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Review Article

Enhancing meat quality through marination: principle, ingredients and effects

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Abstract

Marinating meat is a popular technique that involves injecting, immersion, or tumbling a mixture of salt, spices, acid, or alkaline ingredients into the muscle to enhance its tenderness, juiciness, and flavor. Marination can enhance not only sensory properties but also functional attributes such as cooking loss and water-holding capacity. Additionally, depending on the additives, marinades also can exhibit antioxidant and antimicrobial properties. For this purpose, various ingredients such as salt, phosphate salts, sugar, fruit juices and/or extracts, fermented dairy products, oils, and spices have been used in marinade formulations to improve the quality characteristics and shelf life of meat. Marination helps in protein coagulation and moisture retention during cooking, thereby enhancing meat's binding capabilities and slicing qualities. Due to the physical and chemical reactions, marinating meat before cooking can reduce the formation of heterocyclic amines and biogenic amines. In this review, the basic principles of the marination process and certain effects on different kinds of meat were discussed.

Keywords

marination, meat, tenderness, meat quality, sensory, toxicity

Abbreviations

WHC – water holding capacity; TBARS – 2-thiobarbituric acid reactive substances; HCAs – heterocyclic amines

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Introduction

Marination is a process for enhancing the functional and sensory properties of meat through methods such as soaking, injecting, or tumbling with acidic or alkaline solutions (Vlahova-Vangelova and Dragoev 2014; Ehsanur Rahman et al. 2023). Marination can be applied to the muscles of animals such as pork (Jeong et al. 2020; Mantzourani et al. 2023), beef (Önenç et al. 2004; Çarbuğa 2019; Şengün et al. 2021), chicken (Vlahova-Vangelova et al. 2016; Ünal et al. 2020; Dilek et al. 2023), turkey (Bouacida et al. 2020; Serdaroğlu et al. 2023) and horse (Vlahova-Vangelova et al. 2014). The process improves meat tenderness, juiciness, flavor, and water-holding capacity (WHC) and extends meat's shelf life (Latoch et al. 2023). It is particularly effective in enhancing the tenderness and juiciness of tough muscles, such as turkey and chicken breast muscles. In addition, the marination technique is applied to increase the tenderness of DFD meats, which also exhibit texture problems (Dragoev et al. 2018). The main principle of marination is changing the pH of the tissue by incorporating acidic or alkaline solutions into the product (Alvarado and MacKee 2007; Xiong 2004; Fadıloğlu and Serdaroğlu 2018; Serdaroğlu et al. 2023). Acidic marination is commonly used traditionally; traditional marinade solutions contain salt, oil, water, and various acidic components, such as wine, vinegar, and fruit juice (Serdaroğlu et al. 2023). The selection of marinade ingredients, including the type and concentration of acidic components, spices, and seasonings, can be strategically adjusted to achieve desired outcomes. Alkaline marinades consist of a salt-phosphate mixture, whereas acid marinades incorporate weak organic acids or their salts (Xiong 2004; Latoch 2023). In the marination process, emulsions prepared with salt, sugar, citric acid, or acetic acid can also be used as a marinade solution (Vlahova-Vangelova and Dragoev 2014). In meats marinated with acidic or alkaline solutions, when the pH moves further away from the isoelectric point, the space between the myofilaments and the areas where water is retained increases (Önenç et al. 2004). This change essentially illustrates the underlying principle of the marination process. Depending on the marinade formulation, the process can have effects not only on texture and juiciness but also exhibit antioxidant and antimicrobial properties (Latoch et al. 2023; Serdaroğlu et al. 2023).

Marinating meat is performed through diverse techniques, including dipping (soaking), tumbling, and injecting into the product (Alvarado and McKee 2007; Ehsanur Rahman et al. 2023). The duration of marination and the quantity of absorbed marinade vary in each of these marination methods (Ehsanur Rahman et al. 2023). The assessment of marinating performance typically involves various metrics, such as marinade absorption and retention (Yusop et al. 2011). This review critically examines the marination ingredients, methods, and the effects of marination on meat quality.

Marination Ingredients

Understanding how different marinades affect meat structure can improve meat quality by enhancing tenderness, flavor, and juiciness (Gómez et al. 2020). Researchers analyze changes in meat tissue structure post-marination to comprehend how marinades impact muscle fiber and protein breakdown, aiding tenderization (Ünal et al. 2022; Dilek et al. 2023). This insight assists both the meat industry and consumers in selecting appropriate marinades for desired sensory attributes. Additionally, studying marinade effects on meat structure can inform food safety practices. Different types of marinades for marinating meats are shown in Fig. 1. The highly used chemical marinades in the meat industry are organic acids, soy sauce, sodium chloride (NaCl), sodium biphosphate ($NaHCO_3$), sodium triphosphate, phosphates, calcium chloride ($CaCl_2$), ammonium hydroxide (NH_4OH), and wine (Ehsanur Rahman et al. 2023).

Especially in alkaline marinades, sodium chloride is used at rates of 1-1.5%. Salt increases marinade pick-up by increasing the space between the thick and thin filaments. In alkaline marinade formulations, the use of salt alongside phosphates generally enhances the effect of the phosphates (Alvarado and McKee 2007).

Oil in marinades helps tenderize the meat, enhancing flavor, and retaining moisture. Oils assist in transferring fat-soluble flavors from seasonings onto the meat surface, contributing to the overall flavor profile of marinated meat (Ehsanur Rahman et al. 2023). Additionally, oil can mitigate the ill effects of acid inclusion, dissolve the aromas of

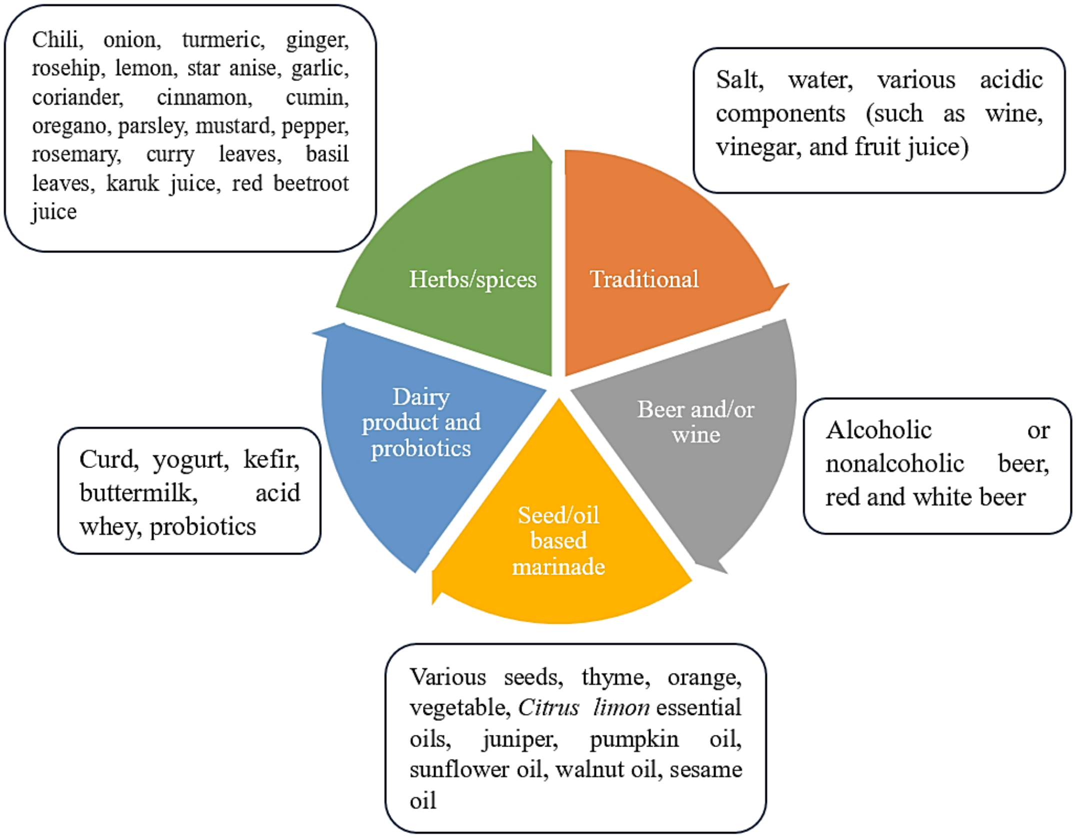

Figure 1. Different types of marinades are utilized in meats (Compiled by Ehsanur Rahman et al. 2023 and Latoch et al. 2023)

added spices, and seal in moisture, preventing the meat from drying out during cooking (Shtonda and Semeniuk 2021).

The impact of marination on meat is primarily linked to the influence of acids on collagen connective tissue, which significantly contributes to beef tenderness (Chang et al. 2010; Fadıloğlu and Serdaroğlu 2018). Studies have indicated that acid-sensitive cross-linkages within the collagen molecule are released, leading to a relaxation in the structure (Toldrá and Mora 2022).

Organic acids in acidic marinades denature proteins by disrupting hydrogen bonds in collagen fibrils (Chang et al. 2010), facilitating tissue breakdown and enhancing moisture absorption, leading to a juicier end product. Furthermore, these marinades can reduce the pH of meat, leading to the solubilization of myosin and actin. This process results in the dissociation of actomyosin and the depolymerization of filaments (Latoch et al. 2023). This process tenderizes the meat and improves its texture (Ünal et al. 2020). Therefore, the mechanism of acidic marination involves protein denaturation, tissue breakdown, and myosin and actin solubilization, ultimately resulting in meat tenderization.

Sodium bicarbonate, sodium tripolyphosphates, and sodium chloride are generally used in alkaline marinades (Santos et al. 2012). One important characteristic of alkaline marinades is their ability to move meat pH away from the isoelectric range, thus increasing the proportion of negative charges on the meat proteins and improving tenderness and water-holding capacity (Alvarado and Mckee 2007; Fadıloğlu and Serdaroğlu 2018). In alkaline marination, the degree of enhancement in meat quality depends on the type of phosphates used, given the variations in their solubility and impact on pH and WHC (Ehsanur Rahman et al. 2023). Generally, short-chain phosphates like orthophosphates and pyrophosphates exhibit superior buffering capacity, while longer chain phosphates have a lower buffering capacity (Kim et al. 2009). For instance, while both types facilitate myofibril swelling and myosin extraction, pyrophosphates, being a more soluble form of diphosphates, are consequently more convenient to use (Alvarado and McKee 2007; Ehsanur Rahman et al. 2023). Phosphate concentration equal to or exceeding 0.3% is thought to influence muscle proteins by elevating pH and ionic strength. Additionally, it is believed to interact specifically with protein-bound Mg^{2+} and Ca^{2+}, leading to the formation of complexes. This interaction ultimately enhances the solubilization of myosin and actin, resulting in the dissociation of actomyosin and the depolymerization of thick and thin filaments (Xiong 2004; Shi et al. 2022). The inclusion of phosphate salts, especially pyrophosphate and tripolyphosphate, enhances the WHC of meat, improves texture, increases product yield, and decreases cooking losses (Glorieux et al. 2017). During the marination process, it is believed that meat absorbs the solution within the gaps between the thick and thin filaments of the myofibrils (Mazaheri Kalahrodi et al. 2021). Consequently, any factor influencing the spacing between these filaments will impact the absorption and retention of the marinade. (Xu et al. 2019).

Marination Methods

The absorption of marinade varies depending on the marination method as well as the marinade formulation (Gamage et al. 2017). Immersion, injection, and vacuum tumbling are the three procedures used for the marination process (Alvarado and McKee 2007; Saygun and Tokur 2021; Ehsanur Rahman et al. 2023). Immersion entails soaking meat in marinade, allowing gradual absorption. However, it's deemed unreliable due to inconsistent ingredient distribution and heightened bacterial contamination risk (Oyetunji 2009). Moreover, it's impractical with extended processing times and limited marinade absorption (Xargayó et al. 2001; Gamage et al. 2017). The multi-needle injection is the most popular method of marinating as it enables precise dosing and ensures consistency. Multi-needle injection marination is likely the most commonly employed technique as it is consistent in products without the time-consuming immersion process (Harikedua 2016). To administer the marinade, needles or probes are inserted, and as the probes or needles are withdrawn, the marinade is evenly distributed throughout the piece (Yusop et al. 2011).

The injection pressure has significant effects on cook loss and overall yield, with Warner-Bratzler shear showing interaction. The technique of needle injection followed by tumbling (staged-marination) results in the highest yields, making it a favorable option for achieving high cook yields. Although the addition of vacuum tumbling increases overall yield compared to injection-only at 345 kPa, it does not significantly impact tenderness (Detienne et al. 2003).

Vacuum tumbling is a technique for mostly marinating poultry meat to produce a value-added, ready-to-cook product. Protein exudates are extracted during tumbling and massaging, primarily the salt-soluble proteins actin and myosin, which aid in particle cohesion during thermal processing (Serdaroğlu and Öztürk-Kerimoğlu 2023). Products produced by tumbling have enhanced juiciness and slicing qualities. Furthermore, factors such as marination time, temperature, and the use of vacuum or mechanical techniques can maximize the effects of marination on meat quality (Detienne et al. 2003; Alvarado and McKee 2007). Ultrasonication and vacuum impregnation (VI) can also affect marinade absorption positively due to inducing cavities in the structure and forced migration of the marinade. For instance, marinade uptake improves sensory attributes in combination with other technologies, including sous-vide (Latoch 2020), ultrasounds (Xiong et al. 2020), and high hydrostatic and hydrodynamic pressure (Bowker et al. 2010; O'Neill et al. 2019). Furthermore, in conjunction with the marination process, additional techniques for food preservation can be integrated, with some of these methods enhancing the absorption of marinades. It's important to note that the marination process should be carefully timed. Over-marinating can result in a mushy texture and an overpowering flavor while under-marinating may not produce the desired tenderness and juiciness (Ehsanur Rahman et al. 2023; Latoch 2023).

Certain effects of Marinating

The specific effects of marination on different types of meat have been examined under separate headings, including textural properties, antioxidant and antimicrobial effects, techno-functional properties (such as water holding capacity and cooking yield), sensory properties, and toxicity (Fig. 2). Additionally, recent studies related to marinating various types of meat are summarized in Table 1.

Textural Properties

Understanding and addressing meat tenderness is crucial for the meat industry. Meat texture encompasses its physical characteristics, such as tenderness, juiciness, and mouthfeel. The texture of meat is attributed to the muscle fibers, whereas the connective tissue is responsible for holding these fibers together (Listrat et al. 2020). It requires a multidisciplinary approach involving animal breeding, processing techniques, and culinary science (Listrat et al. 2020; Santos et al. 2020). Meat tenderness is defined as the difficulty or ease with which the meat can be cut or chewed (Xargayó et al. 2021; Kataria and Morey 2020). From a scientific standpoint, meat tenderness is influenced by several factors. Animal's age, diet, and genetics, the

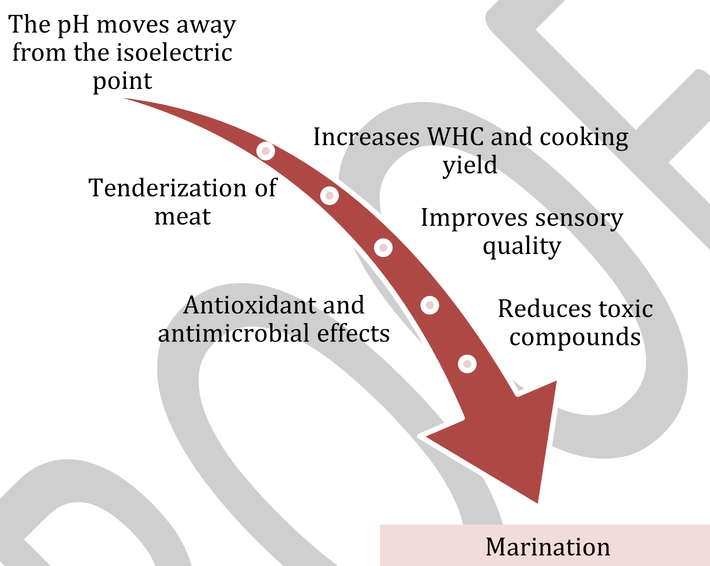

Figure 2. Certain effects of marination

composition and structure of muscle fibers, collagen content, and intramuscular fat distribution as well as the way it is handled and processed contribute to the physical properties (Ma and Kim 2020; Toldrá and Mora 2022). Different mechanisms aimed at tenderization include the type and quantity of collagen degrading (Veiseth et al. 2004), decreasing the diameter of muscle fiber bundles (Renand et al. 2001), altering sarcomere length during rigor mortis and the chemical and structural changes that occur with tenderizing (Lomiwes et al. 2013). Through an understanding of these molecular mechanisms, scientists have developed techniques to enhance meat tenderness. Tenderizing meat is a process that aims to enhance the texture and tenderness of the meat by breaking down the tough connective tissues and collagen found in muscle fibers (Bhat et al. 2018; Toldrá and Mora 2022). Various methods have been employed to enhance meat tenderness, with marination deemed suitable for its ability to improve palatability and the water-holding capacity of meats. In acidic marination, tenderness increases as a result of the swelling of myofibrils with the decrease in pH (Ke et al. 2009; Serdaroğlu et al. 2007; Serdaroğlu et al. 2023). Tenderness may be affected by marinating in different ways; pH-induced swelling of connective tissue and/or muscle fibers, increased proteolysis caused by cathepsins, and increased conversion of collagen to gelatin at a low pH during cooking (Önenç et al. 2004; Gómez et al. 2020). Lowering the pH by placing the meat in a marinade can significantly increase the activity of cathepsins, for which the optimal pH is in the range of 3.5-5.0, which can also be observed in studies by Żochowska-Kujawska et al. (2012).

Table 1. Recent studies related to the utilization of various marinades in different kinds of meat

Type of meat	Purpose	Marinade	Findings	Reference
Beef	Determination of heterocyclic amine content	Blueberry, raspberry, and strawberry juice (1:1, meat: marinade)	-The formation of HCAs decreased, particularly with marinade times of at least 6 h, with a 40-100% reduction	(Khan et al. 2021)
	Determination of texture and quality parameters	Pineapple waste enriched with bromelain (10-20 mg tyrosine, 100 g^{-1} meat)	- Marinades and concentration of bromelain reduced pH and hardness - Marination yield increased - L* values increased	(Santos et al. 2020)
	Investigation of antioxidant activity, total phenolic content, and color	Marinade (tarhun, 3% sunflower oil, 1% salt) at different concentrations (5-15%)	- Moisture content increased - Peroxide values decreased - Cooking loss decreased - The amount of soluble dry matter increased with increasing marination concentration	(Çağlar 2021)
	Improving the safety and sensory quality	Koruk (12.5 ml koruk juice, 25 ml water), onion juice (11.5 ml onion juice, 25 ml water), and probiotics (*Lactobacillus acidophilus*, *Lactobacillus casei*, *Lactobacillus rhamnosus* or their combination)	- The numbers of *Escherichia coli* O157: H7, *L. monocytogenes* and *S. typhimurium* (≅6 log $CFU.g^{-1}$) decreased - Samples containing *L. casei* had higher sensory scores	(Gargı and Şengün 2021)
	Evaluation of the effects of organic fruit vinegars on safety and quality	50 ml vinegar, 25 ml water, 25 ml olive oil, 1 g salt, 0.1 g black pepper, 2 bay leaves	-Rosehip vinegar was the most effective against all pathogens -Marination with rosehip vinegar had the lowest hardness value	(Şengün et al. 2021)
	Effects on heterocyclic amine and quality	Apple, pomegranate, grape, and balsamic vinegar (200 ml)	-Springiness decreased with the utilization of balsamic and grape vinegar - Total HCA content decreased with balsamic and apple vinegar	(Fencioğlu 2021)

	Investigation of onion juice with ultrasonic bath and vacuum impregnation techniques	Onion juice (1: 5, meat: marinade)	- Ultrasonic bath and VI pretreatments significantly improved the marinade uptake - Hardness values decreased - Lipid oxidation reduced	(Demir et al. 2022)
	Effects on the nutritional, textural, and sensory attributes	Aromatic herbs (rosemary, thyme, oregano, mountain thyme, basil, and ginger) and cold-pressed oils (olive oil, pumpkin oil, sunflower oil, walnut oil, and sesame oil)	- Hardness, chewiness, and gumminess decreased, resilience, and cohesiveness increased - Samples marinated with olive oil and rosemary had the highest hedonic score	(Vişan et al. 2021)
Camel	Effects on physicochemical characteristics	30% ginger extract with 0.5%, 1%, and 1.5% citric acid	- Tenderness, juiciness, flavor, and odor increased - Marinade uptake, Warner Bratzler Shear Force, L* and a* values decreased, pH, tenderness, and b* value increased with ginger extract and citric acid	(Moeini et al. 2022)
	Inactivation on *Listeria monocytogenes*, *Salmonella spp.*, and *Escherichia coli* O157:H7	1.9 g salt, 0.7 g black pepper, 1.5 g paprika, 14.0 g onion, 4.0 g tomato, 4.0 g olive oil, 4.0 g vinegar, 20.0 g full-fat yogurt, 1.6 g kiwi (52 g.100 g^{-1}, marinade/ meat)	-Marinade with essential oil components (thymol, carvacrol, and cinnamaldehyde) *E. coli* O157:H7 and *Salmonella spp.* reduced	(Osaili et al. 2021)
Pork	Effects on meat quality and biogenic amines formation	1.43% (v/w) black currant juice	-pH and volatile basic nitrogen reduced with black currant juice -Bacterial spoilage and the formation of biogenic amines inhibited	(Cho et al. 2021)
	Effect on the texture and color	Kefir, yogurt, and buttermilk (marinade at a rate of 10% by meat mass)	-Tenderness increased, hardness and chewiness decreased -Thermal stability increased	(Latoch 2020)

	Determination of physicochemical and textural effects	*Sigumjang* (1: 1, meat: marinade)	-Free amino acids increased -Cooking loss decreased -Sensory properties improved	(Jeong et al. 2020)
	Evaluation of microbial stability and sensory properties	Wine-based marinades with ethanol pomegranate extract and oregano essential oil (3:1, meat: marinade)	-*Enterobacteriaceae*, Total mesophilic bacteria, yeasts/molds, *Staphylococcus spp.*, *Pseudomonas spp.*, and LAB inhibited	(Mantzourani et al. 2023)
Turkey	Evaluation of microbiological, physicochemical, color, and sensorial characteristics	*Eruca vesicaria* extract (200, 600, 800 et 1000 ppm)	-Consumer acceptance improved -Water holding capacity increased -Coliforms, total aerobic mesophilic flora, psychotropic flora, *Staphylococcus* flora, and yeast and molds inhibited	(Bouacida et al. 2020)
	Investigation of technological properties and microbiological quality	Buttermilk, acid whey, and lemon juice (1:2, meat: marinade)	-Samples containing buttermilk and whey had higher b* values -The number of mesophilic aerobic bacteria, *Pseudomonas spp.* and *Enterobacteriaceae* reduced with buttermilk and whey	(Augustýnska-Prejsnar et al. 2021)
	Effects on lipid oxidation and color parameters	Rosehip powder at different concentrations (6.67%, 10%, and 13.33%; 1:1 meat: marinade)	-Rosehip marination caused significant changes in the color parameters -Marinating with rosehip tea led to a significant reduction in TBARS values	(Serdaroğlu et al. 2023)
Goat	Improving the quality characteristics	Plant juices (ginger and pineapple) and sodium bicarbonate (0, 1, 3, 5%), 4:1 (meat: plant juice)	- Shear force decreased with plant juice -Samples marinated with pineapple juice had a higher cooking loss	(Kaewthong et al. 2021)

Chicken	Investigation of physical quality	Sweet basil (*Ocimum basilicum*) marinade (0, 3, 6, 9%)	- pH increased - Tenderness increased in samples containing 6% and 9% marinade	(Patriani et al. 2021)
	Effects on sensory, textural, and microstructural characteristics	Citric acid 0.5%, lemon, and grapefruit juice (150: 250 w/ v meat: marinade)	- Water holding capacity and marinade absorption increased, cooking loss and pH decreased - L*, b* and chroma values increased - Sensory properties improved	(Ünal et al. 2022)
	Effects on technological, textural, microstructural, and sensory properties	Aronia vinegar, Grape vinegar, or hawthorn vinegar (160 ml), 160 ml water, 80 ml olive oil, 4 g salt, 0.3 g black pepper	- Samples formulated with grape vinegar had the lowest hardness and chewiness - Samples marinated with vinegars had higher texture scores - Aronia and hawthorn vinegars decreased cooking loss	(Dilek et al. 2023)
	Investigation of curing efficiency	6% salt (A), 6% salt+2% sodium bicarbonate	- Curing rate, tenderness, and water holding capacity improved with ultrasound-assisted $NaHCO_3$	(Xiong et al. 2020)
	Effect on *Salmonella enterica* inactivation	Lemon juice, lemon juice + 0.5% yucca extract, or lemon juice + 0.5% yucca extract + thyme oil (0.5% or 1%), (2:1, marinade: meat)	- Lemon juice and utilization with yucca extract reduced *S. enterica* - The death rate of *S. enterica* increased in samples with thyme oil (0.5% or 1%) compared to samples with lemon juice + yucca extract	(Kiprotich et al. 2021)
	Improvement of the technological and sensory properties	50% whey water solution with addition of 2% NaCl	- Tenderness improved with marinade solution containing 50: 50 water and whey, and 2% salt - The best sensory properties (aroma and flavor) were obtained after marinating with whey and 2% NaCl for 12 h	(Vlahova-Vangelova et al. 2016)

Marination can increase proteolysis activity in several ways. One of the ways is enzymatic action. Marinating meat in acidic marinades such as vinegar or citrus juices may activate enzymes present in the meat that help to break down proteins (Ertbjerg et al. 1999). These enzymes include proteases, which are responsible for the breakdown of proteins and can increase proteolytic activity. The second way is mechanical action. When meat is marinated, the acidic marinade penetrates the surface of the meat and creates small pockets or channels (Rostamani et al. 2021; Ehsanur Rahman et al. 2023). This allows proteolytic enzymes to more easily access the myofibrillar proteins, enhancing proteolysis. Another factor that increases proteolytic activity in marination is temperature (Ehsanur Rahman et al. 2023). Marinating meat in acidic marinades can cause a chemical reaction that increases the meat temperature. This can also help to accelerate proteolysis. Overall, marination can help to increase proteolytic activity and make meat more tender by breaking down proteins into smaller, more easily digestible molecules (Bhat et al. 2018). The relationship between the chemical composition of the marinade solution used and the improved texture of the muscle structure is apparent.

Various marinade solutions (tropical fruits such as papaya, kiwi, and pineapple by-products, grape juice, lemon, lime, onion juice, olive oil, rosemary, thyme, basil, ginger, pumpkin, sunflower, walnut, and sesame oil) were used for marinating beef along with different technologies (Çarbuğa 2019; Çelik 2019; Santos et al. 2020; Vişan et al. 2021). Several studies have explored the impact of various marinades on texture, using ingredients like lemon juice and ginger extract (Kumar et al. 2017), pineapple juice (Kadıoğlu 2019), potassium alginate (Shi et al. 2020), sweet basil extract (Patriani et al. 2021), and combinations like citric acid, lemon juice, and grapefruit juice (Ünal et al. 2022), as well as aronia, grape, and hawthorn vinegar (Dilek et al. 2023). These studies generally found that marination led to decreased shear force and shear energy values compared to non-marinated samples (Kadıoğlu et al. 2019; Dilek et al. 2023). According to Kumar et al. (2017), the final product formulated with a marinade containing fresh lemon juice and ginger extract lowers hardness and muscle fiber diameter values. Springiness, cohesiveness, and resilience values increase while gumminess and chewiness decrease post-marination of chicken breast fillets (Ünal et al. 2022). Santos et al. (2020) reported that all the experimental samples exhibited positive modifications in the characteristics of meat, induced by the low pH and high bromelain content of the marination solution. Çarbuğa (2019) similarly noticed a texture profile that is softer, springier, more cohesive, more resilient, and chewier using this formulation, though olive oil was ineffective. Kaewthong et al. (2021) reported a significant decrease in the shear force values in goat meat marinated with sodium bicarbonate or ginger and pineapple juices. Marination with buttermilk, acid whey, and lemon juice improved the tenderness of raw and cooked pheasant products. It has also been noted that acid whey had the lowest shear force value (Augustyńska-Pesjnar et al. 2021). On the other hand, Çelik (2019) there was no significant difference in hardness and springiness across various pH values. However, chewiness exhibited an increasing trend between pH values of 5.7 and 3.3, while adhesiveness decreased consistently until pH 3.3, after which it began to rise again. In another study using kefir, yoghurt, and buttermilk to improve the texture profile of pork, it was concluded that while hardness and stickiness values were significantly reduced, springiness did not make a significant difference with the marinating process (Latoch 2020). The other components present in the marinade formulation also determine the effect of marination on texture. Similarly, tenderness increased with the increasing concentration of sweet basil extract in marinade formulation (Patriani et al. 2021). As for Vişan et al. (2021), the use of cold-pressed oils exhibited lower hardness, chewiness, and gumminess values along with higher resilience and cohesiveness values.

In addition to the marinade formulation, the method of marination application also influences the tenderness. Marinating with VI method vacuum and ultrasonication applications results in greater effects on texture. Shi et al. (2020) have recorded that marination has a remarkable effect on the tenderness values, moreover, ultrasonication further supported the tenderness by destroying lysosomes to release proteolytic enzymes. Pretreatments with ultrasound (60 min) and VI (40 min) reduced the hardness of beef by 28.25% and 21.62%, respectively, compared to traditional marination for beef (Demir et al. 2022).

Techno-Functional Properties

Water-holding capacity (WHC). One of the key attributes of meat is its capacity to bind inherent water, known as WHC, as well as additional water introduced during marination. WHC affects tenderness and juiciness, which are the main factors of a product's acceptability (Serdaroğlu and Öztürk-Kerimoğlu 2023). Marination influences the WHC of meat through two factors: salt content and pH. The myofibrillar proteins, namely actin, myosin, and actomyosin, play a primary role in WHC and the absorption/retention of marinade (Önenç et al. 2004; Fadıloğlu and Serdaroğlu 2018; Kaewthong and Wattanachant 2018). The other effect of the marination process on WHC is based on the reduction of rigidity of the myofibrillar system. During marination, solutions are absorbed by the meat within the spaces between the thick and thin filaments of the myofibrils (Alvarado et al. 2007). Consequently, any factor influencing the spacing between these filaments will impact marinade absorption and retention. In addition to tenderization, marination significantly impacts the juiciness of meat (Demir et al. 2022). Ünal et al. (2022) demonstrated that marination with 0.1 M and 0.2 M acetic acid significantly increased the WHC of chicken meat.

Marination affects WHC in different ways in turkey, sheep, duck, and rabbit meats. Vlahova-Vangelova et al. (2017) reported that the WHC increased with both acidic (2% sodium lactate) and alkaline (2% polyphosphates) marinades in sheep meat. In parallel with this, Suradi et al. (2019) reported that marinating with green tea extract slightly increased the WHC. The use of lemon juice and ginger extract in marinade formulation increases the juiciness of spent hen's breast muscle (Kumar et al. 2017). Ünal et al. (2022) showed that apple cider vinegar increased the WHC of chicken breast meat, while Singh et al. (2019) showed marinating chicken meat with red beetroot juice had little effect on WHC. Similarly, the WHC was not affected by the marination with the basic amino acids (l-Arginine, l-Lysine, or phosphate) in chicken meat (Zhang et al. 2020).

Cooking yield. One of the primary benefits of marination is the retention of moisture in the meat. The marinade acts as a barrier, preventing the loss of moisture during cooking (Yusop et al. 2010). This is particularly important when working with lean cuts of meat that are prone to drying out. The liquid components of the marinade permeate the meat, contributing to its overall moisture content. As a result, the meat retains its natural juiciness, ensuring a more succulent and flavorful end product (Gómez et al. 2020). The oil in the marinade formulation coats the meat, preventing excessive moisture loss during cooking. Several articles have been published on post-marination cooking yield in beef, including pineapple by-products (Santos et al. 2020), olive oil, grape juice, and tomato juice (Çarbuğa 2019), ultrasound-assisted L-histidine (Shi et al. 2022), blackberry, pomegranate, rosehip, and grape vinegars (Şengün et al. 2021), aromatic herbs and cold pressed oils (Vişan et al. 2021), and wine (Arcanjo et al. 2019). Some researchers reported insignificant changes in terms of cooking loss after marination (Arcanjo et al. 2019; Santos et al. 2020; Şengün et al. 2021). Vişan et al. (2021) discovered that marination substantially reduced cooking loss. Interestingly, they noted that samples marinated for 12 h did not experience significant benefits from marination. Similarly, Jeong et al. (2020) observed a significant drop in the cooking yield of marinated pork on the first day, followed by a gradual increase up to day 14. Kaewthong et al. (2021) reported that both ginger juice and pineapple juice alone increased cooking loss, but the addition of sodium bicarbonate drastically reduced the level of cooking loss. Vlahova-Vangelova et al. (2017) conducted a study using four distinct methods: one involving a 2% polyphosphate alkaline solution, another utilizing a 2% sodium lactate acidic solution, a third employing a 2% salt brine solution, and finally, a method incorporating a 1:1 ratio of water to sunflower oil emulsion. The use of 6% sweet basil in the marinade formulation reduced drip loss and cooking loss in chicken (Patriani et al. 2021). This finding was explained by the strong effect of low pH values on proteins. Dilek et al. (2023) found that in marination solutions with added aronia, grape, and hawthorn vinegar, the highest cooking yield in chicken meat was observed in samples marinated with hawthorn vinegar.

Antioxidative effect. The oxidation induced chemically by ferrous iron and hydrogen peroxide begins with the formation of free radicals (Mercier et al. 2004). Factors such as raw meat composition and freshness, heat treatment, size reduction, emulsification, deboning, and the addition of salt, nitrites, spices, and antioxidants affect the oxidative changes in meat and meat products (Kavuşan and Serdaroğlu 2021; Kolev 2022). Oxidative changes can cause quality problems in flavor, color, texture, and nutritional value and toxic compounds can be formed (Kanner 1994). In particular, acidic marinade solutions boast higher levels of secondary products indicating increased lipid oxidation compared to non-marinated control groups. It is possible to slow down oxidative changes in marinated meats with different marinade formulations (Latoch et al. 2023). In cases where acidic marinade solutions do not contain components with phenolic compounds, it leads to a faster progression of oxidative changes (Fencioğlu et al. 2021). Most of the antioxidative compounds commonly found in herbs and spices act by reacting with free radicals created during the initial stages of oxidation or forming complexes with radical metal ions (Embuscado 2015). Natural oxidants found in thyme, oregano, or wine are used to inhibit lipid oxidation in marinated meat (Vlahova-Vangelova and Dragoev 2014). In recent years lots of studies noted the antioxidative activities of various marinades using wine (Arcanjo et al. 2019), and onion juice (Demir et al. 2022) in beef. TBARS and peroxide values also significantly decreased over incrementally longer periods of marination with rosehip powder (Serdaroğlu et al. 2023). Similarly, Demir et al. (2022) reported significantly lowered degrees of oxidation for both cooked and uncooked samples compared to non-marinated groups. In a study related to the lipid oxidation of buffalo meat marinated with different concentrations of the pomegranate-peel-extract-based solution, marinated samples, across all concentrations, exhibited significantly lower levels of peroxides indicating lower degrees of lipid oxidation when compared with control groups during storage (Rasuli et al. 2021). Kozhakhiyeva et al. (2018) stated that oxidative stability and quality of the new functional horse meat delicacy improved with the addition of 1% seed kernel pumpkin flour and 1% fruit extract of sea buckthorn. To determine the effects of marination on the oxidative stability of chicken, some studies have been done using different marinades such as onion juice (Çelik 2019), balsamic, pomegranate, apple, and grape vinegars (Fencioğlu 2021), soybean oil, mustard oil, and flaxseed oil (Das et al. 2022). Fencioğlu (2021) reported that the TBARS values for the experimental groups do not differ when compared to the non-marinated groups. On the other hand, Çelik (2019) indicated that the TBARS values of marinated samples were significantly lower than their non-marinated counterparts. Similarly, Das et al. (2022) concluded that the antioxidative effect of the marinade solution formulated with flaxseed, soybean, and mustard oil is apparent and significant due to marinated samples having significantly lower TBARS values than the control groups. In addition, marinade liquids incorporate rosehip, pomegranate, grape, and blackberry due to their high bioactive components, which contribute to their antioxidant and antimicrobial properties (Table 1).

Protein oxidation leads to various biological modifications such as protein fragmentation, aggregation, and reduced protein solubility, thereby impacting the quality of meat and meat products (Mercier et al. 2004). Researchers reported that the wine-based marinades significantly reduced the formation of protein carbonyls in roasted strip steaks, due to the radical scavenging activity of wine phenolics (Arcanjo et al. 2019).

Antimicrobial effect. The pH value of the marinade solution, especially the presence of antimicrobial compounds affects the shelf life of the marinated meat. Marinade solutions with acidic pH values are more effective against gram-negative bacteria compared to gram-positive bacteria (Vlahova-Vangelova and Dragoev 2014). The primary antimicrobial activity of weak acids occurs predominantly in their undissociated state. In this form, they can permeate the cell membrane, acidify the cytoplasm, and elevate the toxicity level of the dissociated acid anion. Furthermore, organic acids like citric and malic acid possess chelating properties that can destabilize the outer membrane of the cell (Mani-Lopez et al. 2012). Şengün et al. (2021) found that the level of antimicrobial effect on pathogens depends on the formulation of the marination and the type of probiotic added. Osaili et al. (2021) used yoghurt-based marinades laced with carvacrol, trans-cinnamaldehyde, and thymol to assess the behavior of *L. monocytogenes*, *Escherichia coli* O157:H7 and *Salmonella spp*. It has been tested with wine, oregano, and thyme essential oils, and ethanolic pomegranate extract (Mantzourani et al. 2023). The lethality levels of *Enterobacteriaceae*, *LAB*, *Pseudomonas*, and mesophilic bacteria species strongly depend on the formulation of the marinades, while *Staphylococci* counts were consistently lower in marinated samples when compared to control groups (Van Haute et al. 2016). Marination of chicken meat with red wine, pomegranate-based marination, bitter orange juice, edible oils, lemon juice, and *Yucca schidigera* extract shows red wine decreases *Salmonella typhimurium* count by 0.4-2.0 logs (Kiprotich et al. 2019). Vinegar, yoghurt, wine, and fruit juice in the marinade provide a long shelf life to the products by reducing the pH of the marinating medium (Latoch 2023). When integrated with other preservation techniques, this type of marination enhances the susceptibility of typical foodborne pathogens to treatments. If carefully formulated and utilized in conjunction with other preservation methods, marinades serve as valuable and cost-effective barriers, contributing to enhanced product safety and stability (Meneses and Teixeira 2022). Moreover, in certain cases involving preservation technologies, being exposed to the marination solution heightens the responsiveness of the meat microbiota to microbial reduction processes, such as thermal inactivation (Karyotis et al. 2017).

Bacus and Bontenbal (1991) concluded that the inclusion of 4% sodium lactate in frankfurters or chicken rolls effectively hindered the growth of *Listeria monocytogenes* throughout refrigerated storage. Furthermore, the addition of lactate led to a decrease in aerobic plate counts within the products. Similarly, Carroll et al. (2007) found that treatment with organic acids, including the combination of sodium lactate and sodium diacetate prolongs the lag phase of streptomycin-resistant *Listeria monocytogenes* up to day 63.

Sensory properties. Sensory evaluation of marinated meat involves assessing various attributes, including flavor, tenderness, juiciness, and appearance. Marination improves sensory characteristics such as juiciness, tenderness, and flavor in meat (Kadıoğlu et al. 2019). The influence of marination on the sensory quality is directly related to marination time, (Serdaroğlu et al. 2007; Ünal et al. 2022), and the ingredients used in the marinade (Gómez et al. 2020). The flavors in the marinade are absorbed by the meat, providing it with a distinct taste (Miller 2017). The choice of herbs, spices, and other seasonings in the marinade can create a wide range of flavor profiles, from tangy and zesty to sweet and savory (Vişan et al. 2021). Flavor profiling of marinated meat can be conducted using techniques such as gas chromatography-mass spectrometry to identify the volatile compounds responsible for specific flavors.

The chemical mechanism of marination involves the denaturation of muscle proteins through the acidic components of the marinade. Moreover, the acidic environment created by the marinade influences the pH level on the surface of the meat. This altered pH level can have a significant impact on the subsequent cooking process (Hwang et al. 2000). Marinating meat in an acid solution causes a lowering of pH which results in significant hydration of proteins (Thierry et al. 2011). This phenomenon promotes the development of Maillard reactions, which are responsible for the appealing browning and flavor formation observed in cooked meat. Maillard reactions occur between amino acids and reducing sugars present in the meat, resulting in a wide range of complex flavor compounds (Wei et al. 2016). Panelists report that marinated samples are salty and browner than controls, suggesting that penetration of salt deeper into the structure was enhanced by the marination liquid and the sugar content of onion juice (Çelik 2019). This denaturation leads to improved moisture retention and tenderness.

Marination is a chemical tenderization procedure due to the naturally increasing rate of proteolysis in meat. To assess how beef samples' sensory properties are influenced by marination, olive oil, grape juice and tomato juice, organic fruit vinegars, onion juice, aromatic herbs, cold pressed oils, and wine were used as marination mediums (Table 1). Panelists detected significant differences in color, odor, juiciness, and flavor attributes, but did not detect any changes in brightness, fibrousness, hardness, and meat flavor (Samant et al. 2016). Marinated steaks exhibited stronger color, wine flavor and aroma, and acidic odor while possessing reduced rancidity (Arcanjo et al. 2019). Suradi et al. (2019) observed perceptive sensorial changes in duck meat post-marination, yet the middle concentration caused an unexpected brown color. The causality of color degradation was described as a zero-order kinetic model related to the pH level of the solution. However, some researchers claim the addition of citric and acetic acids does not result in any adverse alterations to products, except for a slightly acidic flavor observed in certain instances following extended marination periods (González-Fandos et al. 2009; Schirmer et al. 2010).

The impact of marination on the sensorial qualities of chicken meat was evaluated using pineapple juice (Kadıoğlu et al. 2019), citric acid, lemon juice, grapefruit juice (Ünal et al. 2022), aronia vinegar, grape vinegar, hawthorn vinegar (Dilek et al. 2023) and onion juice (Çelik 2019).

Toxicity. During the process of grilling or cooking muscle foods at high temperatures, heterocyclic amines (HCAs) are formed, which are considered potential carcinogens for humans (Smith et al. 2008). Marinating meat before cooking is one of the most effective ways to reduce the overall formation of HCAs. This is due to both the physical and chemical effects of marinades on the Maillard reaction, which leads to the formation of HCAs (Manful et al. 2021). The effect of marination on the formation of HCAs in beef was investigated by Fencioğlu (2021). Results of this study showed that the total content of HCAs decreased in the samples marinated in balsamic and apple vinegar. Similarly, marinades containing spices can effectively inhibit the formation of HCAs in grilled beef steaks (Smith et al. 2008; Sepahpour et al. 2018). Red wine marinades were found to reduce the formation of some of the HCAs (especially pH IP) in fried chicken breast (Busquets et al. 2006). In a study, conducted on grilled chicken samples marinated with different types of sugar (table sugar, brown sugar, and honey), the concentrations of all HCA species (except 2-amino-3-methyl-3*H*-imidazo[4,5-f]quinoxaline) in marinated samples with refined sugar were significantly higher than brown sugar followed by honey (Hasnol et al. 2014).

Demir et al. (2022) analyzed the content of biogenic amines in beef marinated and reported that the tyramine levels in traditionally marinated samples did not differ from the levels recorded in the control groups, however, with the use of ultrasonication and VI, the levels were significantly reduced. On the other hand, neither traditional marination nor advanced marination methods had a significant effect on serotonin levels. In addition to tyramine and serotonin, spermine was not detected in the unmarinated and raw beef samples. Putrescine, cadaverine, histamine, tyramine, and spermidine were chosen as the target biogenic amines to be investigated (Cho et al. 2021). Marinating with blackcurrant juice reduced the levels of putrescine, cadaverine, and tyramine during storage, but had no effect on histamine levels. Spermidine levels fluctuated during storage, so the effect of marinating was considered inconclusive. Nonetheless, the total biogenic amine content of marinated samples was lower than that of non-marinated controls. Phenylethylamine, putrescine, and cadaverine are the predominant amines in marinated (based on potato juice fermented by selected *Pediococcus* strains) pork, but the concentrations of biogenic amines analyzed in pork samples were well below levels posing a health risk (Mozuriene et al. 2016). Furthermore, utilizing indigenous spices in the marination process for grilled beef will effectively minimize the presence of hazardous and carcinogenic HCAs (Jinap et al. 2015).

Conclusions

Marination is a practical method of tenderizing meat and has been used for many years. Marinating increases proteolytic activity in different ways, resulting in tender meat. Acidic or basic marinades increase the water-holding capacity by moving the pH away from the isoelectric point, thus reducing cooking loss. It is necessary to provide the desired textural and sensory properties, especially in low-fat meats such as poultry. At the same time, the ingredients used in the marinade may have antioxidative or antimicrobial effects. In addition to all these, the formation of toxic compounds such as HCAs and biogenic amines is reduced when herbs/spices are used in marinades. On the other hand, some ingredients, such as sodium carbonate cause problems with the color of the meat. Additionally, acidulants such as citric acid can lower the pH to the point where the meat has an extremely sour flavor, which may lead to consumer rejection. For this reason, marinating studies should be carried out to improve textural, microstructural, and techno-functional properties, and shelf life while ensuring that the sensory properties are at an acceptable level.

References

Alvarado C., McKee S. Marination to improve functional properties and safety of poultry meat. *Journal of Applied Poultry Research*, 2007, 16(1): 113-120. https://doi.org/10.1093/japr/16.1.113

Arcanjo N.M., Ventanas S., González- Mohíno A., Madruga M.S., Estévez, M. Benefits of wine- based marination of strip steaks before roasting: inhibition of protein oxidation and impact on sensory properties. *Journal of the Science of Food and Agriculture*, 2019, 99(3): 1108-1116. https://doi.org/10.1002/jsfa.9278

Augustyńska-Prejsnar A., Hanus P., Sokołowicz Z., Kačániová M. Assessment of technological characteristics and microbiological quality of marinated turkey meat with the use of dairy products and lemon juice. *Animal Bioscience*, 2021, 34(12): 2003-2011. https://doi.org/10.5713/ab.21.0120

Bacus J., Bontenbal E. Controlling *Listeria*. *Meat Poultry*, *1991*, 37: 64-69.

Bhat Z.F., Morton J.D., Mason S.L., Bekhit A.E.D.A. Applied and emerging methods for meat tenderization: A comparative perspective. *Comprehensive Reviews in Food Science and Food Safety*, 2018, 17(4): 841-859. https://doi.org/10.1111/1541-4337.12356

Bouacida S., Snoussi A., Koubaier H., Essaidi I., Aroua M., Jemmali B., Bouzouita N. Effect of marination with *Eruca vesicaria longirostris* leaves on Turkey meat properties during storage and consumer acceptance. *Journal of New Sciences - Sustainable Livestock Management*, 2020, 12(1): 253-264. Available at: https://www.jnsciences.org/sustainable-livestock-management/103-slm-12/611-effect-of-marination-with-eruca-vesicaria-longirostris-leaves-on-turkey-meat-properties-during-storage-and-consumer-acceptance.html

Bowker B.C., Callahan J.A., Solomon M.B. Effects of hydrodynamic pressure processing on the marination and meat quality of turkey breasts. *Poultry Science*, 2010, 89(8): 1744-1749. https://doi.org/10.3382/ps.2009-00484

Busquets R., Puignou L., Galceran M.T., Skog K. Effect of red wine marinades on the formation of heterocyclic amines in fried chicken breast. *Journal of Agricultural and Food Chemistry*, 2006, 54(21): 8376-8384. https://doi.org/10.1021/jf0616311

Carroll C.D., Alvarado C.Z., Brashears M.M., Thompson L.D., Boyce J. Marination of turkey breast fillets to control the growth of *Listeria monocytogenes* and improve meat quality in deli loaves. *Poultry Science*, 2007, 86(1): 150-155. https://doi.org/10.1093/ps/86.1.150

Chang H.J., Wang Q., Zhou G.H., Xu X.L., Li C.B. Influence of weak organic acids and sodium chloride marination on characteristics of connective tissue collagen and textural properties of beef semitendinosus muscle. *Journal of Texture Studies*, 2010, 41(3): 279-301. https://doi.org/10.1111/j.1745-4603.2010.00226.x

Cho J., Kim H.J., Kwon J.S., Kim H.J., Jang A. Effect of marination with black currant juice on the formation of biogenic amines in pork belly during refrigerated storage. *Food Science of Animal Resources*, 2021, 41(5): 763. https://doi.org/10.5851/kosfa.2021.e34

Çağlar N. Marinating red meat with tarragon and optimization of marination conditions. Master's Thesis by Gaziantep University, 2021 [in Turkish]

Çarbuğa Ü. Determination of chemical, sensory and textural effects of marination treatments on beef meat. Master's Thesis by Necmettin Erbakan University, 2019 [in Turkish]

Çelik S. Investigation on the use of onion juice for meat marination. Master's Thesis, Osmaniye Korkut Ata Üniversitesi, 2019 [in Turkish]

Das A., Hashem M.A., Azad M.A.K., Rahman M.M. Edible oil marination in broiler meat for short-term preservation. *Meat Research*, 2022, 2(3): 22. https://doi.org/10.55002/mr.2.3.22

Demir H., Çelik S., Sezer Y.Ç. Effect of ultrasonication and vacuum impregnation pretreatments on the quality of beef marinated in onion juice a natural meat tenderizer. *Food Science and Technology International*, 2022, 28(4): 340-352. https://doi.org/10.1177/10820132211012919

Detienne N.A., Reynolds A.E., Wicker L. Phosphate marination of pork loins at high and low injection pressures. *Journal of Food Quality*, 2003, 26(1): 1-14. https://doi.org/10.1111/j.1745-4557.2003.tb00222.x

Dilek N.M., Babaoğlu A.S., Unal K., Ozbek C., Pırlak L., Karakaya M. Marination with aronia, grape, and hawthorn vinegars affects the technological, textural, microstructural and sensory properties of spent chicken meat. *British Poultry Science*, 2023, 64(3): 1-7. https://doi.org/10.1080/00071668.2022.2163616

Dragoev S.G., Vlahova-Vangelova D.B., Balev D.K., Igenbaev A.K., Kassimov S.K. A specificity of microstructural and biochemical changes during ripening of dark, firm and dry sheep meat. *Food Science and Applied Biotechnology*, 2018, 1(2): 140-147. https://doi.org/10.30721/fsab2018.v1.i2.38

Ehsanur Rahman S.M., Islam S., Pan J., Kong D., Xi Q., Du Q., Yang Y., Wang J., Oh, D.H., Han, R. Marination ingredients on meat quality and safety - A review. *Food Quality and Safety*, 2023, 7(6): fyad027. https://doi.org/10.1093/fqsafe/fyad027

Embuscado M.E. Spices and herbs: Natural sources of antioxidants-a mini review. *Journal of Functional Foods*, 2015, 18(6): 811-819. https://doi.org/10.1016/j.jff.2015.03.005

Ertbjerg P., Mielche M.M., Larsen L.M., Møller A.J. Relationship between proteolytic changes and tenderness in prerigor lactic acid marinated beef. *Journal of the Science of Food and Agriculture*, 1999, 79(7): 970-978. https://doi.org/10.1002/(SICI)1097-0010(19990515)79:7<970::AID-JSFA312>3.0.CO;2-X

Fadıloğlu E.E, Serdaroğlu M. Effects of pre- and post-rigor marinade injection on some quality parameters of longissimus dorsi muscles. *Korean Journal for Food Science of Animal Resources*, 2018, 38(2): 325-337. https://doi.org/10.5851/kosfa.2018.38.2.325

Fencioğlu H. The effects of marination process with different vinegar types on various quality criteria and heterocyclic aromatic amine formation in heat-treated beef steak. Master's Thesis by Atatürk University, 2021 [in Turkish]

Gamage H.G.C.L., Mutucumarana R.K., Andrew M.S. Effect of Marination Method and Holding Time on Physicochemical and Sensory Characteristics of Broiler Meat. *The Journal of Agricultural Sciences*, 2017, 12(3): 172-184. http://dx.doi.org/10.4038/jas.v12i3.8264

Gargi A., Sengun I.Y. Marination liquids enriched with probiotics and their inactivation effects against food-borne pathogens inoculated on meat. *Meat Science*, 2021, 182(12): 108624. https://doi.org/10.1016/j.meatsci.2021.108624

Glorieux S., Goemaere O., Steen L., Fraeye I. Phosphate reduction in emulsified meat products: Impact of phosphate type and dosage on quality characteristics. *Food Technology and Biotechnology*, 2017, 55(3): 390. https://doi.org/10.17113/ftb.55.03.17.5089

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

González-Fandos E., Herrera B., Maya N. Efficacy of citric acid against *Listeria monocytogenes* attached to poultry skin during refrigerated storage. *International Journal of Food Science and Technology*, 2009, 44(1): 262-268. https://doi.org/10.1111/j.1365-2621.2007.01673.x

Harikedua S.D. The Application of Brine Injection Technology to Improve Quality of Pacific Whiting (*Merluccius productus*) Fillets. MSc Thesis, Oregon State University, USA, 2016. Available at: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/70795991c

Hasnol N.D.S., Jinap S., Sanny M. Effect of different types of sugars in a marinating formulation on the formation of heterocyclic amines in grilled chicken. *Food Chemistry*, 2014, 145(2): 514-521. https://doi.org/10.1016/j.foodchem.2013.08.086

Hwang I.H., Lin C.W., Chou R.G.R. Effect of lactic or acetic acid on degradation of myofibrillar proteins in post- mortem goose (*Anser anser*) breast muscle. *Journal of the Science of Food and Agriculture*, 2000, 80(2): 231-236. https://doi.org/10.1002/(SICI)1097-0010(20000115)80:2<231::AID-JSFA521>3.0.CO;2-L

Jeong H., Lee S., Han G.D. The effect of s igumjang (Korean fermented barley bran) marination on the physicochemical properties of pork loin. *Food Science and Biotechnology*, 2020, 29(3): 1195-1199. https://doi.org/10.1007/s10068-020-00767-x

Jinap S., Iqbal S.Z., Selvam R.M. Effect of selected local spices marinades on the reduction of heterocyclic amines in grilled beef (satay). *LWT-Food Science and Technology*, 2015, 63(2): 919-926. https://doi.org/10.1016/j.lwt.2015.04.047

Kadıoğlu P., Karakaya M., Unal K., Babaoğlu A.S. Technological and textural properties of spent chicken breast, drumstick and thigh meats as affected by marinating with pineapple fruit juice. *British Poultry Science*, 2019, 60(4): 381-387. https://doi.org/10.1080/00071668.2019.1621990

Kaewthong P., Wattanachant S. Optimizing the electrical conductivity of marinade solution for water-holding capacity of broiler breast meat. *Poultry Science*, 2018, 97(2): 701-708. https://doi.org/10.3382/ps/pex334

Kaewthong P., Wattanachant C., Wattanachant S. Improving the quality of barbecued culled-dairy-goat meat by marination with plant juices and sodium bicarbonate. *Journal of Food Science and Technology*, 2021, 58(5): 333-342. https://doi.org/10.1007/s13197-020-04546-8

Kanner J. Oxidative processes in meat and meat products: quality implications. *Meat Science*, 1994, 36(1-2): 169-189. https://doi.org/10.1016/0309-1740(94)90040-X

Karyotis D., Skandamis P.N., Juneja V.K. Thermal inactivation of *Listeria monocytogenes* and *Salmonella spp*. in sous-vide processed marinated chicken breast. *Food Research International*, 2017, 100: 894-898. https://doi.org/10.1016/j.foodres.2017.07.078

Kataria J., Morey A. Antimicrobial interventions in poultry processing to improve shelf life and safety of poultry meat: A review with special attention to *Salmonella spp*. *Journal of Food Quality and Hazards Control*, 2020, 7(5): 52-59. https://doi.org/10.18502/jfqhc.7.2.2884

Kavuşan H.S., Serdaroğlu M. Oxidative changes in fermented meat products and their effects on product quality. *Gıda*, 2021, 46(2): 443-462. https://doi.org/10.15237/gida.GD20122

Ke S., Huang Y., Decker E.A., Hultin H.O. Impact of citric acid on the tenderness, microstructure and oxidative stability of beef muscle. *Meat Science*, 2009, 82(1): 113-118. https://doi.org/10.1016/j.meatsci.2008.12.010

Khan M.R., Busquets R., Azam M. Blueberry, raspberry, and strawberry extracts reduce the formation of carcinogenic heterocyclic amines in fried camel, beef and chicken meats. *Food Control*, 2021, 123(5):

107852. https://doi.org/10.1016/j.foodcont.2020.107852

Kim J.S., Schnee R., Park J.W. Chemical and functional properties of various blends of phosphates. *Journal of Food Quality*, 2009, 32(4): 504-521. https://doi.org/10.1111/j.1745-4557.2009.00265.x

Kiprotich S., Mendonça A., Dickson J., Shaw A., Thomas-Popo E., White S., Moutiq R., Ibrahim S.A. Thyme oil enhances the inactivation of *Salmonella enterica* on raw chicken breast meat during marination in lemon juice with added *Yucca schidigera* extract. *Frontiers in Nutrition*, 2021, 7(2): 619023. https://doi.org/10.3389/fnut.2020.619023

Kolev N. Natural antioxidants – an alternative for reduction of nitrites in cooked meat products. *Food Science and Applied Biotechnology*, 2022, 5(1): 64-76. https://doi.org/10.30721/fsab2022.v5.i1.167

Kozhkhiyeva M., Dragoev S., Uzakov Y., Nurgazezova A. Improving of the oxidative stability and quality of new functional horse meat delicacy enriched with sea buckthorn (*Hippophae rhamnoides*) fruit powder extracts or seed kernel pumpkin (*Cucurbita pero* L.) flour. *Comptes rendus de l'Académie bulgare des Sciences*, 2018, 71(1): 132-136. https://doi.org/10.7546/CRABS.2018.01.18

Kumar Y., Singh P., Pandey A., Tanwar V.K., Kumar R.R. Augmentation of meat quality attributes of spent hen breast muscle (*Pectoralis major*) by marination with lemon juice vis-a-vis ginger extract. *Journal of Animal Research*, 2017, 7(3): 523-529. https://doi.org/10.5958/2277-940X.2017.00077.8

Latoch A. Effect of meat marinating in kefir, yoghurt and buttermilk on the texture and color of pork steaks cooked sous-vide. *Annals of Agricultural Sciences*, 2020, 65(2): 129-136. https://doi.org/10.1016/j.aoas.2020.07.003

Latoch A., Czarniecka-Skubina E., Moczkowska-Wyrwisz M. Marinades based on natural ingredients as a way to improve the quality and shelf life of meat: A review. *Foods*, 2023, 12(19): 3638. https://doi.org/10.3390/foods12193638

Listrat A., Gagaoua M., Andueza D., Gruffat D., Normand J., Mairesse G., Hocquette J.F. What are the drivers of beef sensory quality using metadata of intramuscular connective tissue, fatty acids, and muscle fiber characteristics? *Livestock Science*, 2020, 240(10): 104209. https://doi.org/10.1016/j.livsci.2020.104209

Lomiwes D., Farouk M.M., Wu G., Young O.A. The development of meat tenderness is likely to be compartmentalized by ultimate pH. *Meat Science*, 2013, 96(1): 646-651. https://doi.org/10.1016/j.meatsci.2013.08.022

Ma D., Kim Y.H.B. Proteolytic changes of myofibrillar and small heat shock proteins in different bovine muscles during aging: Their relevance to tenderness and water- holding capacity. *Meat Science*, 2020, 163(5): 108090. https://doi.org/10.1016/j.meatsci.2020.108090

Manful C.F., Pham T.H., Nadeem M., Wheeler E., Warren K.J., Vidal N.P., Thomas R.H. Assessing unfiltered beer-based marinades effects on ether and ester linked phosphatidylcholines and phosphatidylethanolamines in grilled beef and moose meat. *Meat Science*, 2021, 171(1): 108271. https://doi.org/10.1016/j.meatsci.2020.108271

Mani-López E., Garcia H.S., López-Malo A. Organic acids as antimicrobial to control Salmonella in meat and poultry products. *Food Research International*, 2012, 45(2): 713-721. https://doi.org/10.1016/j.foodres.2011.04.043

Mantzourani I., Daoutidou M., Nikolaou A., Kourkoutas Y., Alexopoulos A., Tzavellas I., Dasenaki M., Thomaidis N., Plessas S. Microbiological stability and sensorial valorization of thyme and oregano essential oils alone or combined with ethanolic pomegranate extracts in wine marinated pork meat. *International Journal of Food Microbiology*, 2023, 386(2): 110022. https://doi.org/10.1016/j.ijfoodmicro.2022.110022

Mazaheri Kalahrodi M., Baghaei H., Emadzadeh B., Bolandi M. Degradation of myofibrillar and sarcoplasmic proteins as a function of marinating time and marinade type and their impact on textural quality and sensory attributes of m. semitendinosus beefsteak. *Journal of Food Processing and Preservation*, 2021, 45(9): e15691. https://doi.org/10.1111/jfpp.15691

Meneses R., Teixeira P. Marination as a Hurdle to Microbial Pathogens and Spoilers in Poultry Meat Products: A Brief Review. *Applied Sciences*, 2022, 12(22): 11774. https://doi.org/10.3390/app122211774

Mercier Y., Gatellier P., Renerre M. Lipid and protein oxidation in vitro, and antioxidant potential in meat from Charolais cows finished on pasture or mixed diet. *Meat Science*, 2004, 66(2): 467-473. https://doi.org/10.1016/S0309-1740(03)00135-9

Miller R.K. The eating quality of meat: V Sensory evaluation of meat. In *Lawrie's Meat Science* (Ninth Edition). 2017, pp. 509-548. https://doi.org/10.1016/B978-0-323-85408-5.00020-0

Moeini R., Zamindar N., Aarabi Najvani F. The effect of marination by using ginger extract and citric acid on physicochemical characteristics of camel meat. *Food Science and Technology International*, 2022, 30(2). https://doi.org/10.1177/10820132221136590

Mozuriene E., Bartkiene E., Krungleviciute V., Zadeike D., Juodeikiene G., Damasius J., Baltusnikiene A. Effect of natural marinade based on lactic acid bacteria on pork meat quality parameters and biogenic amine contents. *LWT-Food Science and Technology*, 2016, 69(6): 319-326. https://doi.org/10.1016/j.lwt.2016.01.061

O'Neill, C.M., Cruz-Romero M.C., Duffy G., Kerry J.P. Improving marinade absorption and shelf life of vacuum packed marinated pork chops through the application of high pressure processing as a hurdle. *Food Packaging and Shelf Life*, 2019, 21(9): 100350. https://doi.org/10.1016/j.fpsl.2019.100350

Osaili T.M., Hasan F., Dhanasekaran D.K., Obaid R.S., Al-Nabulsi, A.A., Karam L., Savvaidis I.N., Olaimat A.N., Al-Holy M. Holley R. Effect of yogurt-based marinade combined with essential oils on the behavior of *Listeria monocytogenes*, *Escherichia coli* O157: H7 and *Salmonella spp.* in camel meat chunks during storage. *International Journal of Food Microbiology*, 2021, 343(4): 109106. https://doi.org/10.1016/j.ijfoodmicro.2021.109106

Oyetunji O.T. Evaluation of the effect of marination processes on the quality and safety of pork products. PhD thesis by University of Georgia, 2009. Available at: https://esploro.libs.uga.edu/esploro/outputs/9949333768502959

Önenç A., Serdaroğlu M., Abdraimov K. Effect of various additives to marinating baths on some properties of cattle meat. *European Food Research and Technology*, 2004, 218(11): 114-117. https://doi.org/10.1007/s00217-003-0828-7

Patriani P., Hafid H., Sepriadi S. The effect of marination using sweet basil (*Ocimum basilicum*) spices on the physical quality of local chicken meat. In *IOP Conference Series: Earth and Environmental Science*, 2021, 782(2): 022075. IOP Publishing. https://doi.org/10.1088/1755-1315/782/2/022075

Rasuli N., Bintoro V.P., Purnomoadi A., Nurwantoro N. The shelf life of buffalo meat marinated with pomegranate (*Punica granatum*) peel extract. *Journal of Advanced Veterinary and Animal Research*, 2021, 8(4): 612. https://doi.org/10.5455/javar.2021.h552

Renand G., Picard B., Touraille C., Berge P., Lepetit J. Relationships between muscle characteristics and meat quality traits of young Charolais bulls. *Meat Science*, 2001, 59(1): 49-60. https://doi.org/10.1016/S0309-1740(01)00051-1

Rostamani M., Baghaei H., Bolandi M. Prediction of top round beef meat tenderness as a function of marinating time based on commonly evaluated parameters and regression equations. *Food Science & Nutrition*, 2021, 9(9): 5006-5015. https://doi.org/10.1002/fsn3.2454

Samant S.S., Crandall P.G., O'Bryan C.A., Lingbeck J. M., Martin E.M., Tokar T., Seo H.S. Effects of smoking and marination on the sensory characteristics of cold-cut chicken breast filets: A pilot study. *Food Science and Biotechnology*, 2016, 25(12): 1619-1625. https://doi.org/10.1007/s10068-016-0249-6

Santos D.I., Fraqueza M.J., Pissarra H., Saraiva J.A., Vicente A.A., Moldão-Martins M. Optimization of the effect of pineapple by-products enhanced in bromelain by hydrostatic pressure on the texture and overall quality of silverside beef cut. *Foods*, 2020, 9(12): 1752. https://doi.org/10.3390/foods9121752

Santos V.M.O.D., Caldara F.R., Seno L.D.O., Feijó G.L. D., Paz I.C.D.L.A., Garcia R.G., Nääs, I.A., Altemio Â.D.C. Marinade with alkaline solutions for the improvement of pork quality. *Pesquisa Agropecuária Brasileira*, 2012, 47(11): 1655-1662. https://doi.org/10.1590/S0100-204X2012001100013

Saygun F., Tokur B. Pişirmeye Hazır Marine Edilmiş Palamut Balığı (*Sarda sarda*)'nın Dondurularak Depolama Boyunca Lipit Ve Duyusal Kalite Parametrelerinin İncelenmesi. *Journal of Anatolian Environmental and Animal Sciences*, 2021, 6(1): 4-13. https://doi.org/10.35229/jaes.791623

Schirmer B.C., Langsrud S. A dissolving CO_2 headspace combined with organic acids prolongs the shelf-life of fresh pork. *Meat Science*, 2010, 85(2): 280-284. https://doi.org/10.1016/j.meatsci.2010.01.013

Sengun I.Y., Turp G.Y., Cicek S.N., Avci T., Ozturk B., Kilic G. Assessment of the effect of marination with organic fruit vinegars on safety and quality of beef. *International Journal of Food Microbiology*, 2021, 336(1): 108904. https://doi.org/10.1016/j.ijfoodmicro.2020.108904

Sepahpour S., Selamat J., Khatib A., Manap M.Y.A., Abdull Razis A.F., Hajeb P. Inhibitory effect of mixture herbs/spices on formation of heterocyclic amines and mutagenic activity of grilled beef. *Food Additives & Contaminants*: *Part A*, 2018, 35(10): 1911-1927. https://doi.org/10.1080/19440049.2018.1488085

Serdaroğlu M., Abdraimov K., Onenc A. The effects of marinating with citric acid solutions and grapefruit juice on cooking and eating quality of turkey breast. *Journal of Muscle Foods*, 2007, 18(2): 162-172. https://doi.org/10.1111/j.1745-4573.2007.00074.x

Serdaroğlu M., Öztürk-Kerimoğlu B. Et Teknolojisi Et Ürünleri Üretiminde Temel Teknolojiler ve Ürün Kalitesi (First Edition). Sidas, 2023, pp. 1-316, ISBN: 978-6-05-526798-8 [In Turkish]

Serdaroğlu M., Yüncü-Boyacı Ö., Karaman M., Kavuşan H.S. Investigating the influence of rosehip tea marination on lipid oxidation in turkey breast meat. *Scientific journal" Meat Technology*, 2023, 64(2): 344-349. https://doi.org/10.18485/meattech.2023.64.2.65

Shi H., Khan I.A., Zhang R., Zou Y., Xu W., Wang D. Evaluation of ultrasound-assisted L-histidine marination on beef *M. semitendinosus*: Insight into meat quality and actomyosin properties. *Ultrasonics Sonochemistry*, 2022, 85(4): 105987. https://doi.org/10.1016/j.ultsonch.2022.105987

Shi H., Zhang X., Chen X., Fang R., Zou Y., Wang D., Xu W. How ultrasound combined with potassium alginate marination tenderizes old chicken breast meat: Possible mechanisms from tissue to protein. *Food Chemistry*, 2020, 328(10): 127144. https://doi.org/10.1016/j.foodchem.2020.127144

Shtonda O., Semeniuk K. Aspects of the influence of vegetable-oil-based marinade on organoleptic and physicochemical indicators of the quality of semi-finished natural marinated meat products. *Slovak Journal of Food Sciences*, 2021, 15(6): 513-520. https://doi.org/10.5219/1527

Singh P., Yadav S., Pathera A., Sharma D. Effect of vacuum tumbling and red beetroot juice incorporation on the quality characteristics of marinated chicken breast and leg meat. *Nutrition and Food Science*, 2019, 50(1): 143-A156. https://doi.org/10.1108/NFS-03-2019-0079

Smith J.S., Ameri F., Gadgil P. Effect of marinades on the formation of heterocyclic amines in grilled beef steaks. *Journal of Food Science*, 2008, 73(6): 100-105. https://doi.org/10.1111/j.1750-3841.2008.00856.x

Suradi K., Gumilar J., Ladyani G.M.L., Putri N.S.W. The effect of duck meat marination with various concentrations of green tea extract (*Camellia sinensis*) on physical, microbiological and acceptability properties. *Scientific Papers-Animal Science Series: Lucrări Ştiinţifice-Seria Zootehnie*, 2019, 72: 137-142. Available at: https://www.uaiasi.ro/firaa/Pdf/Pdf_Vol_72/Kusmajadi_Suradi.pdf

Thierry G., Philippe B., Julien R., Gilles T., Antoine C. Swelling and shrinkage regimes during the acidic marination of meat in presence of salt. In: Proceedings of the 11th International Congress on Engineering and Food; 2011 May 22-26, Athens, Greece. IAEF. Athènes, 2011, pp. 1349-1350. ISBN 978-960-89789-6-6. Available at: https://d1wqtxts1xzle7.cloudfront.net/79904788/EPF199-libre.pdf?1643544336=&response-content-disposition=inline%3B+filename%3DSwelling_and_shrinkage_regimes_during_th.pdf&Expires=1723558007&Signature=PQ1STYsoGDBrgkspA-h6ZGdigNN52hqHwQzLlWSGD4zAmKshRkaac1C5ocjTZ1Vnp9MnfAWiYZfGkmrHlzMT5PcI1qwLWck-jx~5jpuz9tXPt5ZbfWdXQE0B81gH8T38KL5T~Jwt56oC-hDP9A12ktjWH0MGxAj5H5mvgih-~LVMCaHNQB-BZtVANS7c~6kaYpbhLGissMPCJnOCsLJdnH9ImLphDKCGpYwwabPMeUdfjDX8ZBzXNnZiYTGXmbrP8nhOd3hc-BTtCiZJjZsYhI5sF0zcXWBVLREyvuUkkoyYBvgzwee9GJzhCOAkr55wb08TugelhYi2FuAWf2kYyA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

Toldrá F., Mora L. Chapter One - Peptidomics as a useful tool in the follow-up of food bioactive peptides. *Advances in Food and Nutrition Research*, 2022, 100(6): 1-47. https://doi.org/10.1016/bs.afnr.2022.03.001

Ünal K., Alagöz E., Çelik İ., Sarıçoban C. Marination with citric acid, lemon, and grapefruit affects the sensory, textural, and microstructure characteristics of poultry meat. *British Poultry Science*, 2022, 63(1): 31-38. https://doi.org/10.1080/00071668.2021.1963674

Ünal K., Alagöz E., Cabi A., Sarıçoban C. Determination of the effect of some acidic solutions on the tenderness and quality properties of chicken breast meat. *Selcuk Journal of Agriculture and Food Sciences*, 2020, 34(1): 19-23. https://doi.org/10.15316/SJAFS.2020.190

Van Haute S., Raes K., Van Der Meeren P., Sampers I. The effect of cinnamon, oregano and thyme essential oils in marinade on the microbial shelf life of fish and meat products. *Food Control*, 2016, 68(10): 30-39. https://doi.org/10.1016/j.foodcont.2016.03.025

Veiseth E., Shackelford S.D., Wheeler T.L., Koohmaraie M. Factors regulating lamb longissimus tenderness are affected by age at slaughter. *Meat Science*, 2004, 68(4): 635-640. https://doi.org/10.1016/j.meatsci.2004.05.015

Vişan V.G., Chiş M.S., Păucean A., Mureşan V., Puşcaş A., Stan L., Vodnar D.C., Dulf F.V., Ţibulcă D., Vlaic B.A., Rusu I.E., Kadar C.B., Vlaic, A. Influence of Marination with Aromatic Herbs and Cold Pressed Oils on Black Angus Beef Meat. *Foods*, 2021, 10(9): 2012. https://doi.org/10.3390/foods10092012

Vlahova-Vangelova D., Dragoev S. Marination: Effect on meat safety and human health. A review. *Bulgarian Journal of Agricultural Science*, 2014, 20(3): 503-509. Available at: https://agrojournal.org/20/03-01.pdf

Vlahova-Vangelova D., Abjanova SH, Dragoev SG. Influence of marinating type on the morphological and sensory properties of horse meat. *ACTA Scientiarum Polonorum Technologia Alimentaria*, 2014, 13(5): 403-411. http://doi.org/10.17306/J.AFS.2014.4.7

Vlahova-Vangelova D.B., Balev D.K, Dragoev S.G., Kirisheva G.D. Improvement of the technological and sensory properties of meat by whey marinating. *Scientific Works of UFT*, 2016, 63(1): 7-13. https://uft-plovdiv.bg/site_files/file/scienwork/scienworks_2016/docs/original%20SWUFT201601103%20(final).pdf

Vlahova-Vangelova D.B., Dragoev S.G., Balev D.K., Assenova B.K., Amirhanov K.J. Quality, microstructure, and technological properties of sheep meat marinated in three different ways. *Journal of Food Quality*, 2017, 2017(1): 1-10. https://doi.org/10.1155/2017/5631532

Wei X., Wang C., Zhang C., Li X., Wang J., Li H., Tang C. A combination of quantitative marinating and Maillard reaction to enhance volatile flavor in Chinese marinated chicken. *Journal of the Science of Food and Agriculture*, 2017, 97(3): 823-831. https://doi.org/10.1002/jsfa.7803

Xargayó M., Lagares J., Fernández E., Ruiz D., Borrell D. Marination of fresh meats by means of spray effect: influence of spray injection on the quality of marinated products. *Fleischwirtschaft International*, 2001, 81(2): 93-98. Available at: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Marination+of+fresh+meats+by+means+of+spray+effect%3A+influence+of+spray+injection+on+the+quality+of+marinated+products&btnG=

Xiong G., Fu X., Pan D., Qi J., Xu X., Jiang, X. Influence of ultrasound-assisted sodium bicarbonate marination on the curing efficiency of chicken breast meat. *Ultrasonics Sonochemistry*, 2020, 60(1): 104808. https://doi.org/10.1016/j.ultsonch.2019.104808

Xiong Y.L. Muscle Protein. In: *Proteins in Food Processing* (R.Y. Yada Ed.). Woodhead Publ. Ltd. 2004, pp. 100-122. Print ISBN: 978-0-08-100722-8, eBook ISBN: 978-0-08-100729-7. https://doi.org/10.1016/C2015-0-01620-3

Xu H., Zhang X.K., Wang X., Liu D.H. The effects of high pressure on the myofibrillar structure and meat quality of marinating Tan mutton. *Journal of Food Process Engineering*, 2019, 42(6): e13138. https://doi.org/10.1111/jfpe.13138

Yusop S.M., O'Sullivan M.G., Kerry J.P. Marinating and enhancement of the nutritional content of processed meat products. In: *Processed Meats. Improving Safety, Nutrition and Quality* (J.P. Kerry, J.F. Kerry Eds.). Woodhead Publishing Series in Food Science, Technology and Nutrition. 2011, pp. 421-449, Print ISBN: 978-1-84569-466-1, https://doi.org/10.1533/9780857092946.3.421

Yusop S.M., O'Sullivan M.G., Kerry J.F., Kerry, J.P. Effect of marinating time and low pH on marinade performance and sensory acceptability of poultry meat. *Meat Science*, 2010, 85(4): 657-663. https://doi.org/10.1016/j.meatsci.2010.03.020

Zhang Y., Zhang D., Huang Y., Chen L., Bao P., Fang H., Xu B., Zhou C. Effects of basic amino acid on the tenderness, water binding capacity and texture of cooked marinated chicken breast. *LWT-Food Science and Technology*, 2020, 129: 109524. https://doi.org/10.1016/j.lwt.2020.109524

Żochowska-Kujawska J., Lachowicz K., Sobczak M. Effects of fibre type and kefir, wine lemon, and pineapple marinades on texture and sensory properties of wild boar and deer longissimus muscle. *Meat Science*, 2012, 92(4): 675-680. https://doi.org/10.1016/j.meatsci.2012.06.020