Factors Influencing the Quality of Chicken Meat: A Review

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Abstract
The quality of poultry meat has become an increasingly prominent topic in scientific and industrial discourse, driven by the global rise in poultry product consumption and growing consumer expectations regarding nutritional composition, food safety, and sensory appeal. This review paper synthesizes current knowledge from scientific literature on the diverse and interconnected factors that influence poultry meat quality. Special attention is given to the dynamic interaction between genetic type, nutritional management, environmental conditions, and pre- and post-slaughter practices. While selection for rapid growth rates and increased pectoral muscle yield has improved production efficiency, it has also been associated with the emergence of muscle disorders and quality defects such as pale, soft, and exudative (PSE) meat, white striping, and woody breast. Nutritional interventions particularly those that regulate protein intake, fatty acid balance, and antioxidant levels play a crucial role in maintaining muscle integrity and oxidative stability. Environmental stressors, especially heat stress, along with animal transport and handling, significantly alter meat quality parameters, including pH, water-holding capacity, and storage stability. In addition, postmortem procedures such as chilling and packaging have a major impact on meat quality preservation. Through a critical evaluation of existing studies, this review highlights areas of convergence as well as unresolved challenges, proposing an integrative approach to guide future research and optimize quality management throughout the poultry production chain. Growth systems directly influence poultry meat quality. Alternative systems, such as free-range farming, provide meat with superior sensory properties and nutritional value, while intensive systems yield higher production efficiency but may negatively affect meat texture and composition.

Keywords: meat texture, oxidative stability, poultry welfare, slaughtering conditions, quality of poultry meat, tenderness

1. Introduction

Poultry meat production has continued to grow rapidly, outpacing traditional meat sources such as pork, beef, and sheep. Projections indicate that global poultry meat production will surpass 139 million metric tons in 2023, representing a nearly 3% increase compared to 2022 [1]. This growth is largely attributed to increased output in producing countries such as Brazil and the United States. In the same timeframe, China exported 628,500 tons of poultry meat, totaling an export value of $2.212 billion. Roughly 80% of these exports originated from Brazil, the United States, and Russia. Chicken meat accounted for the majority of exports (84.7%), followed by duck (12.8%) and goose (2.5%) products [2]. Processed poultry products represented 57.4% of these exports, with frozen and chilled products making up 28.0% and 14.6%, respectively [**Error! Bookmark not defined.**].

The share of poultry meat in global meat production rose significantly, from 8.3% in 1985 to 26.57% by 2021, reflecting the dynamic expansion of the poultry sector. However, the

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rapid growth of industrial, intensive farming systems has introduced a complex array of factors that complicate the production and processing of high-quality poultry meat [**Error! Bookmark not defined.**].

This upward trend in consumption has been driven by both economic development and increased consumer awareness regarding health, especially in Asia most notably China and India. Likewise, Western markets have exhibited growing demand for organic and antibiotic-free poultry products. These evolving preferences have intensified scientific interest in improving poultry meat quality. Current efforts focus on enhancing feed efficiency, optimizing genetic selection, and refining management techniques to consistently deliver superior meat [3].

Moreover, greater public attention to food safety, animal welfare, and environmental sustainability has encouraged the adoption of stricter regulations and innovative practices across the poultry value chain [4]. A commonly held view is that carcass quality directly impacts the commercial value of poultry meat. As such, quality evaluation has become a priority in international trade, particularly as consumer expectations now include both sensory and aesthetic criteria [5].

Modern broiler farming especially in indoor-intensive systems can result in visual defects such as skin pigmentation, abrasions, and lesions, all of which negatively affect consumer appeal [6]. Beyond appearance, poultry health is a critical concern. Suboptimal management practices can lead to heat stress, nutritional imbalances, and metabolic diseases, which in turn impair meat quality. Feed composition and the quality of feed additives also play essential roles, with issues like mycotoxin, heavy metal, or chemical contamination having especially detrimental effects on meat integrity [7].

In light of these challenges, researchers are exploring targeted strategies to enhance poultry meat quality [8]. Among them, probiotics beneficial microorganisms that support intestinal health have gained attention for their ability to improve growth performance, increase feed conversion efficiency, and positively influence meat quality by boosting polyunsaturated fatty acid content and reducing oxidative stress [9]. Similarly, prebiotics organic compounds that stimulate beneficial gut microbiota have been shown to enhance meat flavor, immune function, and overall production performance [10].

Natural plant-based compounds and extracts have also emerged as promising alternatives to synthetic additives, due to their non-toxic and bioactive properties [11]. These compounds have demonstrated efficacy in improving meat quality, offering a sustainable solution that aligns with consumer demand for cleaner-label poultry products [12].

2. Results and discussion

Meat Color

Meat color is a crucial sensory trait that heavily influences consumer purchasing behavior, as it is often seen as a sign of freshness and overall meat quality. Bright pink or cherry-red meat typically signals freshness, whereas discoloration or browning can lead to consumer rejection, even if the product remains safe [13]. This visual attribute primarily depends on the chemical state of heme pigments like myoglobin, hemoglobin, and cytochrome c, which are modulated by genetic and environmental variables [14].

Pre-slaughter factors such as handling, feeding, and stress levels, along with post-mortem influences like temperature, pH decline, and processing conditions, significantly affect protein denaturation and, consequently, meat appearance. For instance, meat with a high ultimate pH ($\geq$6.0) appears darker and more translucent, while meat with a pH below 6.0 reflects more light, resulting in a paler appearance [15, 16].

Genetic factors notably influence meat pigmentation. Fast-growing commercial broilers, like Ross 308 or Cobb 500, typically produce lighter meat due to lower myoglobin levels, while slow-growing or indigenous breeds such as Hubbard JA57 or Ligor accumulate more pigments through slower metabolism and extended rearing periods [17]. This is particularly evident in thigh muscles, where slow-growing birds display higher redness (a*) and yellowness (b*) due to oxidative muscle fiber predominance and increased iron content [18].

Housing conditions also impact meat coloration. Birds reared in free-range or organic systems often exhibit deeper pigmentation due to greater exercise, exposure to natural light, and diets rich in carotenoids from forage [19, 20]. Corn-rich or carotenoid-supplemented diets further intensify skin and meat yellowness due to pigment accumulation in muscle and subcutaneous fat [21, 22]. Additionally, genetic predispositions like the GG allele in the BCMO1 gene correlate with higher yellowness values [**Error! Bookmark not defined.**].

Age is another determining factor. Older poultry typically develops darker and redder meat, driven by heme pigment buildup. For example, Muscovy duck fillets darkened and reddened as birds aged from 8 to 15 weeks [23], and chickens selected for high pH fillets displayed darker, less red and yellow meat compared to low pH lines [24].

Post-slaughter storage and packaging techniques also play a pivotal role in color stability. Oxidation of heme proteins during refrigeration leads to discoloration, particularly loss of redness. Dietary antioxidants like vitamin E and selenium can alleviate these effects [**Error! Bookmark not defined.**].

Meat Tenderness and Juiciness

Tenderness is a primary determinant of consumer satisfaction in poultry meat, influenced by the structural characteristics of muscle proteins, maturity of connective tissue, and postmortem biochemical processes. Upon slaughter, cessation of blood flow depletes muscle oxygen and energy, triggering contraction and the onset of rigor mortis. Subsequent proteolysis softens the muscle, improving tenderness, though this process is modulated by age, genotype, rearing practices, and carcass processing. Older or slower-growing broilers, especially from organic systems, typically produce tougher meat due to increased collagen cross-linking and connective tissue density [**Error! Bookmark not defined.**, 25, 26].

The rigor mortis rate and final muscle pH are critical. Low pH values, as observed in PSE (Pale, Soft, Exudative) meat, lead to excessive proteolysis and soft textures, while high pH values, as in DFD (Dark, Firm, Dry) meat, result in firmer textures. For example, breast fillets from high pH broilers (6.09) were darker and more tender than those from low pH birds (5.67), which were tougher and paler [**Error! Bookmark not defined.**]. Deboning timing also matters: meat deboned within two hours postmortem tends to be firmer and less palatable than meat deboned after 24 hours [27].

Muscle structure significantly affects texture.

Fast-growing broilers have enlarged fibers and lower connective tissue density, which can paradoxically lead to both toughness and, in pathological cases, mushiness. Wooden breast (WB) is characterized by collagen accumulation and fibrosis, resulting in hard meat, while spaghetti meat exhibits extreme softness due to fiber disintegration [28, 29]. Objectively, tenderness is assessed via Warner-Bratzler shear force or sensory panels, and consistently, breast meat from free-range or older birds is tougher than from intensively raised, younger broilers [30, 31].

Juiciness, closely associated with tenderness, depends on WHC and intramuscular fat. Fast-growing broilers have lean breast meat with minimal fat, making them susceptible to dryness if overcooked. Conditions like white striping (WS) and wooden breast reduce juiciness by increasing water and fat loss during cooking and storage [32-34].

Genetics and environment further influence these traits (Figure 1). Free-range birds develop firmer, more active muscles with increased shear force values, indicating tougher texture [35]. Organic and Label Rouge birds, slaughtered at older ages, often yield firmer and less juicy meat due to larger muscle fibers and more connective tissue [16]. Though slow cooking can enhance tenderness, underlying genetic and environmental differences in texture and moisture retention persist.

In essence, tenderness and juiciness in broiler meat are multifaceted traits governed by biology, environment, and processing. Industry interventions like electrical stimulation and marination help mitigate quality issues, but optimal outcomes hinge on genetic selection, housing conditions, and slaughter techniques.

Meat Flavor

Flavor is a vital sensory factor influencing poultry meat acceptance, particularly chicken breast. While raw meat has minimal odor, cooking initiates complex thermal reactions like the Maillard reaction, lipid oxidation, and thiamine degradation that create volatile compounds such as aldehydes (octanal, nonanal, decanal) and unsaturated hydrocarbons (hexenal, heptanal) responsible for the characteristic aroma of cooked chicken [36].

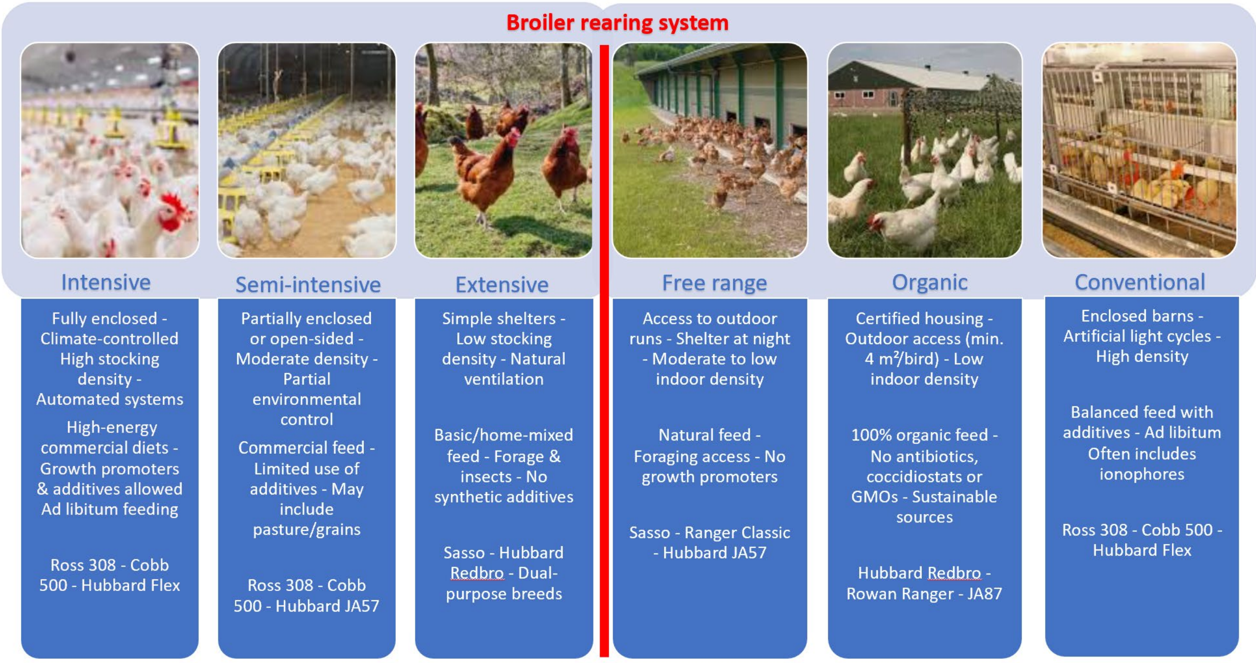

Figure 1. Comparative study regarding different rearing systems

Compounds like hexenal and nonanal impart grassy or citrusy notes, while octanal and decanal provide fatty and rich profiles [37].

Flavor development is heavily influenced by fat content and composition. Birds with higher intramuscular fat, such as slow-growing or overfed breeds, tend to produce more flavorful meat due to increased lipid-derived aroma precursors [38]. However, excessive inclusion of omega-3 rich sources like fish oil can lead to undesirable fishy flavors, particularly in thigh meat [39]. Antioxidants like vitamin E help maintain flavor during storage by preventing lipid oxidation [40]. Rearing systems also impact flavor. Free-range and organic chickens with diverse diets and more physical activity develop “gamey” or “brothy” flavors, often considered more natural or traditional by consumers [**Error! Bookmark not defined.**, 41]. Conventional broilers, raised indoors with uniform diets, typically yield milder flavors. Increased muscle metabolism in active birds contributes to a broader range of flavor compounds [42]. Meat pH and postmortem proteolysis also influence flavor by altering amino acid and peptide availability. High pH birds may generate

distinct flavor profiles during cooking due to alternative reaction pathways [**Error! Bookmark not defined.**]. Storage practices further affect flavor: higher storage temperatures or air-permeable packaging can accelerate rancidity, while modified-atmosphere packaging preserves taste better during refrigeration [43, 44].

Meat pH

Meat pH is a fundamental determinant of chicken meat quality, influencing tenderness, juiciness, WHC, color, and shelf life. Postmortem, lactic acid accumulation from glycolysis reduces pH, denaturing myofibrillar proteins (myosin, actin), impairing water retention, and modifying meat microstructure [45, 46].

The optimal pH for chicken breast is 5.8–6.3. Values of pH below 5.7, compromise broiler meat and often is regarded as pale, soft, and exudative (PSE) while the values of pH above 6.3, influences the boiler meat texture and appearance darker, drier, and tougher – wooden breast meat [47, 48]. Intensive systems often produce higher pH meat than organic or free-range systems, possibly due to reduced pre-slaughter stress. For instance, Castellini et al. (2002) [**Error! Bookmark not defined.**], noted that organic chickens had lower pH in breast and thigh muscles than conventional birds, indicating reduced WHC and higher toughness. Stress management is vital to stabilize pH. Gentle handling and proper transport reduce glycogen depletion and pH drops [49]. Antioxidant supplementation and optimized chilling can mitigate rapid pH declines [**Error!**

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Genotype and age also influence pH. Slow-growing strains tend to have lower pH due to sustained glycolysis and higher muscle glycogen at slaughter. Studies comparing fast-growing (Ross 308) and slow-growing breeds (Sasso, Hubbard) consistently show lower pH in older or more active birds [50, 51]. In conclusion, meat pH reflects the physiological and metabolic status of poultry and is affected by rearing conditions, genotype, nutrition, and postmortem processing. Ensuring optimal pH is essential for maintaining consumer-acceptable meat quality.

3. Chemical Composition (Nutrient and Chemical Differences)

Protein and Fat Content

The rearing system significantly influences the proximate composition of broiler meat, particularly regarding broiler carcass fat and lean mass. Generally, chickens raised in free-range or organic systems tend to produce leaner meat with higher protein content, whereas intensively reared indoor chickens accumulate more fat, especially abdominal and intramuscular fat.

A controlled comparison showed that free-range broilers had the highest *pectoralis* muscle protein content and the lowest fat content among the systems, while intensively raised broilers showed the opposite (lower protein, higher fat).

For instance, Niepes et al., [52] reported that the breast meat of free-range birds had the highest protein and lowest fat content, while breast meat from intensively raised birds contained significantly more fat, although the percentage differences were not statistically significant [52].

Table 1. Effects of high stocking densities on variation in meat quality

Species	Stocking densities	Position	Variation in meat quality
Chicken	28 birds/m^2	Breast and thigh meat	The abdominal fat percentage and the fat content of thigh muscle declined
Chicken	23 and 26 birds/m^2	Breast meat	Shear force in breast meat increased
Chicken	20, 25 and 30 birds/m^2	Breast and wing meat	Final body, drumstick, breast, and wing weights linearly declined with stocking density
Chicken	18 birds/m^2	Breast meat	Cooking loss and pH at 45 min decline; activity of lactate dehydrogenase increased
Chicken	18.6 birds/m^2	Breast meat	Lightness at 45 min and 24 h after slaughter increased; drip loss at 24 h and 48 h increased
Chicken	18 birds/m^2	Breast meat	Meat color b* declined
Chicken	20 birds/m^2	Breast and thigh meat	Cooking loss and drip loss of breast and thigh muscles increased
Chicken	26 and 35 birds/m^2	Breast meat	Cooking loss, meat color L* and a* at 48 h postmortem increased linearly with decreasing stocking density; ultimate breast pH and nitrogen content decreased linearly with decreasing stocking density
Chicken	18 birds/m^2	Breast meat	pH at 24 h increased
Chicken	12 birds/m^2	Breast meat	Breast weights declined
Chicken	22.5 birds/	Breast meat	pH values increased slightly as density increased
Chicken	37 kg/m^2	Breast and thigh meat	Breast meat pH at 24h, shear force, and cooking loss declined; thigh meat shear force increased
Chicken	25.3 and 30.4 birds/m^2	Breast meat	Breast weights declined

Similarly, thigh meat from free-range chickens had lower total fat and slightly more protein than that from industrial broilers, which had 3.4–5.0% fat in thigh/drumstick cuts, compared to approximately 3.0% in the free-range birds. Birds regulates their food intake and nutritional needs based on their energy requirements. Moreover, the required energy of birds is dependent of the level of activity, environmental condition, and physiological stage of the bird [53]. In contrast, intensive confinement promotes rapid weight gain and fat accumulation due to abundant feed and limited movement. Excess fat in conventional broilers carcass has been noted as a quality concern (leading to bland taste and potential health issues). Thus, from a nutritional perspective, alternative rearing can improve the leanness of chicken carcass meat [53].

Fatty Acid Profile and Cholesterol

One major qualitative difference between alternative and conventional systems lies in the fat composition. Free-range and organic reared broilers typically consume a more varied diet, rich in omega-3 fatty acids (from grass, insects), which increases the proportion of polyunsaturated fatty acids (PUFAs) in the meat fat [54]. A study comparing intensively raised, organic, and free-range broilers found that fat from free-range chicken had significantly higher levels of PUFAs (both ω-6 and ω-3) than conventional chicken fat. As a result, the total ω-3 fatty acid concentrations (α-linolenic acid and even longer-chain EPA/DHA) were elevated in the breast and thigh meat of free-range chickens. Organic broilers in that study, which were fed organic feed likely including flaxseed or fishmeal, exhibited particularly high levels of beneficial long-chain ω-3s like EPA and DHA in thigh meat. This suggests that organic diets can enrich chicken meat with heart-healthy fatty acids. On the other hand, intensively raised broilers tend to have higher proportions of saturated and ω-6 fatty acids due to standard grain-based diets [55]. The total meat cholesterol content also varies by system and cut: one study noted that conventional breast meat had the highest cholesterol (~34 mg/100g), whereas free-range thighs showed higher cholesterol compared to thighs from other systems. Nevertheless, when evaluating the entire carcass, alternative systems are generally considered healthier offering overall lower fat and cholesterol and a more favorable unsaturated fat profile. Punchihewage-Don et al., [56] concluded that meat from chickens raised with outdoor access or using organic methods “poses less risk to cardiovascular health” due to its lower lipid and cholesterol levels and greater PUFA content [**Error! Bookmark not defined.**5]. It is worth noting, however, that the higher PUFA levels in free-range/organic meat can predispose it to faster oxidation (rancidity). Researchers found that organic chicken meat had higher thio barbituric acid reactive substances (TBARS), an indicator of lipid oxidation, than conventional meat likely due to its higher unsaturated fat content despite the presence of antioxidants. This trade-off suggests that, while the fat composition is nutritionally superior, careful handling and storage of free-range/organic meat are necessary to maintain quality [56].

Microbiological Quality and Food Safety

Rearing systems create different microbiological environments for broilers, influencing both the prevalence of pathogens and the microbial community on the meat. Bacterial Pathogen Contamination: A food safety concern is the rate of *Campylobacter* and *Salmonella* contamination in broiler flocks, which may differ between intensive indoor and outdoor systems [57]. Outdoor access exposes chickens to soil, insects, and wild birds, increasing the risk of contamination. A recent study found *Campylobacter* in organic broilers but not in conventional ones raised in isolation. *Salmonella* prevalence showed less consistent patterns; some studies found no significant differences between conventional and free-range farms, while others reported slightly higher *Salmonella* rates in organic carcasses at retail [58]. Processing hygiene may help equalize such differences by the time the meat reaches consumers. Nonetheless, older and outdoor-raised birds tend to carry a higher bacterial load on their skin and feathers before slaughter (from litter, dust, and the environment), which can be transferred to carcasses without proper hygiene [59]. Therefore, good biosecurity and sanitary practices are crucial in free-range and organic systems to achieve food safety levels comparable to intensive systems. On the positive side, extensive systems may foster a more diverse gut microbiota and, in some cases, reduce *Salmonella* shedding due to microbial competition, though evidence remains mixed. In conclusion, while conventional indoor systems offer reduced environmental exposure, crowding can quickly spread pathogens if introduced; outdoor systems face natural exposure risks, especially *Campylobacter*, and require specific controls such as strict biosecurity and meat freezing strategies [60].

Spoilage and Shelf Life

The background microbial flora responsible for spoilage (*Pseudomonas*, lactic acid bacteria) may also differ slightly depending on the rearing system, though data are limited. Meat with higher ultimate pH (as in some unstressed slow-growing birds) may spoil faster due to neutral pH favoring bacterial growth [61]. However, many free-range chickens actually produce meat with lower pH (when mildly stressed), and the lower muscle glycogen can limit the growth of spoilage organisms. Additionally, the higher natural antioxidant content (vitamin E) in organic meat can delay oxidative spoilage. Some studies reported that, despite initial microbial load differences, the shelf life of refrigerated chicken did not significantly differ between organic and conventional systems when processing and packaging conditions were equivalent. In all systems, proper cold-chain management and hygiene remain the most critical factors for shelf life [62].

According to food safety standards, all systems must meet the same criteria for end products (pathogen-free meat ready for sale under EU and USDA regulations). Thus, while free-range and organic systems require closer microbiological monitoring, especially for *Campylobacter,* they can produce equally safe products with good management [63]. Conversely, intensive systems must guard against in-flock outbreaks due to high density. Each system presents unique challenges: conventional farming emphasizes biosecurity and vaccination (against *Salmonella*), while outdoor systems require environmental monitoring and pathogen testing. With proper management, differences in contamination rates can be minimized. Nonetheless, meat microbiological profiles will inherently vary by rearing method [57, 60]. For instance, meat from a free-range farm might have a higher likelihood of *Campylobacter* contamination at retail, requiring careful cooking, while meat from an intensive farm might be more likely to contain bacteria with antibiotic resistance. Both cases demand vigilant oversight across the farm-to-fork continuum to ensure safe poultry meat for consumers [64, 65].

Recent Romanian research highlights that microbial spoilage, and the shelf life of poultry meat are significantly affected by factors such as pH, muscle glycogen levels, and the presence of antioxidants particularly vitamin E. According to [66], poultry raised in alternative systems (such as free-range or organic) tend to have higher concentrations of antioxidant compounds, which can slow oxidative degradation and improve the refrigerated shelf life of the meat. Additionally, a reduced glycogen content in the muscle, typically associated with lower physiological stress, may hinder the proliferation of spoilage-related microorganisms. Indicated that vitamin E levels in broiler meat from free-range systems were approximately 25% higher than in conventional meat, a factor that played a key role in delaying oxidative deterioration.

As for the background microbial flora, *Pseudomonas spp.* and lactic acid bacteria remain the primary contributors to spoilage under refrigeration. However, the microbial composition can vary based on the rearing method and the birds' diet. The microbial load of chicken meat stored at 4°C stayed under the critical threshold of 6 log CFU/g for up to 6 days in free-range production systems. In comparison, meat from intensive farming maintained similar microbial levels for 7 to 8 days, depending on the type of packaging used [67]. National studies indicate that while intensive systems often have lower initial microbial loads due to stricter biosecurity measures, meat from extensive systems may require more rigorous pathogen monitoring particularly for Campylobacter spp. [68]. Even so, with effective cold-chain management and sanitary processing practices, shelf life disparities between systems can be significantly reduced, aligning with findings from international literature.

4. Conclusions

The continued global expansion of poultry meat production reflects both economic incentives and evolving consumer preferences, particularly for lean, affordable, and health-conscious protein sources. However, this growth largely achieved through intensive genetic selection and high-efficiency rearing systems has introduced a complex array of challenges regarding meat quality, animal welfare, and sustainability.

Our analysis highlights that meat quality in broilers is shaped by a multifactorial interplay between genetics, rearing conditions, nutrition, and processing protocols. Genetic selection has significantly improved growth rates and feed efficiency yet has also contributed to histological muscle changes that predispose broilers to structural defects and myopathies such as white striping, wooden breast, and spaghetti meat. These conditions impair texture, water retention, and overall consumer acceptance, underscoring the trade-offs of productivity-driven selection.

Main meat quality attributes such as color, tenderness, juiciness, flavor, and pH stability-are all sensitive to both intrinsic (genotype, sex, age) and extrinsic (diet, rearing system, pre-slaughter handling) factors. For example, birds raised in free-range and organic systems often yield meat with superior nutritional profiles (higher protein, lower fat, richer PUFA content), though they may present greater microbial risks due to environmental exposure and longer growth periods.

Meanwhile, conventional intensive systems ensure high efficiency and scalability, but may require technological or management interventions such as marination, electrical stimulation, or antioxidant supplementation to offset the potential decline in sensory and functional quality associated with rapid growth and low intramuscular fat content.

Importantly, microbiological safety and antibiotic resistance patterns also vary significantly across production systems, with antibiotic-free models showing reduced prevalence of multidrug-resistant pathogens yet facing higher risks for *Campylobacter* contamination. These findings emphasize the need for robust biosecurity, hygiene practices, and postharvest monitoring regardless of the production method.

In conclusion, achieving optimal poultry meat quality in a modern context demands a balanced and integrative approach. Sustainable strategies should harmonize genetic potential with animal welfare, environmental impact, and consumer health priorities. Future advancements in breeding, nutrition, and production systems must aim not only to enhance yield but also to ensure the consistent delivery of safe, palatable, and nutritionally rich poultry products across global markets. Future research on optimizing poultry production systems by integrating animal welfare, environmental sustainability, and economic efficiency is needed. Emphasis should be placed on developing adaptable management strategies and breeding programs tailored to each rearing system, while ensuring compliance with evolving consumer expectations and regulatory frameworks.

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