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IMPROVEMENT OF THE TENDERNESS OF HEN'S MEAT : A REVIEW LITERATURE

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ABSTRACT

The massive breeding of the laying hen's industry leads to the availability of large quantities of their meat at the end of their economically productive life. Chicken produces a sufficient amount of breast and thigh meat. Moreover, their meat is cheap and healthy. It is a rich source of protein and omega-3 fatty acids, containing a low percentage of cholesterol without religious or cultural restrictions. However, the meat of laying hens is challenging due to the age-related increase in cross-linking of refractory connective tissue, which has banned its use, thus reducing its market value. Chickens are slaughtered after their production cycle, and their meat is used for food and pet food production. In this sense, different means must be found to improve the softness and flavor of these meats. Therefore, this review article is designed to focus on the meat of aged laying hens at the end of its economic production life and identify ways to improve its tenderness and flavor to facilitate its marketing and sale to the consumer. The classical methodology was used to analyze appropriate literature retrieved from Scopus, PubMed, and ScienceDirect using relevant key terms in November 2022. Studies showed that the weight of the muscles and the ratio of their parts to each other depends on the hen's age, sex, type, production aspect, survival, and feeding conditions. Some studies have referred to the many methods used to improve the tenderness of laying chicken meat, including enzymes, salts, phosphates, and calcium chloride. Moreover, other studies described some physical methods to tenderize the meat, such as pressure treatment, ultrasonic waves, and electrical stimulation. In conclusion, this review study showed that the published research focused on developing methods for improving the tenderness of hen's meat by reducing the amount of connective tissue without a breakdown of meat proteins.

Keywords: Laying hens, aged, meat, meat tenderness, enzyme methods.

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Introduction

Chicken meat, or poultry meat, is a widely consumed and versatile protein source crucial in diets and cuisines worldwide. The derived chicken meat from domesticated chickens has become a staple in various cultures due to its nutritional value, culinary versatility, and accessibility. Whether enjoyed in its traditional form or incorporated into various dishes, chicken meat offers cultural significance and health benefits (Baldassini *et al.,* 2021). Chicken meat is renowned for its rich protein content, making it an essential component of a balanced diet. It provides a complete protein source and comprises all the essential amino acids required for various bodily functions. Additionally, chicken meat is relatively low in

fat, especially when the skin is removed, and it possesses essential nutrients such as B vitamins (niacin, B6), phosphorus, selenium, and iron (Dragan Milicevic *et al*., 2015; da Silva *et al.,* 2017; Ismail & Joo. 2017). One of the most compelling features of chicken meat is its adaptability in the kitchen. From comforting classics to gourmet creations, chicken can be prepared using various cooking techniques, including grilling, roasting, sautéing, frying, and baking. Its neutral flavor profile allows it to absorb marinades, spices, and seasonings, enhancing its taste and suiting various culinary preferences (Mir *et al.,* 2017).
Chicken meat consumption is deeply intertwined with cultural traditions and cuisines worldwide. It is a centerpiece in festive meals, family gatherings, and celebratory occasions. Different cultures have developed unique methods of preparing chicken dishes, showcasing the diversity of culinary creativity across the globe. In addition to its culinary merits, chicken meat offers health benefits that contribute to overall well-being. Its lean protein content supports muscle growth, tissue repair, and metabolic functions. By choosing skinless cuts and practicing healthy cooking methods, individuals can enjoy the nutritional advantages of chicken meat without excess saturated fat. Chicken farming is generally more resource-efficient than other livestock, making chicken meat a relatively sustainable protein source. Its affordability and widespread availability contribute to its accessibility for a broad range of consumers, ensuring it plays a significant role in addressing protein needs globally (Oliveira *et al.,* 2021 A; Oliveira *et al.,* 2021 B).

"Hens meat" typically refers to the meat obtained from mature female chickens, also known as hens. While chicken meat from younger birds (broilers) is often more tender and sought after for its culinary qualities, hen meat can also be a valuable protein source with unique characteristics. Hens are chickens that have matured and have reached the end of their egg-laying cycle. As hens age, their meat tends to be slightly more rigid than younger birds due to the development of connective tissues (Weng *et al.,* 2022). However, hen meat can be flavorful and suitable for various cooking methods when prepared correctly. While hen meat may require longer cooking times or methods to tenderize it, it can still be used in many dishes. Cooking methods like slow cooking, stewing, braising, and roasting can help break down the connective tissues and produce tender, flavorful meat. Hen meat is often used to prepare hearty soups, stews, and casseroles. Hen meat provides a similar nutritional profile to that of younger chickens. It is a good source of protein, essential amino acids, and nutrients such as B vitamins (niacin, B6), iron, zinc, and phosphorus. Like other poultry meats, hen meat is relatively low in saturated fat compared to red meats. Utilizing hens for meat after their egg-laying cycle contributes to the sustainability of the poultry industry. Rather than discarding older hens, the meat from these birds can be utilized, reducing waste and using available resources (Baldinger & Bussemas, 2021).
A literature review regarding the tenderness of hen's meat and its improvement revealed scarce publications. Based on the preceding, this study aims to study the meat of aged laying hens and its composition at its economically productive age, in addition to identifying the different methods used to improve the tenderness of aged laying hens.

Methodology

In November 2022, traditional methodology was used to review appropriate literature collected from Scopus, PubMed, and ScienceDirect using relevant key terms. The document was searched by article title, abstract, and keywords. Only original articles in the English language published until 2023 were included. These researches were viewed and read in-depth; accordingly, this article was written.

The importance of chicken meat in the food pyramid

Chicken meat is significant in the food pyramid, a visual representation of recommended dietary guidelines for maintaining a balanced and healthy diet (Ioan & Monica, 2020). There are several reasons why chicken meat fits into the food pyramid and its importance, including:

1. Protein Group (Second Tier): Chicken meat falls under the protein group, an essential part of a balanced diet. In the food pyramid, the protein group is typically placed in the second tier, indicating that it should be consumed in moderate amounts. Chicken meat is a primary source of high-quality protein, providing essential amino acids for various bodily functions, including growth, repair, and hormone production.
2. Lean Protein Source: The food pyramid emphasizes choosing lean protein sources to reduce saturated fat intake. Skinless chicken breast is a prime example of a lean protein that aligns with this recommendation. It offers a substantial amount of protein with minimal saturated fat, making it a heart-healthy option.
3. Dietary Variety: The food pyramid encourages dietary variety, and chicken meat offers a versatile option for protein consumption. By incorporating chicken meat into meals, individuals can vary their protein sources and enjoy a range of flavors and textures.
4. Balancing Nutrient Intake: Chicken meat contributes to a well-rounded diet by providing protein and essential nutrients such as B vitamins (including niacin and B6), phosphorus, and selenium. These nutrients are vital for energy metabolism, immune function, and bone health.
5. Moderation and Portion Control: The food pyramid emphasizes moderation in food consumption. Chicken meat can be included in meals to meet protein requirements, but it is essential to control portion sizes to maintain a balanced diet and manage calorie intake.
6. Customization and Dietary Preferences: The food pyramid recognizes that individual dietary preferences and needs may vary. Chicken meat is an adaptable option for individuals who prefer or require a lean source of protein due to dietary restrictions or health considerations.
7. Flexibility in Meal Planning: Chicken meat's versatility allows for diverse meal planning. It can be grilled, baked, roasted, stir-fried, or used in various cuisines, adding culinary interest and making it easier to follow dietary recommendations.
8. Economic Accessibility: Chicken meat's affordability and widespread availability contribute to its inclusion in the food pyramid. It is a cost-effective protein source that allows more individuals to access nutritious options within their budgets.
9. Chicken meat occupies a significant place in the protein group of the food pyramid (Figure. 1) due to its nutritional value, versatility, and suitability for various dietary preferences. Its role in providing lean protein, essential nutrients, and options for balanced meal planning underscores its importance in supporting a healthy diet.

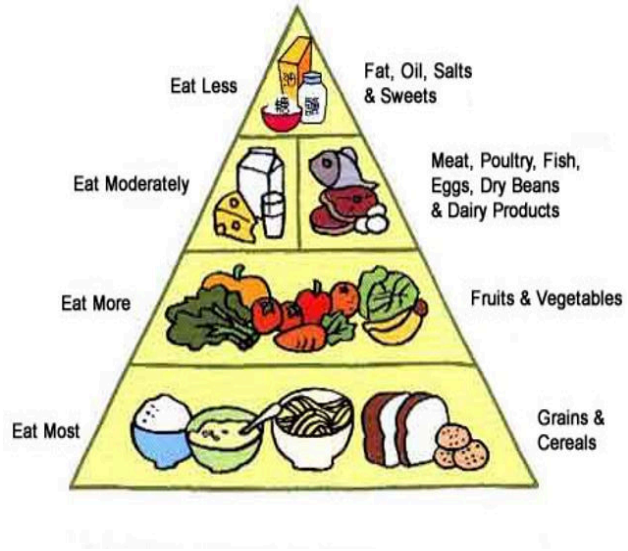

Figure.1: Shows the location of poultry meat in the food pyramid

Disadvantages of broiler and hen meat

While chicken and hen meat offer numerous nutritional benefits and culinary versatility, there are also some potential disadvantages. There are a few drawbacks associated with consuming chicken and hen meat. Chicken and hen meat, especially the skin, can contain relatively higher cholesterol levels than some other lean protein sources (Giampietro-Ganeco *et al.,* 2020). Individuals with certain health conditions, such as high cholesterol or heart disease, may need to monitor their intake of these meats. In some conventional poultry farming practices, antibiotics and hormones may promote growth and prevent disease (Jammoul & El Darra, 2019). Concerns about the potential transfer of these substances to the meat could impact human health. Opting for organic or responsibly raised chicken may help mitigate this concern. Improper handling, storage, or cooking of chicken and hen meat can lead to foodborne illnesses, such as salmonella or campylobacter infections (Thames & Sukumaran, 2020). Thoroughly cooking chicken meat to a safe internal temperature and practicing proper food safety measures are essential to prevent such risks. Intensive poultry farming practices can have environmental impacts, including waste disposal issues, water pollution, and the emission of greenhouse gases (Leigh & Mary, 2011). Sustainable and responsible farming practices can help address some of these concerns.

In some cases, the conditions in which chickens and hens are raised for meat production can raise animal welfare concerns (Fuseini *et al.,* 2023). Confined spaces and inhumane treatment can lead to ethical considerations for consumers. Some individuals may develop allergies or sensitivities to chicken or hen meat, leading to adverse reactions such as skin rashes, digestive issues, or respiratory symptoms (Zacharisen, 2006). While chicken and hen meat provide protein and specific nutrients, they may need more nutrients from other protein sources such as seafood, beans, and legumes. Consuming a diverse diet is essential for overall health. It is important to note that many of these disadvantages can be mitigated by making informed choices. Opting for organic, responsibly raised, and antibiotic-free chicken can help address antibiotic use and environmental impact concerns. Additionally, safe food handling and cooking techniques can reduce the risk of foodborne illnesses. As with any food, moderation and balance in consumption are vital to enjoying the benefits of chicken and hen meat while minimizing potential drawbacks (Soglia *et al.,* 2016).

Properties of Poultry muscle

Poultry muscle, which includes the muscles found in chicken, turkey, duck, and other poultry, possesses various properties that contribute to its culinary appeal and nutritional value. There are some critical properties of poultry muscle. Poultry muscle is known for its tender and delicate texture when properly cooked. The muscle fibers are relatively fine, contributing to the meat's overall tenderness. This texture makes poultry meat suitable for various cooking methods, from grilling and roasting to frying and braising. Poultry meat is generally considered lean compared to red meat. It has a lower fat content, especially compared to beef or pork cuts. However, the fat content can vary depending on factors like the type of poultry, the cut, and the cooking method used (Soglia *et al.,* 2016). Poultry muscle is an excellent source of high-quality protein, providing all the essential amino acids for various bodily functions. Protein is essential for muscle growth, tissue repair, and the production of enzymes and hormones. Poultry muscle is rich in essential nutrients such as B vitamins (including B6, niacin, and riboflavin), iron, zinc, phosphorus, and selenium. These nutrients are essential for energy metabolism, immune function, and overall health. Poultry meat has a relatively neutral flavor profile**,** which allows it to absorb marinades, spices, and seasonings effectively. This makes it versatile and suitable for various culinary styles and flavor profiles. Poultry muscle can retain moisture when cooked, contributing to its succulent texture. Proper cooking techniques and careful monitoring of cooking times help maintain the moisture content and prevent dryness. Poultry muscle can be prepared using various cooking methods and incorporated into diverse dishes. It adapts well to different cuisines and can be used in everything from salads and sandwiches to elaborate main courses. Poultry muscle contains relatively lower collagen levels than meats like beef or pork. This contributes to its tenderness and reduces the need for prolonged cooking times to break down tough connective tissues.

Due to its lean and tender nature, poultry muscle often cooks relatively quickly compared to other meats (Oliveira *et al.,* 2021 A; Oliveira *et al.,* 2021 B). This property makes it convenient for busy cooks and those seeking to prepare meals quickly. Poultry meat, especially chicken, holds cultural significance in various cuisines worldwide. It is a staple in many traditional dishes and is often associated with celebrations and special occasions. Overall, the properties of poultry muscle make it a sought-after protein source prized for its texture, flavor-absorption capabilities, nutritional value, and versatility in cooking. Whether enjoyed in a classic roast chicken dinner or incorporated into innovative recipes, poultry muscle plays a vital role in culinary creations across cultures. There are different types of poultry muscles. These are:

1. White muscles

Poultry white muscles, fast-twitch or glycolytic muscles, are muscle tissue found in birds, particularly in their breast and wing muscles. These muscles are responsible for rapid and robust movements, such as short bursts of flight and quick take-offs. Poultry's white muscles appear pale compared to other muscle types due to their lower myoglobin content. Myoglobin is a protein that stores oxygen in muscle fibers. The lower myoglobin levels contribute to the pale appearance (Hee-Jin *et al.,* 2020). White muscles contract quickly and generate a high level of force. This allows birds to perform rapid and forceful movements, essential for escaping predators, evasive maneuvers, and quick take-offs. These muscles primarily rely on anaerobic metabolism, generating energy without using oxygen. They use stored glycogen for energy production, which can sustain short bursts of activity but leads to quicker fatigue than muscles that use aerobic metabolism. Due to their reliance on

anaerobic metabolism, poultry white muscles tend to fatigue relatively quickly. They are designed for short-duration, high-intensity activities rather than prolonged endurance efforts. Poultry white muscles are essential for activities like short-distance flight. While birds with more white muscles may not have the same level of sustained flight endurance as those with higher proportions of red muscles, they can perform rapid and agile movements in flight. Poultry white muscles are often considered desirable for culinary purposes due to their tenderness. The relatively low levels of myoglobin and fat content contribute to the meat's mild flavor and delicate texture. In culinary terms, cuts of poultry meat from white muscles, such as chicken breasts, are often favored for their tenderness and versatility in cooking. However, the predominance of white muscles in the breast area can lead to quicker fatigue during flight in some bird species (Ezugwu *et al.,* 2023). Overall, white muscles play a crucial role in allowing birds to perform quick, powerful movements and are a vital factor in the unique characteristics of poultry meat.

2. Red muscles

Poultry red muscles, or slow-twitch or oxidative muscles, are muscle tissue found in birds, particularly in their leg and thigh muscles. These muscles are responsible for sustained and endurance-based activities, such as walking, standing, and maintaining flight over longer distances. Poultry red muscles appear darker than white muscles due to their higher myoglobin content. Myoglobin is a protein that stores oxygen in muscle fibers. The increased myoglobin levels give these muscles a darker appearance. Red muscles contract more slowly than white muscles and generate less force. This makes them well-suited for activities that require endurance and sustained effort rather than quick bursts of movement. These muscles rely on aerobic metabolism, which uses oxygen to generate energy. They primarily use fat as a fuel source, allowing for sustained and prolonged activity. Poultry red muscles have a greater endurance capacity compared to white muscles. This makes them suitable for activities that require prolonged effort, such as maintaining posture while standing or walking for extended periods (Lampila, 1990). While red muscles may not generate the same quick bursts of flight as white muscles, they are essential for sustained flight over longer distances. Birds with a higher proportion of red muscles may excel in activities requiring flight endurance. Cuts of poultry meat from red muscles, such as chicken thighs and drumsticks, are often favored for their rich flavor and tenderness when cooked correctly. The darker color of the meat is due to the higher myoglobin content. Poultry red muscles are essential for endurance and sustained effort, such as prolonged flight and standing (Lampila, 1990). These muscles are characterized by their capacity for aerobic metabolism, which allows them to support activities that last longer and require less intense bursts of energy. In culinary terms, red muscle cuts can provide flavorful and tender meat options, mainly when cooked using methods that enhance their natural characteristics.

Chemical structure of poultry muscles

The chemical structure of poultry muscles, like muscles in all animals, is primarily composed of proteins, fats, carbohydrates, water, minerals, and other bioactive compounds. Proteins are the primary structural components of muscles. The main protein in muscle tissue is myosin, which interacts with actin to facilitate muscle contractions **(**Listrat *et al.,* 2016). Other proteins include troponin and tropomyosin, which regulate muscle contraction. Collagen is another protein present in connective tissues within muscles. **Intramuscular fat,** also known as marbling, contributes to poultry meat's flavor, tenderness, and juiciness. These fats are triglycerides, consisting of glycerol and fatty acids (Luo *et al.,* 2022). Muscle

tissues contain glycogen, which serves as a stored form of glucose. Glycogen is an energy source that can be broken down into glucose for muscle activity. Water is a significant component of muscle tissue, making up a large portion of its weight. The water content contributes to the juiciness and texture of cooked poultry meat. Muscle tissues contain potassium, sodium, calcium, magnesium, and phosphorus minerals. These minerals play roles in muscle contraction, nerve transmission, and various physiological functions. Muscle tissue also contains vitamins, particularly B vitamins such as niacin (B3), riboflavin (B2), and vitamin B6. These vitamins affect energy metabolism and overall health (Ismail & Joo, 2017).

Poultry muscles may contain bioactive compounds such as antioxidants (e.g., vitamin E) and creatine, which are involved in energy storage and transfer within muscle cells. Connective tissues connect muscles to bones and other muscles, including tendons and ligaments. Collagen is a significant component of these tissues. The chemical structure of poultry muscles is complex, reflecting the intricate combination of various compounds that contribute to muscle function, texture, flavor, and nutritional value. The composition of these components can vary based on factors such as the type of poultry, its age, diet, and genetics. Understanding the chemical makeup of poultry muscles is essential for poultry meat consumption's culinary and nutritional aspects (Ismail & Joo, 2017).

Histological structure of poultry muscles

The histological structure of poultry muscles refers to the arrangement and organization of tissues at the microscopic level. Like other animals, poultry muscles consist of various components that enable muscle function and movement. The basic structural unit of muscle tissue is the muscle fiber, also known as a myofiber or muscle cell. Each muscle fiber is a long, cylindrical cell that contracts when stimulated by nerve impulses. Muscle fibers are multinucleated, meaning they contain multiple nuclei along their length. Within each muscle fiber are myofibrils, which are long, thread-like structures containing the contractile proteins actin and myosin. Myofibrils are responsible for muscle contraction. They give skeletal muscle its striated appearance under a microscope. Sarcomeres are the repeating units along the length of myofibrils responsible for muscle contraction. They are delimited by Z-lines (Z-discs) and contain overlapping actin and myosin filaments. The interaction between these filaments generates muscle contraction. Muscle fibers are surrounded by connective tissues, including endomysium (around individual fibers), perimysium (around bundles of fibers called fascicles), and epimysium (surrounding the entire muscle). These connective tissues provide structural support and house blood vessels and nerves. Blood vessels and nerves run through the connective tissues to supply oxygen, nutrients, and nerve impulses to the muscle fibers. Nerves are responsible for initiating muscle contractions. Satellite cells are specialized cells located between the muscle fiber and the endomysium. They play a role in muscle growth and repair by differentiating into new muscle fibers or fusing with existing fibers to increase size. Muscle fibers contain numerous mitochondria, which are the cell's energy-producing organelles. They provide the energy required for muscle contractions. Muscle fibers store glycogen in the form of glycogen granules. *Glycogen* is an energy reserve that can be broken down into glucose for muscle activity. As with all muscles, the histological structure of poultry muscles is highly specialized to enable contraction, movement, and various physiological functions. Understanding this micro-level structure is crucial for grasping how muscles function, respond to training, and contribute to overall poultry meat quality (Soglia *et al.,* 2016).

Differences in chemical and histological structure of hen and broiler muscles

Due to age, genetics, diet, and growth rate, hen and broiler muscles can exhibit differences in their chemical composition and histological structure. Broiler muscles tend to have higher intramuscular fat content (marbling) than hens. The rapid growth rate of broilers can result in higher fat deposition. Protein content is generally similar between hens and broilers, as both are raised for meat production. Hens may have slightly more connective tissue due to their age and the presence of spent layers. This can affect tenderness and cooking methods. Due to the accelerated growth rate and intensive feeding practices, broiler muscles might have higher nutrient density, including minerals and vitamins. The broiler muscles often have larger muscle fibers due to their rapid growth. This can affect texture and tenderness. Broiler muscles might have a higher density of myofibrils (contractile units) due to the demand for growth. This can influence meat texture. Hens' muscles might show more developed connective tissues due to their age and egg-laying history. This can impact tenderness. The ratio of fast-twitch (white) to slow-twitch (red) fibers can differ. Broilers might have a higher proportion of white muscles for rapid growth, while hens might have more red muscles due to sustained activity (Soglia *et al.,* 2016). It is important to note that these differences can vary based on the poultry's specific genetics, management practices, and feeding regimens. Additionally, processing methods and cooking techniques can influence the final characteristics of hen and broiler meat. When comparing the two, it is essential to consider factors such as age, intended use, and desired culinary outcomes.

Sensory qualities of poultry meat

The sensory qualities of poultry meat are critical factors influencing consumer perception, acceptability, and product enjoyment (Damaziak *et al.,* 2019). These qualities involve the appearance, aroma, flavor, texture, and overall experience when consuming poultry meat.

1. Appearance: The color of poultry meat can range from pale white to deeper shades depending on factors such as breed, age, and diet (Figure. 2). Consumers often associate color with freshness and quality. Intramuscular fat, or marbling, contributes to the appearance by adding juiciness and tenderness. Some consumers prefer more marbling for added flavor. Uniform color and texture throughout the meat cut are desirable for a consistent eating experience.

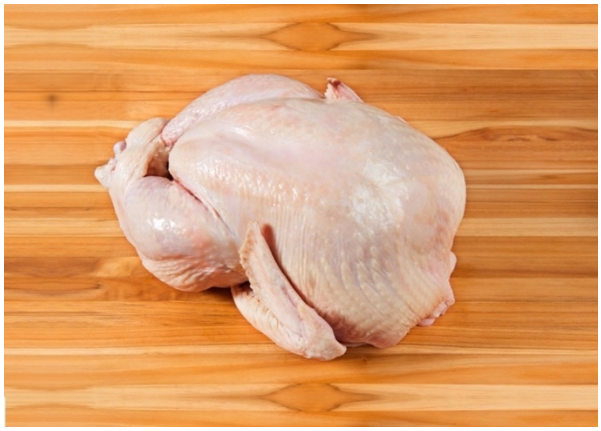

Figure. 2: Shows the appearance of broiler

2. Aroma: A fresh, clean aroma indicates high-quality poultry meat. Any off-putting or sour smells can signal spoilage or poor storage conditions. Different poultry species may have distinct natural aromas due to their diets and metabolic processes (Al-Hajo, 2009).
3. Flavor: Poultry meat is known for its relatively mild flavor compared to red meat. This mildness allows it to absorb marinades and seasonings easily. Adequately raised and prepared poultry should have a clean, natural flavor without any off-flavors. Umami, the fifth basic taste, can be present in poultry meat due to the presence of amino acids like glutamate.
4. Texture: Tenderness is a highly sought-after quality in poultry meat. It refers to the ease with which the meat can be chewed and broken down. Juiciness is the moisture content of the meat, contributing to a pleasant mouthfeel. Proper cooking methods and optimal internal temperature help maintain juiciness. Poultry meat should have a consistent and pleasing fiber structure without challenging or gristly portions.
5. Overall Eating Experience: The combined experience of flavor, texture, and juiciness contributes to the overall mouthfeel of the meat. The lingering taste after consumption can impact overall satisfaction (Bulkaini *et al.,* 2021).
Consumers' preferences for sensory qualities can vary widely based on cultural, regional, and personal factors. While some may prefer a mild taste and tender texture, others might seek more robust flavors or different levels of doneness. Additionally, proper handling, storage, and cooking techniques play a crucial role in preserving and enhancing the sensory qualities of poultry meat.

Tenderness of broiler and hens Meat

Tenderness is a highly desirable quality in poultry meat as it contributes to a pleasurable eating experience. The tenderness of broiler (young chicken) and hen (mature chicken) meat can vary due to factors such as muscle structure, age, genetics, and management practices (Bulkaini *et al.,* 2021; Al-Hajo, 2009).

Broiler Meat Tenderness

Broilers are typically processed at a younger age (around 6 to 7 weeks) when their muscles are still developing and have smaller fiber sizes. This generally results in more tender meat. Broilers have shorter lifespans and less opportunity for muscle development, which can lead to relatively less connective tissue and more tender meat. Broilers are bred for rapid growth, resulting in a lower proportion of mature connective tissue and collagen (Fan & Wu, 2022). This contributes to tenderness. Broiler meat might have lower intramuscular fat (marbling) compared to mature hens, which can contribute to a slightly leaner and possibly less flavourful profile. However, hens are processed at a more mature age (around 1 to 2 years) when their muscles have had more time to develop and become more prominent. This can result in meat with larger and potentially tougher fibers (Figure. 3). Hens have had a longer lifespan and more opportunity for muscle activity, leading to more developed muscle fibers and possibly denser connective tissue. Mature hens may have more developed and thicker connective tissues, which can contribute to slightly less tender meat. However, proper cooking techniques can help break down collagen and improve tenderness. Depending on the breed and management practices, hens may have more marbling than broilers, contributing to potential juiciness and flavor. It is important to note that while broiler meat is generally considered more tender due to the abovementioned factors, cooking methods can significantly influence the tenderness of broiler and hen meat. Techniques such as marinating, brining, and slow cooking can enhance tenderness regardless

of the bird's age. Additionally, consumer preferences vary, and some individuals might enjoy the more robust flavor of mature hen meat.

Figure. 3: Shows the appearance of meat of the egg-laying hens

Methods used to measure meat tenderness

Meat tenderness is a critical quality attribute that influences consumer satisfaction. Several methods are used to measure meat tenderness, including instrumental and sensory approaches (Hussain *et al.,* 2021). There are some standard methods (Zhang *et al.,* 2021) used to assess meat tenderness:

1. **Warner-Bratzler Shear Force Test:** This instrumental method involves cutting a meat sample with a specialized device called a Warner-Bratzler shear force machine. The force required to shear the sample is measured, and higher force values indicate tougher meat (Choe *et al.,* 2016).
2. **Texture Profile Analysis (TPA):** TPA involves subjecting meat samples to controlled compression cycles using a texture analyzer. It measures hardness, springiness, cohesiveness, and chewiness, providing a comprehensive understanding of the meat's texture (de Huidobro *et al.,* 2005).
3. **Allo-Kramer Shear Compression Test:** This method involves compressing meat samples with a device that measures the force required to compress the sample. The Allo-Kramer shear compression test is commonly used for poultry meat (Szczesniak *et al.,* 1970).
4. **Instron Universal Testing Machine:** Similar to the Warner-Bratzler shear force test, this machine measures the force needed to shear or compress a meat sample. It is used for various meat types, including beef, pork, and poultry.
5. **Sensory Evaluation:** Sensory panels of trained or consumer assessors evaluate meat tenderness using their senses. Sensory methods include:
6. **Shear Panel Test:** Assessors chew cooked meat samples and evaluate tenderness subjectively based on their sensory perception.
7. **Bite Test:** Assessors bite into cooked meat and evaluate tenderness.
8. **Tenderness Rating:** Assessors rate meat samples on a scale from tender to tough.
9. **Consumer Panels:** Panels of untrained consumers evaluate meat tenderness using methods such as bite tests or tenderness ratings. This provides insight into the tenderness perception of the general public.

10. **Tenderometer:** A handheld device that measures meat tenderness by assessing the resistance of the meat when a plunger is pushed into it. It provides a quick estimate of tenderness.
11. **Ultrasound:** Ultrasound technology can measure the density of muscle fibers, which can correlate with tenderness. It is a non-destructive method that can be used on live animals and meat samples.
12. **Electronic Nose and Tongue:** These sensory analysis devices mimic human olfactory and gustatory senses. They can assess aroma and flavor attributes that are related to tenderness.
13. **Texture Analysis Instruments:** Instruments that use a probe to apply controlled forces to meat samples and measure parameters like penetration depth or compression.

Combining multiple methods can comprehensively understand meat tenderness, considering instrumental measurements and sensory evaluations. The choice of method depends on factors such as the type of meat, the purpose of measurement, and available resources (de Huidobro *et al.,* 2005).
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Methods for improving the tenderness of hen meat

Improving the tenderness of hen's meat involves various pre-slaughter, post-slaughter, and cooking techniques. According to previously published research (Barido & Lee, 2021), there are some methods to enhance the tenderness of hen's meat; these include:
1. **Age at Processing:** Process hens at a younger age to ensure that muscle fibers are less developed and thus more tender.
2. **Marination:** Marinating hen's meat in acidic solutions (e.g., vinegar, citrus juice) or enzymatic marinades (containing papain and bromelain) can help break down muscle fibers and collagen, resulting in increased tenderness.
3. **Brining:** Submerge hen's meat in a saltwater solution, which can enhance moisture retention and improve texture and tenderness.
4. **Mechanical Tenderization:** Use mechanical methods like needling or blade tenderization to physically disrupt muscle fibers and connective tissues, making the meat more tender.
5. **Cooking Methods:** Choose methods that promote tenderness, such as slow cooking, braising, stewing, or pressure cooking. These methods break down collagen and soften the meat.
6. **Cooking Time and Temperature:** Cook hen's meat at lower temperatures for extended periods to allow collagen to break down gradually, resulting in more tender meat.
7. **Cooking with Moisture:** Cooking hen's meat with moisture, such as in a covered pan or pot with added liquid, helps retain moisture and promotes tenderness.
8. **Papain Enzyme Treatment:** Papain, an enzyme found in papaya, can marinate a hen's meat and enhance tenderness by breaking down proteins.
9. **Velveting:** A Chinese cooking technique where meat is marinated in egg white, cornstarch, and sometimes oil before cooking. This enhances tenderness and retains moisture.
10. **Electrical Stimulation:** Applying a mild electrical current to a hen's meat before slaughter can help relax muscle fibers and improve tenderness.
11. **Aging:** Dry or wet aging hen's meat allows enzymes to break down connective tissues over time, increasing tenderness.

12. **Selecting Breeds:** Choose breeds known for producing more tender meat, as genetic factors can influence meat quality.
13. **Controlled Freezing and Thawing:** Rapidly freezing and controlled thawing can break down cell structures, increasing tenderness.
14. **Thermal Processing:** Sous-vide cooking involves cooking hen's meat in a vacuum-sealed bag at a precise temperature, which can yield consistently tender results.

In conclusion, this review literature paper provides in-depth information on the meat of aged laying hens and its structure during its economic productive period. It also considers the different methods used to tender the meat of aged laying hens to improve its properties. It is important to note that each method may have different effects on flavor, color, and nutritional content, so experimentation and adjustments may be needed to achieve the desired results. Additionally, proper food safety practices should always be followed when handling and preparing poultry meat.

Competing interests

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