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FACTORS INFLUENCING THE QUALITY OF TURKEY MEAT

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Abstract

Genetic, technological, nutritional, and breeding factors influence the quality of turkey meat. In terms of its biochemical composition, turkey meat is characterized by a high protein content and a favourable ratio between unsaturated and saturated fatty acids, which makes it a valuable nutritional source. Also, turkey meat is lower in fat compared to other types of meat. Regarding the quality of turkey meat, it varies depending on the anatomical part used (breast and thighs) and has distinct nutritional values. Processing factors, storage temperature, and post-mortem pH of the meat affect sensory properties such as texture, taste, and colour. Improving the quality of turkey meat involves optimizing growing conditions, as well as correctly managing the slaughtering and preservation processes to prevent damage to organoleptic characteristics and food safety.

Key words*: quality meat, turkey, antioxidants.*

INTRODUCTION

Appreciated for its high nutritional value, low fat content, and balanced protein profile, turkey meat is favored by consumers in many parts of the world (Bianchi & Fletcher, 2002; Baracho et al., 2020; Moise et al., 2024).

On the other hand, it is well known that the qualitative parameters of this type of meat can be influenced by a series of biological and environmental factors (genetics, sex, feeding regime, rearing system, pre-slaughter stress, processing conditions, etc.) (Debut et al., 2003; Alvarado & McKee, 2007; Pietrzak et al., 2013), which also negatively affect its stability during processing and storage (Deeb et al., 1999; Leishman et al., 2022).

For example, genotype and sex influence the texture and color of the meat, as well as the protein and fat content (Cizek, 2019; Costache et al., 2019; Tudorache et al., 2022), while growth and feeding methods affect the development rate and chemical composition of the tissue, influencing the tenderness and juiciness of the final product (Custură et al., 2012; Tougan et al., 2013; Zhang et al., 2015; Pulido & Toledo, 2021). Additionally, environmental factors such as temperature, humidity, and light play a crucial role in the development of muscle mass and the maintenance of bird health (Ferrante et al., 2013; Geers & Madec, 2015; Chang et al., 2021); studies in this regard indicate that a stressful or inadequate environment can negatively affect muscle metabolism, causing undesirable changes in pH and water retention, negatively impacting meat quality (Marchewka et al., 2013; Fraqueza, 2015).

Another essential aspect in determining quality is the influence of factors acting during the slaughter of birds, such as post-mortem processing and handling conditions, storage temperature, etc. (Owens et al., 2009; Okuskhanova et al., 2017); improper transport and handling of birds before slaughter contribute to the onset of stress, resulting in inferior meat quality, characterized by defects such as pale, soft, and exudative meat (PSE - Pale, Soft, Exudative), similar to that found in other animal species (Fletcher, 1995; Woelfel et al., 2002; Owens et al., 2009; Bilgili et al., 2019).

In this context, the present paper aims to analyze in detail the factors that influence the productive performance and meat quality of turkey broilers, to provide a general perspective on the possibilities for optimizing the growth and processing of this category of birds, with a view to obtaining a high-quality final product.

MATERIALS AND METHODS

For the completion of this work, scientific articles, specialized books, and official reports published between 2000 and 2023 were consulted, available in databases such as Google Scholar, Scopus, and on the websites of recognized institutions (EFSA, USDA, ISO). The key words used in the search included: "turkey meat quality", "poultry meat", "PSE meat", "processing methods for turkey meat", "nutrition and turkey growth", and "poultry meat safety".

The selection of works was based on their relevance to the proposed topic, considering both experimental studies and review articles. Only materials that directly analyzed the factors influencing turkey meat quality (genetic, environmental, nutritional, and technological factors), as well as aspects related to food safety, were included. The extracted information was then grouped and synthesized according to the categories of factors presented in the text, with the aim of providing a clear and accessible overview of the main conclusions from the specialized literature.

RESULS AND DISCUSSIONS

1. Biological factors that influence the quality of turkey meat

The quality of turkey meat is determined by a series of essential biological factors, such as genetics, sex, age, and the physiological condition of the birds (Leishman et al., 2022; Adams & Singh, 2023). These factors influence the sensory and physicochemical properties of the meat, such as texture, color, tenderness, juiciness, and water-holding capacity (Petracci & Cavani, 2012; Sarantopoulos et al., 2016).

1.1. *The genotype and its impact on meat quality*

The physical and chemical properties of turkey meat are mostly determined by genetics (Deeb et al., 1999; Pietrzak et al., 2013; Marangoni et al., 2015). Turkeys from different genetic lines differ significantly in terms of meat quality, muscle size, and tissue composition (Lonergan et al., 2003; Cizek, 2019).

A higher proportion of muscle tissue is found in genetically selected turkey lines for rapid growth, but there is also a higher chance of muscular anomalies such pale, soft, and exudative (PSE) meat (Owens et al., 2009; Pietrzak et al., 2013). This results from modifications in muscle metabolism, which can cause reduced water retention and a low post-mortem pH, which reduces the end product's appeal to buyers (Castellini et al., 2002; Lu et al., 2020). However, the muscle yield is lower in traditional turkey breeds with slower growth rates, but the meat is tougher and more juicy (Serbest, 2015; Hiscock et al., 2022). Therefore, genetic selection must be carefully used to manage the trade-off between intensive production and meat quality (Northcutt, 2001; Adams & Singh, 2023).

1.2. *The impact of sex on the characteristics of meat*

Bird sex has a major impact on meat sensory qualities, tissue distribution, and body composition (Tougan et al., 2013; Schantz et al., 2019). According to studies, male turkeys gain more muscle mass than females, which makes their meat thicker but less soft (Zhang et al., 2018; Hiscock et al., 2022).

Women, on the other hand, have a greater percentage of intramuscular fat, which improves the meat's flavour and juiciness (Berri, 2008; Ferrante et al., 2013). Additionally, studies reveal that females have more constant post-mortem pH, which contributes to the meat's better palatable appearance and consistent colour (Debut et al., 2003; Avila & Alvarado, 2013).

Due to consumer preferences for the more tender and juicy meat, these sex variations are significant in the turkey meat industry and can affect the choice of birds for processing (Fletcher, 2002; Berri, 2008).

1.3. *The age of birds and its effects on meat quality*

The meat's texture, colour, and juiciness are all directly impacted by the age at slaughter (Miao et al., 2019; Berri et al., 2020). The customer experience may suffer as older turkeys acquire more fibrous muscle tissue, while younger turkeys often have more soft and juicier meat (Lyon et al., 2004; King & Whyte, 2006).

Studies have shown that young turkeys contain more soluble collagen, which makes their meat

softer and more palatable to chew (Owens et al., 2009; El-Bahy et al., 2021). On the other hand, older birds' greater muscle mass and rest cause insoluble collagen to build up, making their meat stiffer and more challenging to prepare (Fletcher, 1995; Sarantopoulos et al., 2016). Age affects the meat's colour in addition to its texture. Due to pigment buildup and modifications in haemoglobin metabolism, older turkeys have darker meat (Geers & Madec, 2015; Leishman et al., 2022). Given that colour is a key signal of the product's freshness and quality, this change may affect how consumers perceive the product.

1.4. *Physiological state and stress before slaughter*

The amount of stress that birds endure prior to slaughter is a crucial factor that affects the quality of their meat (Marchewka et al., 2013; Awan & Rahman, 2020). Stressor exposure can cause metabolic alterations that impact muscle pH and water retention, including incorrect handling, transportation, and unsuitable environmental conditions (Heckendorn et al., 2015; Bilgili et al., 2019). Stress raises cortisol levels and triggers anaerobic metabolism, which can result in meat that is PSE (pale, soft, exudative) and a sharp drop in post-mortem pH (Marchewka et al., 2013; Avila & Alvarado, 2013). This phenomenon affects consumer acceptance by compromising the meat's texture and look (Owens et al., 2009; EFSA, 2020).

On the other hand, meat from birds grown in ideal conditions with appropriate stress management has a balanced pH and improved sensory qualities (Ferrante et al., 2013; Pulido & Toledo, 2021). To increase the quality of the finished product, the turkey meat business employs techniques like managing the birds carefully, employing suitable transportation circumstances, and lowering pre-slaughter stress (ISO 22000:2018; USDA, 2021).

2. Environmental and nutritional factors that influence the quality of turkey meat

In addition to biological characteristics, environmental and nutritional conditions can affect the quality of turkey meat (Woelfel et al., 2002; Ferrante et al., 2013). The development of the birds and the final properties of the meat are greatly influenced by the growing environment, temperature, humidity, illumination, and feed composition (Chang et al., 2021; Leishman et al., 2022). The final product's texture, colour, softness, and stability can all be enhanced by properly managing these variables (Sante & Voilley, 2021; Chen et al., 2023).

2.1. *Ambient temperature and humidity*

Bird health and metabolism are directly impacted by environmental factors including temperature and humidity (Ferrante et al., 2013; Tougan et al., 2013; Pulido & Toledo, 2021). Meat quality can be adversely affected by extreme temperatures since they can cause stress and interfere with muscle development (Alvarado & McKee, 2007; Petracci & Cavani, 2012).

Temperatures above 30°C raise the danger of heat stress, which reduces food intake and, indirectly, inhibits the formation of muscle mass (Owens et al., 2009; Fraqueza, 2015). This condition may result in less juicy and tender meat. Meat at low temperatures (less than 10°C) uses a lot of energy for thermoregulation, which might affect tissue distribution and result in tougher, more collagen-rich meat (Marchewka et al., 2013; Lu et al., 2020).

Furthermore, birds that experience high humidity levels (>70%) may develop respiratory issues, which may hinder their growth and indirectly impact the quality of their meat (Bianchi & Fletcher, 2002; Adams & Singh, 2023). Conversely, low humidity (<40%) might cause muscular tissues to become dehydrated, which will reduce the meat's softness (Cizek, 2019).

Turkeys develop healthily and produce high-quality meat when kept in a controlled environment with an ideal temperature of 18–22°C and a relative humidity of 50-60% (Avila & Alvarado, 2013; Arslan & Seker, 2021).

2.2. *Breeding systems and bird density*

Turkeys' wellbeing, health, and muscle growth are influenced by the density at which they are grown (Leishman et al., 2022; Chen et al., 2023).

Birds with high densities (>40 kg/m^2) have less room to move, which can result in inadequate muscular growth, poor muscle oxygenation, and excessive fat buildup (Hiscock et al., 2022; Bolek & Węglarz, 2022).

Low densities (less than 30 kg/m^2) enable more vigorous movement, which enhances muscle growth and the meat's ideal protein content, but they also raise production costs (Johnson, 2020).

To get beef with the ideal ratio of tenderness to firmness, density and comfort must be balanced (Marchewka et al., 2013). Furthermore, meat from birds maintained in large systems with outdoor access has greater intramuscular fat, which improves the meat's flavour (Castellini et al., 2002; Leishman et al., 2022).

2.3. *Illumination and its influence on muscle metabolism*

Turkeys' feeding habits, metabolism, and muscle growth are all impacted by lighting (Sarantopoulos et al., 2016; Awan & Rahman, 2020). Research indicates that the kind and length of light can have an impact on the meat's softness and muscle fibre structure (Marchewka et al., 2013; El-Bahy et al., 2021).

Meat that is exposed to constant lighting (24-hour light) may become tougher and less juicy due to stress and hyperactivity (Okuskhanova et al., 2017; Hiscock et al., 2022).

A higher protein content in meat, balanced growth, and ideal muscle mass development are all facilitated by intermittent lighting (16 hours of light and 8 hours of dark) (King & Whyte, 2006; Bayraktar et al., 2021).

Birds' physiological responses are enhanced by natural or selectively spectrum lighting (blue/green LEDs), which results in more succulent and juicy meat (Lonergan et al., 2003; Correa et al., 2019).

The quality of the finished product can therefore be greatly impacted by appropriate lighting management in turkey farms (Hiscock et al., 2022).

2.4. *Nutrition and food composition*

Nutrition is one of the most important factors influencing the development of muscle tissues, meat color, and protein stability (Qiao et al., 2002; Marangoni et al., 2015; Barroeta, 2018).

Proteins and amino acids. Turkeys need a balanced intake of proteins and essential amino acids for optimal muscle development (Castellini et al., 2008; Said et al., 2022). High-quality proteins (e.g., soy, peas, fish meal) contribute to more tender and juicier meat with a high protein content (Berri, 2008; Guo et al., 2018). Protein deficiency leads to stunted growth and less dense, softer meat (Debut et al., 2003; Alvarado & McKee, 2007).

Fats and fatty acids. Omega-3 and Omega-6 fatty acids influence the consistency and stability of fats in meat (Zhang et al., 2018; Sante & Voilley, 2021). Omega-3 enriched diets can improve the lipid profile and flavor of meat (Samuel et al., 2022). Excess saturated fats in the diet can lead to greasier meat with lower sensory quality (Correa et al., 2019).

Vitamins and minerals. Vitamin E and selenium protect muscle cells against oxidative stress, preventing meat rancidity and loss of natural color (EFSA, 2020; Hiscock et al., 2022). Zinc and copper deficiency can reduce the water-holding capacity of meat, affecting its texture and juiciness (Said et al., 2022).

A balanced diet, based on the optimal ratio of proteins, fats, and micronutrients, is crucial for obtaining high-quality meat (ISO 22000:2018; Del Valle et al., 2023; Custură et al., 2024).

3. Technological factors that influence the quality of turkey meat

The stability, texture, juiciness, and safety of the finished product are all greatly impacted by the processing and storage of turkey meat (Hudson, 2012; Awan & Rahman, 2020; Chen et al., 2023). The following are some of the most significant technological elements influencing turkey meat quality:

- techniques for post-mortem handling and slaughter;
- meat storage and cooling;
- the impact of thermal processing on texturing;
- preserving quality through packaging and preservation.

We will examine each of these elements and how they affect the end product's quality in this section.

3.1. *Techniques for post-mortem sacrifice and manipulation*

Muscle pH, texture, and water retention are influenced by the way turkeys are killed and treated after slaughter (Table 1) (Fletcher, 2002; Alvarado & McKee, 2007; Owens et al., 2009). Protein stability and the rate of pH drop are impacted by slaughter practices. Defects

like dry and firm meat (DFD - Dark, Firm, Dry) or pale, soft, and exudative meat (PSE) could arise from improper slaughter (Knox et al., 2012; Mendes, 2017).

Table 1. The influence of the slaughter method

Method of sacrifice	Impact on meat quality
Slaughter by electric stunning	High stress risk results in PSE meat
Sacrifice by gas (CO_2)	Reducing stress results in more tender meat
Slaughter Halal/Kosher (without stunning)	Risk of rapid pH drop results in drier meat

Research indicates that CO_2 gas stunning is associated with superior meat quality, as it reduces bird stress and slows down post-mortem pH decline (Owens et al., 2009; Wilkins, 2015).

3.2. *Cooling and storing meat*

After slaughter, cooling is essential to prevent bacterial growth and maintain freshness (Barroeta, 2018; USDA, 2021). Rapid cooling helps stabilize the pH and reduce the risk of developing PSE and DFD defects (Table 2) (Geers & Madec, 2015).

Table 2. The impact of cooling methods on meat quality

Cooling method	Time	Impact on quality	Details
Cooling in the air (2-4°C)	4-6 h	Reduced moisture loss, tender meat	Air cooling is the most commonly used method in Europe because it preserves the natural texture and color of the meat
Cooling in the whater (0-2°C)	2-4 h	Increased water retention, but risk of contamination	Cooling in water is faster, but it can lead to excessive water retention, affecting the final texture
Cryogenic cooling (-40°C)	<1 h	Rapid crystal formation → affects texture	Faster freezing is used for export, but it can cause the formation of large ice crystals, which degrade the structure of muscle fibers.

3.3. *Thermal processing and its impact on texture*

Turkey meat is often subjected to thermal processing (boiling, roasting, frying, smoking) (Hudson, 2012; Awan & Rahman, 2020). High temperatures can affect protein stability and water retention, leading to changes in texture (Table 3) (El-Bahy et al., 2021).

Table 3. The impact of thermal processing methods on meat quality

Processing type	Temperature (°C)	Impact on meat	Details
Fever	70-80°C	Soft texture, loss of nutrients	Boiling reduces water retention capacity, which can affect juiciness
Baking	150-180°C	Good juice retention, crispy crust	Baking at moderate temperatures maintains the tender texture and reduces water loss
Frying	>180°C	Water loss, firmer meat	Frying at very high temperatures can make the meat drier and tougher, affecting its quality
Smoking	40-60°C	Improved taste, antimicrobial effect	Smoking enhances the taste and shelf life, but it can alter the structure of proteins

To maintain quality, methods such as baking at moderate temperatures or sous-vide techniques (slow cooking at low temperatures) are recommended, which can help preserve the tenderness of the meat (Fletcher, 2002; Castellini et al., 2008).

3.4. *Packaging and preserving turkey meat*

Packaging is essential for maintaining freshness and preventing oxidation (Table 4) (Wilkins, 2015; Hiscock et al., 2022).

Table 4. Packaging and preserving turkey meat

Type of packaging	Advantages	Disadvantages	Details
Vid (vacuum)	Prevents oxidation, maintains freshness	High cost	Vacuum packaging is the most effective method for preserving the quality of meat, preventing dehydration and oxidation
Packaging in a modified atmosphere (MAP - $CO_2/N_2/O_2$)	Increases lifespan, prevents bacterial growth	It requires special equipment.	MAP (modified atmosphere packaging) maintains color and freshness, but requires precise gas control
Traditional packaging (plastic, paper)	Reduced cost	Short storage period	Traditional packaging is the most commonly used for quick sales, but it offers the shortest shelf life

For export and long-term storage, vacuum packaging and quick freezing are the most effective methods (Alonso-Calleja et al., 2004; ISO 22000:2018).

4. Food safety and consumer requirements regarding turkey meat

In addition to biological, environmental, and technological aspects, food safety is an essential factor in maintaining the quality and acceptability of turkey meat (Heckendorn et al., 2015; EFSA, 2020). Food safety regulations aim to control bacterial contamination, the use of additives, and processing standards, ensuring that the final product is safe for consumption (ISO 22000:2018; USDA, 2021).

At the same time, consumer preferences are influencing the turkey meat industry, driving demand for healthier, more natural products with high sensory quality (Berri, 2008; Hiscock et al., 2022).

4.1. *Microbiological contamination and safety measures*

Salmonella spp., *Campylobacter* spp., *Listeria monocytogenes* and *Escherichia coli* are among the bacteria that can contaminate turkey meat (EFSA, 2020; Samuel et al., 2022). If the product is not handled and processed correctly, these bacteria can result in serious food poisoning (Owens et al., 2009; Fraqueza, 2015).

Contamination prevention measures. Equipment should be cleaned and disinfected in accordance with good hygiene practices (GHP) (ISO 22000:2018; Correa et al., 2019).

Keeping an eye on storage temperatures: cooked meat should be kept at 60°C and raw meat below 4°C (Fletcher, 2002; USDA, 2021).

To control microbiological hazards, the HACCP approach is applied, which identifies important points in the manufacturing chain (Owens et al., 2009; EFSA, 2020).

Using films containing antimicrobial compounds to prevent the growth of diseases, also known as antibacterial packaging (Marangoni et al., 2015; Awan & Rahman, 2020).

4.2. *Food additives and preservatives used in processed meat*

Food additives and preservatives may be added to processed turkey meat to preserve freshness and stop bacterial growth (Table 5). Enhancing the flavour, texture, and shelf life is their responsibility (Hudson, 2012; Jensen & Dolberg, 2021; Hiscock et al., 2022).

Table 5. Food additives and preservatives used in processed meat

Aditives	Role	Possible negative effects
Nitrites and nitrates	Prevent the growth of bacteria, stabilize the color	Risk of nitrosamine formation (potentially carcinogenic)
Salt and phosphates	They improve water retention and texture	Excessive consumption can affect cardiovascular health
Antioxidants (e.g., ascorbic acid, tocopherols)	Prevent the rancidity of fats	Safe within the recommended limits
Natural extracts (rosemary, green tea)	Natural preservatives, enhance the flavor	They have no known side effects

The current trend is to reduce the use of synthetic additives and replace artificial preservatives with natural extracts, responding to consumer demands for healthier and less processed products (Bianchi & Fletcher, 2002; Okuskhanova et al., 2017).

4.3. *Consumer perception of turkey meat quality*

Modern consumers are increasingly concerned about the origin, safety, and composition of the meat they consume (Northcutt, 2001; Marchewka et al., 2013). Market studies show that their preferences are influenced by appearance, texture, taste, and nutritional information (Table 6) (Miao et al., 2019; Bolek & Węglarz, 2022).

Table 6. Consumer perception of turkey meat quality

Selection criterion	Influential factors	Impact on the decision
The color of the meat	pH, refrigeration methods	Consumers prefer uniform pink color, avoid pale or dark meat
Tenderness and juiciness	Species, maturity, processing	The soft and juicy texture is preferred, avoiding dry meat.
Origin and cultivation method	Organic farms vs. intensive farming	Products labeled "eco" are more appreciated, even if they are more expensive
The presence of additives	Preservatives, colorants, nitrites	Consumers prefer meat without synthetic additives

Current trends show an increase in demand for organic meat, free from antibiotics and artificial additives. In addition, many consumers choose meat from ethical farming systems, with animal welfare respected (Berri et al., 2020; Arslan & Seker, 2021).

4.4. *Labeling and quality standards*

Products made from turkey meat must be properly labelled to enable customers to make educated decisions (ISO 22000:2018; Jensen & Dolberg, 2021). Labels are required by FDA and EU laws to provide unambiguous information regarding:

Origin and method of production (e.g., "organic", "raised without antibiotics")

Values of nutrition (calories, proteins, fats, and vitamins)

Date of expiration and method of preservation

Ingredients and potential allergies listed

The European Food Safety Authority's (EFSA) rules, which set stringent limits on antibiotic residues and pollutants, govern quality standards in the EU (EFSA, 2020). Consumer confidence and product safety are guaranteed using these standards (Awan & Rahman, 2021; USDA, 2021).

CONCLUSIONS

From the study of specialized literature regarding the factors that influence meat production in turkey broilers, it has been concluded that genetic type and sex directly influence the texture and tenderness of the meat, while slaughter age and rearing conditions determine some aspects related to the color and juiciness of the meat.

Regarding environmental factors, it has been noted that temperature and humidity play a major role in the development of muscle masses, while controlled lighting programs can influence metabolism and, implicitly, meat quality.

Nutrition is another determining element, as the turkey broiler requires a balanced diet rich in proteins, essential fatty acids, and micronutrients to obtain meat with optimal nutritional value and superior sensory characteristics.

Processing live birds was another subject of our study, concluding that transport stress, stunning method, scalding regime, carcass cooling system, and packaging technique influence both the quality and shelf life of the obtained meat.

Another important element of interest was food safety, as preventing microbiological contamination is an essential objective in the meat industry; the use of strict hygiene measures.

Additionally, the increased demand for healthy and natural products has prompted the industry to reduce the use of synthetic additives and place greater emphasis on clear labeling and quality certifications.

Looking to the future, it becomes increasingly evident that sustainability will play a central role in the development of the sector, with the main directions in this regard being the

reduction of environmental impact, the use of alternative food sources, and the improvement of product traceability; additionally, the adoption of new processing and preservation technologies will contribute to increasing product sustainability and offering safer and healthier options for consumers.

From the presented information, the final conclusion is drawn that the quality of turkey meat is the result of a complex interaction between biological and environmental factors, and understanding these allows for the improvement of the sensory and nutritional characteristics of the final product, while also providing the possibility to adapt production to the increasingly demanding requirements of consumers.

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