Meat Research
Vol 4, Issue 3: 1-6, Article 92, June 2024
ISSN: 2790-1971
https://doi.org/10.55002/mr.4.3.92
http://www.bmsa.info/meatresearch

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Keywords:
High-intensity ultrasound
Meat aging
Curing
Sous vide
Sensory

Article Info:
Received: May 03, 2024
Accepted: June 21, 2024
Published online: June 30, 2024

Review Article

Enhancing the qualitative attributes of meat through processing and preservation techniques- A review

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Abstract

Various techniques have been devised to produce more nutritious meat and animal products. Understanding the impact of meat aging and other processing processes on sensory quality is crucial. To enhance the nutritional value and flavor of products, it is necessary to employ a variety of technologies. This review highlighted the processes of aging, curing, and processing to create the optimal product that meets market demand. High-intensity ultrasound (HIUS) and other physical processing techniques along with wet and dry aging enhance the flavor and softness of beef. The fascinating technique of sous vide cooking preserves the nutrition and sensory qualities of food. Utilizing natural preservation techniques can extend the shelf life of beef products without compromising their flavor. These techniques can enhance the range of organically fortified beef products while preserving or enhancing their nutritional and sensory characteristics.

Introduction

Given the inherent susceptibility of meat-based goods to spoilage, preservation, processing, and packaging methods have been continuously evolving to improve the quality and shelf life of meat. Meat preservation is a significant industrial task that involves maintaining the nutritional and sensory properties of food, as well as ensuring its safety. Furthermore, developing methods that guarantee food safety satisfy customer desires, and preserve the nutritional content of conventional beef products is crucial. Consumers nowadays prefer beef products that are less processed, have a longer shelf life, and do not include preservatives (Gómez et al., 2020; Rana et al., 2014; Rima et al., 2019; Sun et al., 2020; Das et al., 2022). To meet these requirements, many preservation techniques have been utilized, such as freezing (Alam et al., 2023; Sharker et al., 2024), refrigeration and aging (Son et al., 2024), irradiation (Hashem et al., 2022 and 2024, Islam et al., 2019), and the inclusion of antimicrobials (Rai et al., 2014).

Meat can experience two primary forms of alterations, namely physical and chemical changes, when subjected to preservation and processing methods. Physical adjustments refer to modifications in the tissue structure that impact the visual appearance, size, texture, color, scent, and flavor of the product (Lee et al., 2024; Beriain et al., 2018). During the dehydration process, meat experiences surface moisture loss. Additionally, proteins undergo denaturation, resulting in increased retention of moisture and fat. Furthermore, the addition of other components enhances the functional characteristics of proteins (Gómez et al., 2020).

The nutritional content and quality of meat products may be impacted by various processing and preservation tactics. The technical, microbiological, and health-conscious features of the product are often taken into consideration while choosing the meat processing procedure. However, a thorough and worldwide approach taking into account the changes in sensory and nutritional qualities as well as consumer appeal is required when choosing a processing and/or preservation method.

So, it is necessary to do thorough examinations on the utilization of various approaches for meat preservation, as well as their impact on health and the environment, in order to meet customer satisfaction. This review aims to provide an overview of the advancements in the meat processing and preservation techniques and its effect on the nutritional value and sensory qualities.

Aging of meat

Meat aging is a traditional technique used for preservation. Meat aging is a prominent technique in the meat industry for processing meat products, as it enhances the longevity, taste, succulence, and tenderness of the flesh (Son et al., 2024; Terjung et al., 2021). Aging plays the main role in manufacturing high-quality products (Mungure et al., 2020). Typically, there are two methods for aging beef: wet aging and dry aging, both of which enhance flavor and increase the tenderness of the flesh (Kemp et al., 2010). Wet aging beef involves placing it in a vacuum-sealed box and storing it in a controlled atmosphere for a designated duration. Dry aging refers to the practice of suspending beef carcasses, subprimals, or unpackaged primal cuts in a refrigerated chamber for a period of several weeks or months. During this time, the temperature, humidity, and airflow are carefully regulated (Stenström et al., 2014).

Throughout the ages, the process of dry aging has been widely employed to preserve and enhance the tenderness of meat. Asian countries, including Korea, Japan, Singapore, Taiwan, and Hong Kong, are showing significant interest in wet and dry aging. Many high-end restaurants in these countries are now including dry-aged beef on their menus. The growing demand for dry-aged beef has led to the emergence of a lucrative niche in the food service business in Korea (Savell, 2008). Figure 1 illustrates the factors associated with meat aging for a better understanding on the subject.

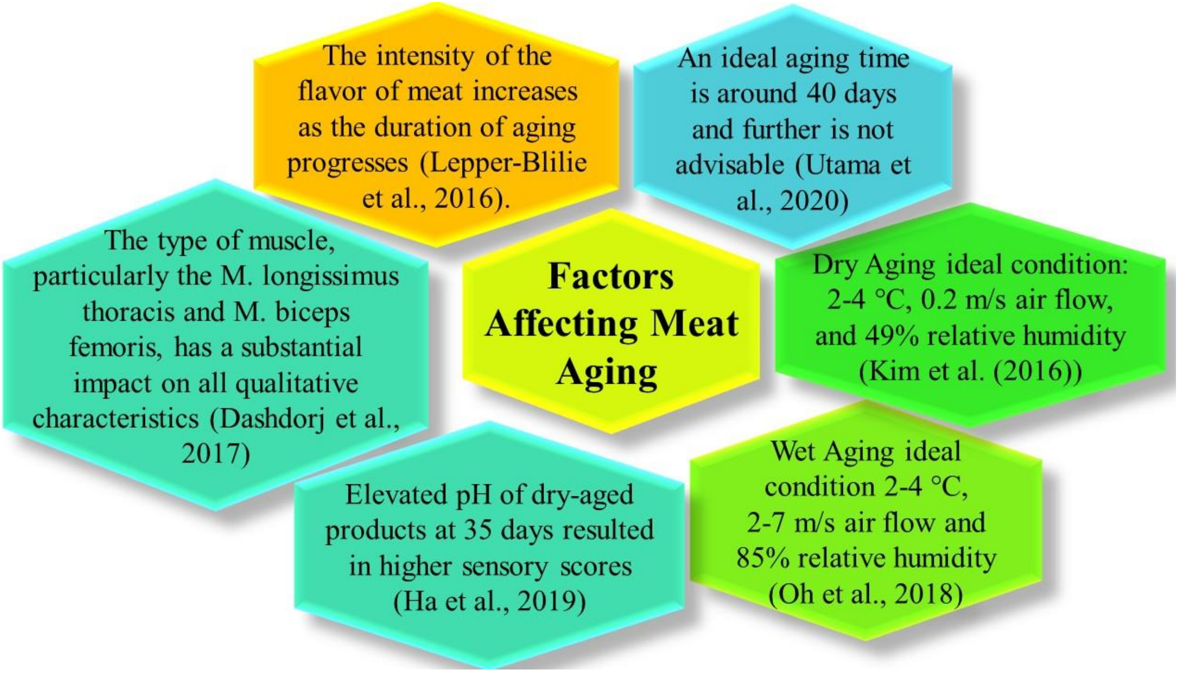

Figure 1. Factors mediating the aging process of meat.

Dry Aging

The process of dry aging whole meat cuts involves exposing them to a carefully controlled environment of temperature, humidity, and ventilation for an extended period of time, often ranging from a few weeks to several months (Son et al., 2024). These days, the meat business makes extensive usage of real-time monitoring and programmable logic controller-equipped automated drying chambers. These chambers allow for the regulation of temperature, relative humidity, flow distribution, and airflow rate in relation to the product's size, shape, structure, and moisture content (Hossain et al., 2024; Son et al., 2024). Meat can have its taste and softness enhanced by dry aging. This technique increases softness by permitting connective tissues to be broken down by the meat's natural enzymes (Warner, 2023). Additionally, the process can develop a desirable crust on the exterior of the meat, which is trimmed away before cooking (Ribeiro et al., 2024). Key factors in dry aging include maintaining proper temperature (usually slightly above freezing), humidity (generally around 80-85%), and air circulation. These conditions help prevent spoilage while facilitating the enzymatic and biochemical changes that enhance the meat's flavor and texture (Son et al., 2024). Table 1 provides an overview of the impacts of the dry aging process on meat quality along with other processing and preservation techniques. Due to the concentrated nature of taste components and the proteolysis and lipolysis processes triggered by water loss, dry-aged beef exhibits remarkable flavor and palatability (Gómez et al., 2020). Dry-aged beef and pig meat have an umami flavor due to the high glutamate concentration (Hwang and Hong, 2020; Hossain et al., 2024; Kim et al., 2016). Meat from cows and pigs is more succulent & juicier during dry aging (Beldarrain et al., 2020). Hyperspectral imaging is one new non-destructive approach that may be used to conceptualize how water is distributed in meat after it's dehydrated, which can assist improve the process. Researchers have successfully used the method on beef slices, where pixel-by-pixel photos were captured at six distinct wavelengths at various times (Hashem et al., 2022).

Wet aging

Wet aging is widely used to improve meat quality e.g., tenderness and flavor and a reasonably inexpensive methodology where meat is vacuum packed and refrigerated to stop bacterial growth and weight loss brought on by water evaporation (Hwang and Hong, 2020). However, wet aging can only be successful with low residual pressures and temperature control at 0-2 °C (Son et al., 2024). Wet aging is the most dominant packaging method in the current meat industry due to associated advantages less weight and trim loss, less space required, adaptable to automation and extended shelf-life without sacrificing palatability traits (Kim et al., 2019).

Wet-dry combined aging is a latest approach used to reveal most of the benefits from both of the methods for better rheological and sensory characteristics of meat (Lepper-Blilie et al., 2016; Son et al., 2024; Smith et al., 2014). Studies have shown that the pH and water retention capacity are improved over the aging process. Furthermore, it was determined that the tenderness and level of oxidation were suitably balanced.

Noble processing techniques to aid meat aging and curing

Ultrasound (US) has been successfully used in meat processing along with aging or curing in the meat processing industry to address several issues through the novel application of mechanical, chemical, and thermal influences on the muscle structure (Barretto et al., 2023). On the other hand, high-intensity ultrasound (HIU) is a nonthermal method that became popular for producing naturally-tasting processed meat products (Son et al., 2024). In this method, sound energy is used lower than microwave frequencies (10 MHz) and higher than the human audible range (>20 kHz) for tenderization of meat and shelf life extension (Alarcon-Rojo et al., 2015). Both low-intensity (20–100 kHz) and high-intensity (>5 W/cm2 or 10–1,000 W/cm^2) are widely employed for processing pork meat (Ashokkumar, 2011). Alternative technologies like HIU have been explored to enhance brining and lower the use of chemical additives/preservatives to maintain meat safety (Delgado-Pando et al., 2021; Singla and Sit, 2021). HIU is appealing since it can especially lower the amount of sodium and phosphates used in cured pig product processing (Zhang et al., 2021) and aids in producing meat products with clean labeling (Al-Hilphy et al., 2020; Rudy et al., 2020).

For a short while, 350–600 MPa of pressure is applied on beef in order to extend its shelf life and ensure microbiological safety. One non-thermal decontamination minimal processing method is high-pressure processing (HPP) (Abera, 2019). Isostatic pressure is applied, and as pressure rises, the product's volume falls. High pressure causes the hydrogen and less strong ionic connections to break, which denatures the protein by changing its quaternary structure and, at higher pressure ranges, its tertiary structure. HPP has very little effect on the meat's nutritional content (Chen et al., 2020). Since covalent bonds are unaffected by pressure, low molecular weight vitamins and flavorings remain intact (Rao et al., 2017). Meat products' ability to be more easily digested may be enhanced by the use of high-pressure treatment. In the muscles treated at 600 MPa, this impact has been more noticeable (Kaur et al., 2016; Xue et al., 2020). Meat protein undergoes modifications when the pressure exceeds 200 MPa. These modifications include gelation, aggregation, and textural changes brought on by the formation and breaking of bonds (Chen et al., 2016). Additionally, the effects change depending on the pressure's application range and timing. When the tertiary and secondary protein structures break down while the fundamental structure remains intact, meat that has been exposed to high pressure tends to adhere to a gel consistency. When pressure is applied, myoglobin's distinctive structure changes and takes on a novel, less soluble protein form that has accumulated (Orlien et al., 2023; Chen et al., 2016). Meat becomes more pliable and hence more tender (Warner et al., 2021). Because high pressure breaks meat's rod-like muscles, HPP tends to tenderize meat, changing its texture (Gómez et al., 2020). HPP causes myofibrillar proteins to unfold, exposing hydrophobic and sulfhydryl groups to the surface. This causes helical structures to unravel and disulfide bonds to form, generating myosin oligomers (Chen et al., 2016). According to Ma et al. (2020), there was a correlation found between oxidized, high pressure (400–600 MPa) beef treated with HPP and browned, and livery tastes. This will affect how consumers and the market respond to the product. The oxidative stress of meat is not immediately affected by HPP (Mia et al., 2023 and 2024). Compared to regular ham samples, the HPP-treated ham samples were softer and had a lighter hue. According to some research, the best conditions for producing ham were HPP at 500 MPa and a gentle heat treatment at 53 °C (Pingen et al., 2016).

Sous Vide and Low-Temperature Long-Time (LTLT)

Meat cooking offers several benefits, the most desired being uniform eating quality, enhanced softness, and regulated doneness. The exact process is responsible for producing more soft meat at the ideal temperature (60 ºC) and time, independent of the animal's age, species, or muscle type, remains to be fully understood. Lowering the LTLT cooking temperature and holding time increases the meat's juiciness, but in a limited temperature range, longer cooking times provide the cooked meat with the taste and fragrance that are sought (Dominguez -Hernandez et al., 2014). Meat cooked at a lower temperature has a medium to lower intensity of taste than meat cooked at a higher temperature. When meat with less connective tissue is cooked at 50–60°C, the degree of tenderization is rather high. However, the lengthy cooking period reduces the forces keeping the myofibrils together in aged meat, causing flesh disintegration upon shearing. Even when the cooking temperature is lower than the temperature at which denaturation occurs, prolonged heating causes the protein to become denatured (Dominguez-Hernandez et al., 2014).

A novel cooking method called sous vide or vacuum cooking is typically employed in the food service industry to create dishes of superior quality (Latoch et al., 2023). Food is vacuum-packed in a heat-stable plastic pouch and then allowed to incubate at low temperatures (53–81ºC) in a water bath under carefully regulated circumstances. A longer cooking time results in a lower cooking temperature being maintained. This method enhances the cooked meat's organoleptic properties while preserving a consistent meat quality. Beef prepared sous vide has a redder and softer texture than beef cooked in a traditional manner. Meat's physicochemical properties and palatability are influenced by cooking time and temperature in a comparable way (Park et al., 2020). These processes culminate in the creation of granular fibers. Higher temperatures during sous vide cooking result in maximal cooking loss and low reheating loss because of the greater shrinkage brought on by the proteins' denaturation (Supaphon et al., 2021). Studies on sous vide cooking have shown that the lack of water causes the meat's surface to become opaquer. Due to a prolonged cooking period that denatures oxymyoglobin and metmyoglobin and increases sulfmyoglobin and metmyoglobin, sous vide cooked beef loses its crimson hue and takes on a brownish red with a hint of green coloration (Faustman et al., 2023). Due to the cooked meat's improved safety and equivalent quality attributes-albeit with less vitamin retention and increased hardness-the high temperature, short time option might be viewed as a more practical and cost-effective procedure. Techniques like marinating can be used with sous vide methods. For example, Gómez et al. (2019) reported on the viability of combining sous vide cooking with marinating procedures to produce novel RTE meat products with high protein content and no undesirable features. This allows for the use of the advantages of two distinct methods without sacrificing the end product's quality.

Meat fermentation

In many parts of the world, fermented pork products are mostly consumed as dry-cured sausages. Meat products with a medium humidity and a long shelf life that are stuffed in casings and spiced with black pepper, paprika, and garlic. They are further cured or ripened to improve the flavor. These meat products are popular across the Mediterranean area. As per Leroy et al. (2023), nitrite therapy before any other treatment is deemed necessary in most European nations. An enzyme called enzyme denatures nitrogen molecules in muscle tissue, giving meat its unique flavor. Meat gets its distinct flavor from the breakdown of proteins in muscles by enzymes like protease, microbial enzymes, and aminopeptidases, which result in tiny peptides and amino acids including alanine, valine, lysine, arginine, leucine, glutamic, and aspartic acid. Certain aroma compounds are created by the secondary oxidation products that result from the lipids' lipolysis and auto-oxidation during the meat's fermentation process.

These compounds include aldehydes, ketones, alcohols, lactones, and esters. Meat proteins have been shown to create bioactive peptides, which increases their suitability for usage as functional additives (Pogorzelska-Nowicka et al., 2022, Mia et al., 2024).

Smoking of meat

As a traditional method of preservation, smoking modifies the sensory and nutritional qualities of meat products by exposing them to smoke. Positive results include lamb meat's improved taste, color, and odor (Suleman et al., 2020). Meat is more susceptible to the effects of smoking the longer it is exposed. There are several forms of smoking treatments, including hot, cold, electrostatic, and the use of condensates, smoke scents, or liquid smoke. When smoking meat cold, it should be done at 20–25º C with a relative humidity of 70–80%, and when smoking it hot, it should be done at 75–80 ºC (Gómez et al., 2020). Staphylococcus aureus, Escherichia coli, Listeria monocytogenes Salmonella spp., and other harmful microbes may be effectively eliminated by the smoke process, which also lessens lipid oxidation, which causes unwanted odors and oxidative rancidity. Smoking helps to lessen the grayish coloring in sausages. Smoking makes it possible to use a variety of meat species to create premium sausages with exquisite flavors (Rahman et al., 2023). Table 1 shows how the sensory and nutritional qualities of beef products are affected by fermentation, smoking, curing and salting, and marinating.

Meat packaging

There are several packaging solutions accessible for meat and meat-related items, including edible coatings, air permeable packaging, vacuum packing, modified environment packaging, active packaging, and smart packaging (Chen et al., 2020). The impact of various packaging examples on the sensory attributes of meat and meat products is compiled in Table 2.

Vacuum packing, modified environment packaging, and air-permeable packaging are the conventional methods of packaging meat and meat products. When compared to vacuum storage, modified environment packing preserves the vivid red color of the meat better (Garcia-Galicia et al., 2020). However, because of the atmosphere's added oxygen concentration, there may be more lipid oxidation. While vacuum packing stops lipid oxidation, which stops bad tastes and odors from developing (Bellés et al., 2017), it turns the meat purple instead of the brilliant red hue that customers associate with fresh meat. Because it has less weight loss and is more aesthetically pleasing than standard vacuum packing, second skin vacuum packaging is therefore thought to be superior to it. Consequently, reducing the adverse quality changes that arise from utilizing these systems individually may be effectively accomplished by combining vacuum packing with changed atmosphere techniques (Łopacka et al., 2016).

Packages with active antioxidant packaging have their oxygen levels regulated. Separate antioxidant devices and packaging materials with integrated antioxidants are the two types of active antioxidant packaging systems. Saccharges, pads, or labels containing oxygen scavengers are examples of stand-alone antioxidant devices. To release antioxidant chemicals into food or absorb unwanted compounds from the headspace, the packing material's walls include the active ingredient (Kuai et al., 2021). One benefit of adding antioxidants to packing materials instead of food directly is that the active ingredient releases slowly. Plant and spice extracts, peptides, essential oils, organic acids, bacteriocins, antibiotics, and silver ions are examples of antimicrobial agents that have been utilized in active antimicrobial packaging (Rajaei et al., 2017; Duran & Kahve, 2020). Recently, there has been increased attention on alternative packaging techniques. Modified environment packaging, vacuum packing, and tray packaging have become popular methods for preserving meat (Wang et al., 2018). There has been a growing interest in active packaging (AP), which could regulate the conditions inside the package including antioxidation, antibacterial properties (Zhang et al., 2020), functional ingredients (Alam et al., 2024a) for consumer health benefits and prolong the duration of food preservation by enhancing food safety without compromising its quality (Song et al., 2020). Edible Films and Coatings: Biopolymers derived from hydrocolloids, including polysaccharides, animal- and plant-derived proteins, are used to make the films. Although the produced films are resistant to gases and moisture, they are not as useful or mechanical as plastic films (McMillin, 2017). Electrospinning could be a promising solution the encapsulate functional ingredients in nanofibers (Alam et al., 2024b; Xu et al., 2024) It is possible to mix edible films and coatings for meat packing with active ingredients that have antibacterial and antioxidant qualities. Natural extracts, natural polymers, essential oils, enzymes, protein hydrolysates, and nanocomponents are among the active ingredients that may be added to edible films (Umaraw et al., 2020). Table 3 illustrates the Impact of adding natural substances on meat quality.

Conclusions

Numerous techniques have been created to produce meat and animal products that are healthier. During meat aging and other processing techniques, it is important to consider how the sensory quality will be altered. To produce goods with an enhanced nutritional profile and the finest sensory quality, it is required to combine several technologies. Nowadays, consumers are searching for sustainably produced goods with little processing. Therefore, this review outlines the aging, curing, and associated processing techniques to combine to achieve the best product to meet consumer demand. Physical processing methods like HIUS are notable because they enable meat products to have a more intense taste and higher level of softness. Sous vide cooking is an interesting physical therapy that effectively preserves nutrients and maintains a high organoleptic quality. Preservation methods drawn from natural sources are distinct in their ability to extend the lifespan of meat products without compromising their taste. By integrating these techniques, the assortment of meat products that are fortified with organic components can be expanded, while ensuring that their nutritional and sensory attributes are maintained or improved for a prolonged duration.

References

Abera G. 2019. Review on high-pressure processing of foods. Cogent Food Agric 5(1): 1568725. https://doi.org/10.1080/23311932.2019.1568725

Alam AMMN, Solberg C, Hashem MA. 2023. Muscle histology and Sensory quality changes during freeze storage of North Atlantic shrimps (Pandulus borealis). Meat Res 3(3). https://doi.org/10.55002/mr.3.3.60

Alam AMMN, Hashem MA, Matar AM, Ali MS, Monti JA, Hossain MJ, Yusuf HM, Mia N. 2024a. Cutting edge technologies for the evaluation of plant-based food and meat quality: A comprehensive review. Meat Res 4(1). https://doi.org/10.55002/mr.4.1.79

Alam AMMN, Kim CJ, Kim SH, Kumari S, Lee EY, Hwang YH, Joo ST. 2024b. Scaffolding fundamentals and recent advances in sustainable scaffolding techniques for cultured meat development. Food Res Int 114549. https://doi.org/10.1016/j.foodres.2024.114549

Alarcon-Rojo AD, Janacua H, Rodriguez JC, Paniwnyk L, Mason TJ. 2015. Power ultrasound in meat processing. Meat Sci 107:86-93. https://doi.org/10.1016/j.meatsci.2015.04.015

Al-Hilphy AR, Al-Temimi AB, Al Rubaiy HHM, Anand U, Delgado-Pando G, Lakhssassi N. 2020. Ultrasound applications in poultry meat processing: A systematic review. J Food Sci, 85:1386-1396. https://doi.org/10.1111/1750-3841.15135

Ashokkumar M. 2011. The characterization of acoustic cavitation bubbles: An overview. Ultrason Sonochem 18:864-872. https://doi.org/10.1016/j.ultsonch.2010.11.016

Barretto TL, Sanches MA, Pateiro M, Lorenzo JM, Telis-Romero J, da Silva Barretto AC. 2023. Recent advances in the application of ultrasound to meat and meat products: Physicochemical and sensory aspects. Food Rev Int 39(7):4529-44. https://doi.org/10.1080/87559129.2022.2028285

Beldarrain LR, Etaio I, Morán L, Sentandreu MA, Barron LJR, Aldai N. 2020. Effect of ageing time on consumer preference and sensory description of foal meat. Food Research International, 129, 108871. https://doi.org/10.1016/j.foodres.2019.108871

Bellés M, Alonso V, Roncalés P, Beltrán J. 2016. A review of fresh lamb chilling and preservation. Small Ruminant Research, 146: 41–47. https://doi.org/10.1016/j.smallrumres.2016.12.003

Beriain MJ, Gómez I, Ibáñez FC, Sarriés MV, Ordóñez AI. 2018. Improvement of the functional and healthy properties of meat products. In Food quality: Balancing health and disease pp. 1-74. Academic Press. https://doi.org/10.1016/B978-0-12-811442-1.00001-8

Chen S, Brahma S, Mackay J, Cao C, Aliakbarian B. 2020. The role of smart packaging system in food supply chain. J Food Sci 85(3):517-25. https://doi.org/10.1111/1750-3841.15046

Chen X, Xu X, Han M, Zhou G, Chen C, Li P. 2016. Conformational changes induced by high-pressure homogenization inhibit myosin filament formation in low ionic strength solutions. Food Res Int 85:1-9. https://doi.org/10.1016/j.foodres.2016.04.011

Das A, Hashem MA, Azad MAK, Rahman MM. 2022. Edible oil marination in broiler meat for short term preservation. Meat Research, 2: 3, Article 22. https://doi.org/10.55002/mr.2.3.22

Dashdorj D, Ochirbat C, Uddin MN, Aguayo D, Lee JS, Kim MJ, Kim YH, Cho SH, Hwang IH. 2017. Quality Characteristics of Dry Aged Biceps Femoris and Longissimus Thorasis Muscles from Hanwoo Beef. In 63rd International Congress of Meat Science and Technology, 2017 Nov 15 (pp. 392-393). Wageningen Academic.

Delgado-Pando G, Ekonomou SI, Stratakos AC, Pintado T. 2021. Clean label alternatives in meat products. Foods 10(7):1615. https://doi.org/10.3390/foods10071615

Domínguez R, Gómez M, Fonseca S, Lorenzo JM. 2014. Effect of different cooking methods on lipid oxidation and formation of volatile compounds in foal meat. Meat Sci 97(2):223-30. https://doi.org/10.1016/j.meatsci.2014.01.023

Duran A, Kahve HI. 2020. The effect of chitosan coating and vacuum packaging on the microbiological and chemical properties of beef. Meat Sci, 162: 107961. https://doi.org/10.1016/j.meatsci.2019.107961

Faustman C, Suman SP, Ramanathan R. 2023. The eating quality of meat: I Color. InLawrie's Meat Sci pp. 363-392. Woodhead Publishing. https://doi.org/10.1016/B978-0-323-85408-5.00023-6

Garcia-Galicia IA, Huerta-Jimenez M, Morales-Piñon C, Diaz-Almanza S, Carrillo-Lopez LM, Reyes-Villagrana R, Estepp C, Alarcon-Rojo AD. 2020. The impact of ultrasound and vacuum pack on quality properties of beef after modified atmosphere on display. J Food Process Eng 43(1): e13044. https://doi.org/10.1111/jfpe.13044

Gómez I, Ibañez FC, Beriain MJ. 2019. Physicochemical and sensory properties of sous vide meat and meat analog products marinated and cooked at different temperature-time combinations. Int J Food Prop 22(1):1693-708. https://doi.org/10.1080/10942912.2019.1666869

Gómez I, Janardhanan R, Ibañez FC, Beriain MJ. 2020. The effects of processing and preservation technologies on meat quality: Sensory and nutritional aspects. Foods, 9 (10): 1416. https://doi.org/10.3390/foods9101416

Ha M, McGilchrist P, Polkinghorne R, Huynh L, Galletly J, Kobayashi K, Nishimura T, Bonney S, Kelman KR, Warner RD. 2019. Effects of different ageing methods on colour, yield, oxidation and sensory qualities of Australian beef loins consumed in Australia and Japan. Food Research International, 125, 108528. https://doi.org/10.1016/j.foodres.2019.108528

Hashem M, Ambia J, Mia N, Ali M, Rahman MM, Ali M. 2024. Detection of adulteration of goat and sheep meat through NIRS and chemometric analysis. Meat Research, 4(2). https://doi.org/10.55002/mr.4.2.86

Hashem MA, Islam MR, Hossain MM, Alam AMMN, Khan M. 2022. Prediction of chevon quality through near infrared spectroscopy and multivariate analyses. Meat Res 2(6). https://doi.org/10.55002/mr.2.6.37

Hossain MJ, Alam AN, Lee EY, Hwang YH, Joo ST. 2024. Umami Characteristics and Taste Improvement Mechanism of Meat. Food Sci Anim Resour 44(3):515-532. https://doi.org/10.5851/kosfa.2024.e29.

Hwang SI, Hong GP. 2020. Effects of high pressure in combination with the type of aging on the eating quality and biochemical changes in pork loin. Meat Sci, 162:108028. https://doi.org/10.1016/j.meatsci.2019.108028

Islam A, Sadakuzzaman M, Hossain MA, Hossain MM, Hashem MA. 2019. Effect of gamma irradiation on shelf life and quality of indigenous chicken meat. Journal of Bangladesh Agricultural University, 17(4): 560-566.

Kaur L, Astruc TT, Venien AA, Loison O, Cui J, Irastorza M, Boland M. 2016. High pressure processing of meat: effects on ultrastructure and protein digestibility. Food & Function, 7(5), 2389–2397. https://doi.org/10.1039/c5fo01496d

Kemp CM, Sensky PL, Bardsley RG, Buttery PJ, Parr T. 2010. Tenderness–An enzymatic view. Meat Sci 84(2):248-56. https://doi.org/10.1016/j.meatsci.2009.06.008

Kim TK, Yong HI, Jang HW, Lee H, Kim YB, Jeon KH, Choi YS. 2019. Quality of sliced cured pork loin with spinach: Effect of incubation period with starter culture. J Food Qual (1):6373671. https://doi.org/10.1155/2019/6373671

Kim YH, Kemp R, Samuelsson LM. 2016. Effects of dry-aging on meat quality attributes and metabolite profiles of beef loins. Meat Sci 111:168-76. https://doi.org/10.1016/j.meatsci.2015.09.008

Kim YH, Ma D, Setyabrata D, Farouk MM, Lonergan SM, Huff-Lonergan E, Hunt MC. 2018. Understanding postmortem biochemical processes and post-harvest aging factors to develop novel smart-aging strategies. Meat Sci 144:74-90. https://doi.org/10.1016/j.meatsci.2018.04.031

Kuai L, Liu F, Chiou BS, Avena-Bustillos RJ, McHugh TH, Zhong F. 2021.Controlled release of antioxidants from active food packaging: A review. Food Hydrocoll 120:106992. https://doi.org/10.1016/j.foodhyd.2021.106992

Latoch A, Głuchowski A, Czarniecka-Skubina E. 2023. Sous-vide as an alternative method of cooking to improve the quality of meat: a review. Foods 12(16): 3110. https://doi.org/10.3390/foods12163110

Lee S, Jo K, Choi YS, Jung S. 2024. Production of freeze-dried beef powder for complementary food: Effect of temperature control in retaining protein digestibility. Food Chem 433:137419. https://doi.org/10.1016/j.foodchem.2023.137419

Lepper-Blilie AN, Berg EP, Buchanan DS, Berg PT. 2016. Effects of post-mortem aging time and type of aging on palatability of low marbled beef loins. Meat Sci 112:63-8. https://doi.org/10.1016/j.meatsci.2015.10.017

Leroy F, Charmpi C, De Vuyst L. 2023. Meat fermentation at a crossroads: where the age-old interplay of human, animal, and microbial diversity and contemporary markets meet. FEMS Microbiol Rev 47(2): fuad016. https://doi.org/10.1093/femsre/fuad016

Łopacka J, Półtorak A, Wierzbicka A. 2016. Effect of MAP, vacuum skin-pack and combined packaging methods on physicochemical properties of beef steaks stored up to 12 days. Meat Sci 119:147-53. https://doi.org/10.1016/j.meatsci.2016.04.034

Ma Q, Hamid N, Oey I, Kantono K, Farouk M. 2020. The impact of High-Pressure Processing on physicochemical properties and sensory characteristics of three different lamb meat cuts. Molecules, 25(11), 2665. https://doi.org/10.3390/molecules25112665

McMillin KW. 2017. Advancements in meat packaging. Meat Sci 132:153-62. https://doi.org/10.1016/j.meatsci.2017.04.015

Mia N, Alam AMMN, Rahman MM, Ali MS, Hashem MA. 2024. Probiotics to enhance animal production performance and meat quality: A review. Meat Research. 4 (2): Article No. 85.

Mia N, Rahman MM, Hashem MA. 2023. Effect of heat stress on meat quality: A review. Meat Res 3(6). https://doi.org/10.55002/mr.3.6.73

Mungure TE, Farouk MM, Birch EJ, Carne A, Staincliffe M, Stewart I, Bekhit AE. 2020. Effect of PEF treatment on meat quality attributes, ultrastructure and metabolite profiles of wet and dry aged venison Longissimus dorsi muscle. Innov Food Sci Emerg Technol 65:102457. https://doi.org/10.1016/j.ifset.2020.102457

Orlien V, Aalaei K, Poojary MM, Nielsen DS, Ahrné L, Carrascal JR. 2023. Effect of processing on in vitro digestibility (IVPD) of food proteins. Crit Rev Food Sci Nutr 63(16):2790-839. https://doi.org/10.1080/10408398.2021.1980763

Park CH, Lee B, Oh E, Kim YS, Choi YM. 2020. Combined effects of sous-vide cooking conditions on meat and sensory quality characteristics of chicken breast meat. Poult Sci 99(6):3286-91. https://doi.org/10.1016/j.psj.2020.03.004

Pingen S, Sudhaus N, Becker A, Krischek C, Klein G. 2016. High pressure as an alternative processing step for ham production. Meat Sci, 118: 22-7. https://doi.org/10.1016/j.meatsci.2016.03.014

Pogorzelska-Nowicka E, Górska-Horczyczak E, Hanula M, Marcinkowska-Lesiak M, Pogorzelski G, Wierzbicka A, Półtorak A. 2022. Sage extracts obtained with cold plasma improves beef quality. Meat Sci 194:108988. https://doi.org/10.1016/j.meatsci.2022.108988

Rahman MM, Hashem MA, Azad MAK, Choudhury MSH, Bhuiyan MKJ. 2023. Techniques of meat preservation-A review. Meat Research, 3(3).

Rai D, Adelman AS, Zhuang W, Rai GP, Boettcher J, Lönnerdal B. 2014. Longitudinal changes in lactoferrin concentrations in human milk: a global systematic review. Crit Rev Food Sci Nutr 54(12):1539-47.

Rajaei A, Hadian M, Mohsenifar A, Rahmani-Cherati T, Tabatabaei M. 2017. A coating based on clove essential oils encapsulated by chitosan-myristic acid nanogel efficiently enhanced the shelf-life of beef cutlets. Food Packaging Shelf 14:137-45. https://doi.org/10.1016/j.fpsl.2017.10.005

Rao PS, Srikanth D, Mahesh Reddy PV, Abhilesh B, Naik KM. 2017. High Pressure Processing Technology in Fruits & Vegetables Processing Industry – A Review. International Journal of Engineering Research & Technology, 6 (8): 151-156.

Ribeiro FA, Lau SK, Furbeck RA, Herrera NJ, Henriott ML, Bland NA, Fernando SC, Subbiah J, Pflanzer SB, Dinh TT, Miller RK. 2024. Effects of relative humidity on dry-aged beef quality. Meat Sci 109498. https://doi.org/10.1016/j.meatsci.2024.109498

Rudy M, Kucharyk S, Duma-Kocan P, Stanisławczyk R, Gil M. 2020. Unconventional methods of preserving meat products and their impact on health and the environment. Sustainability 12(15):5948. https://doi.org/10.3390/su12155948

Savell JW. 2008. Dry-aging of beef: Executive Summary. Center for Research and Knowledge Management. National Cattlemen’s Beef Association. Texas, Estados Unidos. USA.

Sharker B, Mia N, Ali MS, Hashem MA, Rahman MM, Khan M. 2024. Effect of freezing period on the quality of doe liver. Meat Research, 4(2). https://doi.org/10.55002/mr.4.2.90

Singla M, Sit N. 2021. Application of ultrasound in combination with other technologies in food processing: A review. Ultrason Sonochem 73: 105506. https://doi.org/10.1016/j.ultsonch.2021.105506

Smith AM, Harris KB, Griffin DB, Miller RK, Kerth CR, Savell JW. 2014. Retail yields and palatability evaluations of individual muscles from wet-aged and dry-aged beef ribeyes and top sirloin butts that were merchandised innovatively. Meat Sci 97(1):21-6. https://doi.org/10.1016/j.meatsci.2013.12.013

Son YM, Lee EY, Alam AN, Samad A, Hossain MJ, Hwang YH, Seo JK, Kim CB, Choi JH, Joo ST. 2024. The Application of High-Intensity Ultrasound on Wet-Dry Combined Aged Pork Loin Induces Physicochemical and Oxidative Alterations. Food Sci Anim Res 44(4):899. https://doi.org/10.5851/kosfa.2024.e26

Song W, Du Y, Yang C, Li L, Wang S, Liu Y, Wang W. 2020. Development of PVA/EVA-based bilayer active film and its application to mutton. LWT 133:110109. https://doi.org/10.1016/j.lwt. 2020.110109.

Stenström H, Li X, Hunt MC, Lundström K. 2014. Consumer preference and effect of correct or misleading information after ageing beef longissimus muscle using vacuum, dry ageing, or a dry ageing bag. Meat Sci 96(2): 661-6. https://doi.org/10.1016/j.meatsci.2013.10.022

Suleman R, Wang Z, Aadil RM, Hui T, Hopkins DL, Zhang D. 2020. Effect of cooking on the nutritive quality, sensory properties and safety of lamb meat: Current challenges and future prospects. Meat Sci 167:108172. https://doi.org/10.1016/j.meatsci.2020.108172

Supaphon P, Kerdpiboon S, Vénien A, Loison O, Sicard J, Rouel J, Astruc T. 2021. Structural changes in local Thai beef during sous-vide cooking. Meat Sci 175:108442. https://doi.org/10.1016/j.meatsci.2021.108442

Sun MA, Hossain MA, Islam T, Rahman MM. Hossain MM, Hashem MA. 2020. Different body measurement and body weight prediction of Jamuna basin sheep in Bangladesh. SAARC J. Agric, 18 (1): 183-196.

Temporelli PL. 2023. Cardiovascular prevention: Mediterranean or low-fat diet? Eur Heart J Suppl 25 (Supplement_B): B166-70. https://doi.org/10.1093/eurheartjsupp/suad097

Terjung N, Witte F, Heinz V. 2021. The dry aged beef paradox: Why dry aging is sometimes not better than wet aging. Meat Sci, 172: 108355. https://doi.org/10.1016/j.meatsci.2020.108355

Umaraw P, Munekata PE, Verma AK, Barba FJ, Singh VP, Kumar P, Lorenzo JM. 2020. Edible films/coating with tailored properties for active packaging of meat, fish and derived products. Trends Food Sci Technol 98:10-24. https://doi.org/10.1016/j.tifs.2020.01.032

Wang HH, Chen J, Bai J, Lai J. 2018. Meat packaging, preservation, and marketing implications: Consumer preferences in an emerging economy. Meat Sci 145:300-7.https://doi.org/10. 1016/j.meatsci.2018.06.022.

Warner R, Miller R, Ha M, Wheeler TL, Dunshea F, Li X, Vaskoska R, Purslow P, Wheeler T. 2021. Meat tenderness: Underlying mechanisms, instrumental measurement, and sensory assessment. Meat Muscle Biol 8;4(2). https://doi.org/10.22175/mmb.10489

Warner RD. 2023. The eating quality of meat: IV—Water holding capacity and juiciness. In Lawrie's Meat Sci pp. 457-508). Woodhead Publishing. https://doi.org/10.1016/B978-0-323-85408-5.00008-X

Xu M, Wu L, Wang C, Saldaña MD, Sun W. 2024. “Sandwich” Structure (PLA/Thymol Fibre Membranes/SAP/Paper Fibre) Antibacterial Pad for Preservation of Chilled Mutton. Packag Technol Sci. https://doi.org/10.1002/pts.2830

Xue S, Wang C, Kim YHB, Bian G, Han M, Xu X, Zhou G. 2020. Application of high-pressure treatment improves the in vitro protein digestibility of gel-based meat product. Food Chemistry, 306, 125602. https://doi.org/10.1016/j.foodchem.2019.125602

Zhang C, Li Y, Wang P, Zhang H. 2020. Electrospinning of nanofibers: Potentials and perspectives for active food packaging. Compr Rev Food Sci Food Saf (2):479-502.https://doi.org/10.1111/1541-4337.12536.

Zhang F, Zhao H, Cao C, Kong B, Xia X, Liu Q. 2021. Application of temperature-controlled ultrasound treatment and its potential to reduce phosphate content in frankfurter-type sausages by 50%. Ultrason Sonochem 71: 105379. https://doi.org/10.1016/j.ultsonch.2020.105379