid concentrations (0.32±0.02 g/100g) compared to those from intensive systems (0.12±0.01 g/100g) ($p<0.001$). Consequently, the omega-6/omega-3 ratio was much lower in the alternative group (3.7±0.5) versus the intensive group (14.8±1.2) ($p<0.001$) (Table 1), indicating a healthier lipid profile [13, 14]. Similar findings have been documented by Holcman et al. [15] and Pavlovski et al. [23], who reported improved fatty acid profiles in free-range and organically reared broilers.

The results demonstrate the significant influence of rearing systems on the nutritional quality of poultry meat. In agreement with previous findings, birds raised under alternative systems showed a higher content of omega-3 fatty acids such as EPA and DHA, and a markedly lower omega-6/omega-3 ratio, contributing to a healthier lipid profile for human consumption [13].

Also, alternative rearing systems significantly improve the omega-3 content of poultry meat and reduce the omega-6 to omega-3 ratio due to access to forage and natural feeds, contributing to better cardiovascular health profiles in consumers [14].

In addition to the differences in omega-3 content and n-6/n-3 ratio, studies have also shown that birds raised in alternative systems have significantly higher levels of glutamate and inosine monophosphate compounds responsible for umami taste and meat flavor, which may enhance sensory appeal [21].

Although focused on eggs, Usturoi et al. (2021) [22] provide evidence that the fatty acid composition of avian-derived products is highly influenced by both species and feeding strategies. Their findings revealed significant variations in omega-3 and omega-6 levels between egg types, reflecting the metabolic and dietary adaptability of different poultry species. These results suggest that similar variability may also extend to meat, supporting the importance of species-specific and diet-tailored enrichment strategies when evaluating the nutritional impact of rearing systems [22].

When it comes to omega-3 enriched meat, previous exposure to omega-3 products strongly predicts higher willingness to pay. Canadian consumers reported paying a higher premium for omega-3 enriched beef and chicken if they had previously purchased such products [27].

Custură et al have shown that in organically reared Barred Plymouth Rock chickens, variations in dietary nutrient concentrations, specifically reduced protein or energy levels, did not significantly affect overall weight gain or carcass traits. However, a low-protein diet resulted in a decrease in protein content. And essential amino acids in thigh muscles, indicating that dietary composition can influence meat quality parameters even within organic rearing systems [13].

According to Costache et al. (2019) [16], poultry species exhibit notable differences in their nutritional profiles, particularly in the balance of saturated and polyunsaturated fatty acids. For instance, duck and goose meat tend to have higher total fat content, while chicken breast offers lean protein and favorable PUFA/SFA ratios, which are nutritionally desirable. These interspecies differences must be considered when assessing the effect of rearing systems, as baseline meat composition may differ substantially across breeds [16].

The inclusion of polyunsaturated fatty acid (PUFA)-enriched feed combined with probiotic supplementation has been shown to significantly improve the fatty acid composition of poultry meat. Gheorghe et al. (2022) [17] demonstrated that broilers fed such a diet had increased levels of omega-3 and omega-6 fatty acids in breast meat, with improved PUFA/SFA ratios and reduced atherogenic and thrombogenic indices. These results highlight how dietary strategies within conventional systems can modulate meat nutritional quality, offering potential synergies when applied in alternative rearing systems as well [17]. Although focused on eggs, Usturoi et al. (2021) [22] provide evidence that the fatty acid composition of avian-derived products is highly influenced by both species and feeding strategies. Their findings revealed significant variations in omega-3 and omega-6 levels between egg types, reflecting the metabolic and dietary adaptability of different poultry species. These results suggest that similar variability may also extend to meat, supporting the importance of species-specific and diet-tailored enrichment strategies when evaluating the nutritional impact of rearing systems [22]. The metabolic mechanisms underlying these differences have been linked to gene expression patterns associated with lipid metabolism and muscle development, such as PPARα and fibromodulin, which are more active in free-range birds [9]. Additionally, birds raised on forage-rich diets ingest more natural antioxidants (e.g., vitamin E, carotenoids), which contribute to oxidative stability and meat shelf life [10, 18]. Mineral concentrations (Fe, Zn, B12) were relatively similar across systems. Iron content showed no significant difference (1.2±0.1 mg/100g vs. 1.1±0.1 mg/100g, p=0.12), nor did zinc (2.0±0.2 vs. 1.9±0.22 mg/100g, p=0.09) or vitamin B12 (0.88±0.06 vs. 0.85±0.07 µg/100g, p=0.34) (Table 1). These results suggest that mineral deposition is less influenced by rearing conditions [19, 20]. However, vitamin E content was significantly higher in meat from alternative systems (0.55±0.06 mg/100g) compared to intensive systems (0.42±0.05 mg/100g) (p=0.02). This supports previous findings that natural diets rich in antioxidants lead to improved vitamin retention and oxidative stability [18, 24]. The significantly higher vitamin E levels observed in the alternative system group suggest enhanced antioxidant capacity. This supports Barroeta's findings , indicating that increased PUFA levels in meat require proportional vitamin E supplementation to avoid oxidative degradation [18]. Furthermore, the lower fat content and reduced levels of saturated fatty acids suggest a healthier fat composition in free-range poultry meat, consistent with the findings of Pavlovski et al who demonstrated clear differences in fatty acid profiles among extensively and commercially raised chickens [23]. Vitamin E supplementation also plays a crucial role, not only in reducing lipid oxidation and preserving shelf life, but also in improving consumer perceptions of tenderness and juiciness, as reported by Kennedy et al. [24].

Table 1. Comparison of nutritional parameters between intensive and alternative systems

Parameter	Intensive system $\bar{x} \pm s_{\bar{x}}$	Alternative system $\bar{x} \pm s_{\bar{x}}$	p-val
Protein (%)	22.3±0.5	22.9±0.4	0.03
Total fat (%)	5.61±0.42	4.9±0.3	0.01
Omega-3 (g/100g)	0.12±0.01	0.32±0.02	<0.001
Omega-6/Omega-3 ratio	14.8±1.2	3.7±0.5	<0.001
Iron (mg/100g)	1.1±0.1	1.2±0.1	0.12
Zinc (mg/100g)	1.9±0.22	2.0±0.2	0.09
Vitamin B12 (µg/100g)	0.85±0.07	0.88±0.06	0.34
Vitamin E (mg/100g)	0.42±0.05	0.55±0.06	0.02

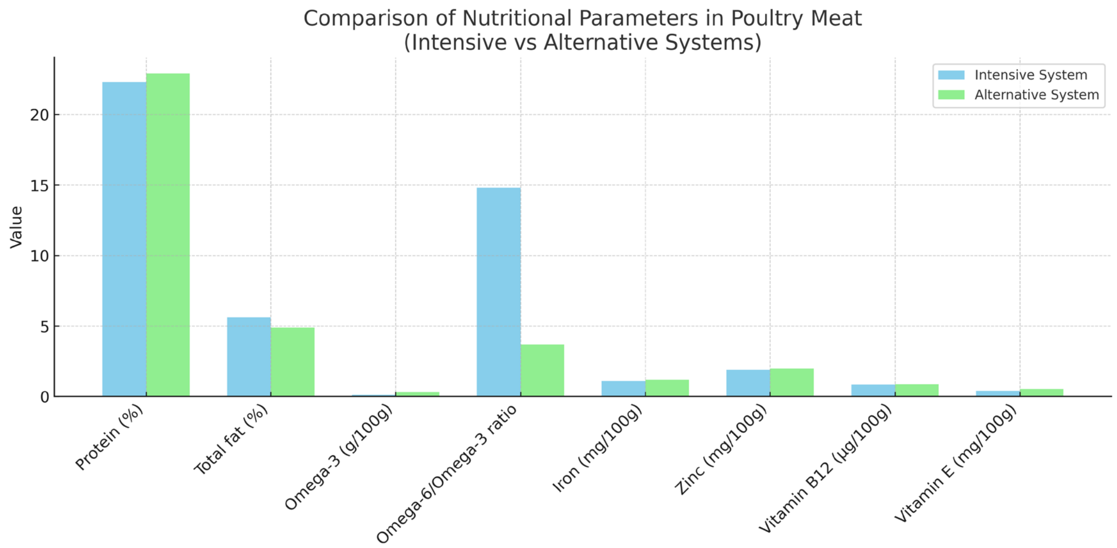

Figure 1. Comparison of nutritional parameters between intensive and alternative systems

Chickens from alternative systems tend to develop more favorable sensory characteristics. Higher physical activity enhances tenderness and reduces intramuscular fat, improving texture and flavor. Moreover, higher levels of compounds such as glutamate and inosine monophosphate (IMP), associated with umami taste, have been observed in free-range meat, contributing to improved sensory appeal [21].

Transcriptomic studies have confirmed that free-range rearing enhances expression of genes involved in oxidative metabolism, contributing to leaner meat with better functional properties [9]. Reduced corticosterone levels due to lower stress in alternative systems further support improved muscle metabolism and meat quality [11].

Consumer attitudes toward poultry meat are increasingly influenced by perceptions of healthiness, animal welfare, sustainability, and production transparency. Alternative rearing systems such as free-range, organic, and omega-3 enriched meat are seen by many consumers as healthier and more ethical compared to conventionally produced poultry.

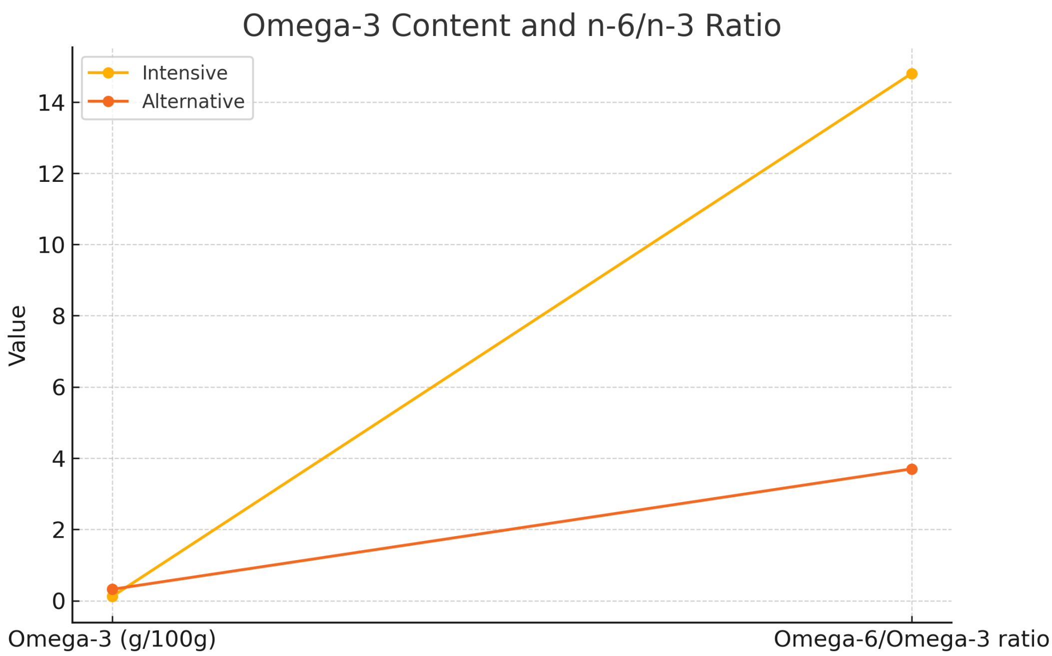

Figure 2. Omega-3 Content and n-6/n-3 Ratio

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A growing body of evidence shows that consumers are willing to pay a premium for poultry products with perceived added value. In a study conducted in Canada, consumers were willing to pay a 34.8% premium for a general organic label and over 100% more for USDA-certified organic chicken [25].

Similarly, research in Argentina revealed that organic chicken was perceived as healthier and safer, and consumers were willing to pay up to 21% more per kilogram [26].

Taste, trust in labeling, and awareness of production methods all shape perception. Castellini et al noted that consumer appreciation of organic poultry meat was linked not only to health aspects but also to sensory appeal and perceived environmental benefit [28].

4. Conclusions

This study demonstrates that rearing systems significantly affect the nutritional quality of poultry meat.

Chickens raised in alternative systems exhibited significantly higher crude protein levels and lower fat content than those reared intensively. This indicates enhanced muscle development and leaner meat resulting from increased physical activity and dietary differences.

Alternative rearing systems led to a substantial improvement in the fatty acid profile, with significantly higher omega-3 concentrations and a lower omega-6/omega-3 ratio.

These findings suggest that free-range and organic practices contribute to the production of meat with greater cardiovascular health benefits.
While iron, zinc, and vitamin B12 contents were not significantly different between systems, vitamin E levels were markedly higher in meat from alternative systems. This supports the role of natural diets and antioxidant-rich forage in enhancing oxidative stability.
Chickens raised in alternative systems demonstrated improved sensory characteristics, including better tenderness, flavor, and umami profile due to higher levels of glutamate and IMP. Lower stress levels and enriched environments positively influenced gene expression linked to muscle metabolism and meat quality.
Diversifying poultry production to include high-nutrient-value systems can align with emerging consumer demands, dietary supplementation with omega-3 sources and antioxidants (e.g., vitamin E) in intensive systems can enhance meat quality without compromising productivity, and clear labeling and effective communication of the health benefits associated with alternative rearing can improve market acceptance and justify premium pricing. Intensive systems remain economically advantageous, providing rapid growth and efficient feed conversion. Moreover, some evidence suggests that optimized feed formulas in intensive systems may also enhance PUFA levels when properly designed.
Consumers increasingly favor alternative rearing systems due to perceived health, ethical, and environmental benefits. This trend is supported by studies indicating a higher willingness to pay for products from such systems.
The comparative data confirm that alternative rearing systems free-range and organic enhance key nutritional parameters such as protein content, fat quality, and antioxidant levels in poultry meat. These improvements are linked to both physiological adaptations and dietary components.

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