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Enhancing the quality of animal meat products by combining plant-based marinations and thermal processes: a treatise

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Abstract

Nowadays, natural preservatives, specifically involving marinades, are being applied to meat products to enhance various quality attributes. The need for food preservation has continually strengthened the processing of meat products. Besides the global production of bovine, porcine, ovine, and caprine animals, including poultry, that varies across continents, meeting the demands/needs of ever-increasing (global) population remains the focus. The growing consumer health awareness alongside intensifying global competition by meat producers cumulatively strengthens the call for healthier products, including preservation strategies. However, as published experimental/synthesized literature involving animal meat products, plant-based marination, and thermal processes continues to grow, there is a need to supplement existing information. Therefore, this treatise aims to discuss how the quality of animal meat products has been enhanced through plant-based marinations and thermal processes, drawing from plant-based marination: some key examples and usefulness; marination/marinades: briefs on preparation and applications; major thermal processes applied to marinated meat products; as well as quality implications of thermally processed marinated meat products. In certain instances, either marination would aid heat processing or vice versa, while in others, thermal processing may well be detrimental to marination.

Keywords: animal meat product; marination; herbs/spices; thermal treatment; product development.

Practical Application: The addition of marinades (the marination process) is capable of enhancing the quality of meat products. The application of thermal processes in some instances may strengthen the efficacy of marinades.

1 INTRODUCTION

Generally, meat products involve edible flesh/muscle tissues from certain domestic animals that serve as food, ranging from bovine, porcine, ovine, and caprine animals to poultry (domestic and non-domestic birds, excluding ratites), etc. (Cobos & Díaz, 2015). Globally, meat production would corroborate with the decreasing trend in all domestic animal species, which is believed to happen as animal farmers adapt to their self-consumption needs alongside limited market demands (Petroman et al., 2013). Typically, meat comprises approximately 72–75% water, 21% nitrogen-based compounds, 2.5–5% lipids, 1% non-nitrogenous compounds (vitamins), and carbohydrates, alongside about 1% ash (potassium, phosphorus, sodium, chlorine, magnesium, calcium, and iron) (Cobos & Díaz, 2015). The variation of meat composition depends on influences from several factors like animal species, breed, sex, feeding, muscle, etc. (Cobos & Díaz, 2015). Besides the global production of bovine, porcine, ovine, and caprine animals, including poultry, that varies across continents, meeting the demands/needs of the ever-increasing (global) population remains the focus. Meat/meat products remain a positive source of bioactive compounds for human health. The growing consumer health awareness alongside intensifying global competition by meat producers cumulatively pressures the need for healthier products, especially targeting preservation strategies (Pogorzelska-Nowicka et al., 2018). Indeed, food preservation continually helps strengthen the various meat processing strategies. Furthermore, the preservation technology involves not only categories I and II (heat treatment), but also categories III and IV (shelf stability), which aim to either reduce water activity (drying, salting) or have the combined effect of reducing both pH and water activity (fermented products) (Vandendriessche, 2008).

Prior to understanding the importance of thermal processes, especially when applied to marinated meat products, preservation needs of meat products still persist. In this, there are processing categories, which, according to Hui (2012), would involve key steps like slaughtering, raw product, heat treated, fully cooked but not shelf stable, not heat treated but shelf stable, heat treated and shelf stable, as well as thermally processed and shelf sterile. From these, meat

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products that emerge can include cured/cooked-cured, fresh enhanced/comminuted/reformed, dried/dried fermented, as well as frozen types (Cobos & Díaz, 2015). Nowadays, natural preservatives specifically involving marinades are being applied to meat products to enhance various quality attributes (Cheok et al., 2011; Istrati et al., 2015; Sokołowicz et al., 2021). In addition to how different herbs/plants are applied via marination to serve their purpose, the manner in which meat samples take up marinade into their muscles depends on (meat) type, (marination) technique, and the duration of (marination) process (Okpala et al., 2022; Siroli et al., 2020). On the contrary, the advances in thermal processing over the decades have helped enhance consumer edibility, decrease microbial proliferation, and enhance flavor/texture of meat products. Examples of thermal processing include aseptic processing, cook-chill, grilling, laser-based packaging, ohmic heating, sous-vide, etc. (Okpala et al., 2023; Schellekens & Martens, 1992; Viegas et al., 2012). The advent of hurdle technology, along with various conventional heat processing techniques and/or novel thermal processes, would be combined and applied to marinated meat products. However, as published experimental/synthesized literature involving animal meat products, plant-based marination, and thermal processes continues to grow, there is a need to supplement existing information. Therefore, this treatise aims to discuss how the quality of animal meat products has been enhanced through plant-based marinations and thermal processes, drawing from plant-based marination: some key examples and usefulness; marination/marinades: briefs on preparation and applications; major thermal processes applied to marinated meat products; as well as quality implications of thermally processed marinated meat products.

2 PLANT-BASED MARINATION: SOME EXAMPLES AND THEIR POTENTIALS

The use of extracts from fruits, herbs, and plants gains popularity given consumers' desire for so-called "natural additives," the latter of which refer to those naturally found with multiple attributed benefits (Balasundram et al., 2006; Lorenzo et al., 2018). As among very important alternatives to chemicals, plant sources remain increasingly applicable to meat products (Jayasena & Jo, 2013). Among several techniques being employed to increase the tenderness of meat, the marination approach appears very promising, especially in terms of its capacity to enhance flavor and water-holding capacity (Vişan et al., 2021). Specifically, marination refers to the process of treating meat with a variety of herbs, spices, organic acids, salt, and oil in order to tenderize and improve its flavor (Meneses & Teixeira, 2022). When combined with other preservation methods, marination makes common foodborne bacteria more vulnerable (Meneses & Teixeira, 2022). Indeed, the composition of marinades would directly influence the efficacy of the marination process; hence, considering the desired marinated product, either single or combined plants could be utilized. Previous studies of different plants/herbs employed for marination purposes are shown in Table 1. In addition to garlic (*Allium sativum* L.), ginger (*Zingiber officinale*), pineapple (*Ananas comosus*), and rosemary (*Rosmarinus officinalis* L.) (as shown in Table 1), several plants and herbs have shown potential as meat-marinating ingredients.

Garlic is one of the most often used culinary flavoring components (Gokoglu et al., 2012). Numerous studies have shown that garlic may lower the population of *Streptococcus*, Klebsiella, Proteus, *Bacillus*, *Clostridium*, *E. coli*, *Salmonella*, *Staphylococcus*, and *Helicobacter pylori* (Ankri & Mirelman, 1999; Banerjee & Sarkar, 2003; Chen et al., 2018; Phan et al., 2019; Sivam, 2001). Garlic contains phenolic compounds considered to draw significant attention as antioxidants (Awuchi & Okpala, 2022). Numerous scientists have used garlic-based marinades to enhance the quality and/or safety of meat products (Farhadian et al., 2012; Nurwantoro et al., 2015; Tkacz et al., 2021). Ginger is a significant root spice that is extensively utilized in the meat industry and in the culinary arts (Awuchi & Okpala, 2022; He et al., 2015). Moreover, ginger extract would incorporate the action of proteolytic enzyme zingibain, which could soften tough meat through a tenderizing impact (Hiemori-Kondo et al., 2022; Kaewthong et al., 2021). In addition to tenderizing meat, Putra et al. (2019) showed ginger juice to reduce the flavor and lipid breakdown of refrigerated Saanen crossbred goat meat. Besides containing the proteolytic enzyme bromelain, pineapple is among the fruits employed in the marination of meat products (Golden & Smith-Marshall, 2012; Kaewthong et al., 2021). Pineapple extract showed antibacterial action against *Staphylococcus aureus* given by the bromelain molecule alongside phytochemical constituents, such as Vitamin C and flavonoid (Loon et al., 2018). Food processors may use pineapple extracts to boost the tenderness and customer acceptability of chicken meat (Abdel-Naeem et al., 2022). Marinating beef in pineapple puree could optimize tenderization and reduce cooking losses (Lawrence & Lawrence, 2021).

Rosemary extracts are widely used as natural antioxidants (Cadun et al., 2008). It has been reported that rosemary contains antioxidant compounds including rosmanol, rosmariquinone, rosmaridiphenol, and carnosol that are up to four times as potent as butylated hydroxyanisole and equivalent to butylated hydroxytoluene (Martínez et al., 2019; Nakatani & Inatani, 1984). Among the main marinating components, the bioactive compounds in rosemary extracts may possess antibacterial properties (Fellenberg et al., 2020; Gazwi et al., 2020; Lee et al., 2020; Lešnik et al., 2021; Rashidaie Abandansarie et al., 2019; Shen et al., 2022). Other plants/herbs employed in marination, as shown in Table 1, include koruk, black pepper, garlic/onion, edible mushroom, red pepper, tomato, coriander, blackberry, pomegranate, rosehip and grape, as well as sweet basil (Fu et al., 2022; Gibis and Weiss, 2012; Kim et al., 2010; Patriani et al., 2021; Sengun et al., 2020, 2021; Testa et al., 2019; Vişan et al., 2021; Yu et al., 2023). Green tea, white tea, yellow tea, oolong tea, dark tea, and black tea, lemon grass, turmeric, curry leaf, torch, hibiscus, lemon, thyme, oregano, sage leaf, hop, licorice root, curcuma, clove bud, oregano leaf, and ajwain seed, as well as Bay leaf, have also been reported (Bilgin Fıçıcılar et al., 2018; Gibis and Weiss, 2010; Gokoglu et al., 2012; Mahrour et al., 2003; Rababah et al., 2011; Sepahpour et al., 2018; Tarvainen et al., 2015; Wang et al., 2018).

Table 1. Previous studies of different plants/herbs employed for marination purposes.

Plants/herbs	Study aim	Key findings	Reference
Koruk	To test the efficacy of koruk products (koruk juice and dried koruk pomace) as a marination agent against high and low inoculum dosages of *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella typhimurium* inoculation on chicken flesh	Total acidity/phenolic content of marinating solutions made with koruk juice and dried koruk pomace, both boosted the efficacy of the marination process, which in turn increased the safety of poultry meat	(Sengun et al., 2020)
Grape seed and rosemary extract	To assess the effectiveness of water-in-oil marinades with grape seed extract or oil marinades including rosemary extract to minimize heterocyclic amines (HCAs) accumulation in beef patties	Rosemary and grape seed extract dispersed in sunflower oil or a water-in-oil emulsion inhibited the formation of various HCAs	(Gibis & Weiss, 2012)
Black pepper, rosemary, oregano, thyme, basil, and ginger	To examine the nutritional, textural, and sensory effects of herbs and oils on Black Angus beef sirloin meat	Aromatic herbs and cold-pressed oils improved the beef's aroma, taste, and texture (particularly tenderness and juiciness) after prolonged marination. Each aromatic plant and oil had a distinct polyphenolic profile	(Vişan et al., 2021)
Garlic and onion	To assess the antioxidant and meat quality impacts of garlic and onion juices marinated at 3 or 6% for cold-storing fresh pork	The antioxidant activity of juices (garlic and onion) on fresh pork during storage depends on marinade concentration. All treated samples obtained greater scores for taste, juiciness, and tenderness than untreated samples	(Kim et al., 2010)
Ginger and pineapple	To enhance the flavor of barbecued culled dairy goat using ginger and pineapple juices as well as sodium bicarbonate (SB)	Marinating dairy goat meat in pineapple juice and SB may result in a quality improvement	(Kaewthong et al., 2021)
Australian garlic	To determine the phytochemical properties and antimicrobial activity of Australian garlic cultivars (*Allium sativum* L.)	Observed significant bioactive phytochemical variations among garlic cultivars and tissues (skin and cloves). Australian garlic skin and cloves contained more bioactive phytochemicals than imported commercial garlic	(Phan et al., 2019)
Edible mushroom	To evaluate qualitative characteristics, microstructure, and protein degradation of pork longissimus dorsi marinated with edible mushroom powders	Mushroom-based marinade enhanced the water holding capacity and tenderness of pork samples and minimized both Z-disk and M-line of pork sarcomere marinated with edible mushrooms	(Fu et al., 2022)
Sweet basil	To identify the physical quality of local chicken through marination with sweet basil seasoning	Sweet basil may decrease the pH value, retain the water content, minimize cooking loss and drip loss, and promote meat tenderness	(Patriani et al., 2021)
Garlic, pepper, onion red pepper, and tomato	To examine the effects of numerous commercial marinades and sous-vide cooking on the color, tenderness, cooking loss, and flavor of semi-membranous cow muscles	Sous-vide beef's eating quality, including tenderness, as enhanced by marinades containing red pepper, garlic, pepper, onion, and tomato	(Tkacz et al., 2021)
Coriander	To examine the impact of coriander root and leaf extract marinades on the development and prevention of polycyclic aromatic hydrocarbons (PAHs) in roasted duck wing	Coriander root extract marinade inhibited the production of PAHs in roasted duck wings to a larger extent than coriander leaf extract marinade	(Yu et al., 2023)
Blackberry, pomegranate, rosehip and grape	To assess the impact of the marination procedure using fruit vinegar marination liquids on the quality and safety of meat	The most efficacious marinade for preventing pathogens was rosehip vinegar. *L. monocytogenes* was the pathogen most sensitive to marinating solutions, and rosehip vinegar effectively reduced the hardness of meat samples	(Sengun et al., 2021)
Olive leaf	To explore the efficacy of olive leaf extract against a broad spectrum of food spoilage microorganisms and the usage of olive leaf extract as a preservative in the anchovy fillet marination process	Because the extract extends the shelf life of the product without changing its organoleptic properties, it might be used in the food sector as a natural antioxidant and antibacterial food additive	(Testa et al., 2019)

Continue...

Table 1. Continuation.

Plants/herbs	Study aim	Key findings	Reference
Ginger, lemon grass, Turmeric, curry leaf, and torch	To examine the ability of four herbs and spices to prevent the development of HCAs in grilled meat	All spices/herbs, whether used alone or in combination, were observed to lower total HCA concentrations in marinated grilled beef	(Sepahpour et al., 2018)
Green tea, white tea, yellow tea, oolong tea, dark tea, and black tea	To examine the prevalence of PAHs in charcoal-grilled chicken wings and the effect of six tea marinades and their fundamental components on the formation of PAHs	The most effective inhibitor of PAH formation was green tea	(Wang et al., 2018)
Lemon, thyme, and rosemary	To determine how the microbiological profile and sensory quality of fresh chicken are affected by marinating the chicken in natural plant extracts prior to irradiation	Irradiation had an additional impact, along with the marinade's effect, in lowering microbial proliferation during storage	(Mahrour et al., 2003)
Tomato and garlic	To examine the impact that extracts of tomato and garlic have on preventing the oxidation of lipids in anchovies that have been marinated	Both tomato and garlic extracts showed inhibitory impact on the lipid oxidation of marinated samples. However, tomato extract seemed more efficient over garlic extract in preventing lipid oxidation	(Gokoglu et al., 2012)
Grape seed and green tea	To examine the effect of natural extracts of green tea or commercial grape seed in combination with different concentrations of synthetic tert-methyl-butylhydroquinone on lipid oxidation and the redness of goat meats	Plant extracts would substantially reduce lipid oxidation in goat meats, although grape seed extract enhanced redness, although green tea extract lowered it	(Rababah et al., 2011)
Bay leaf and green tea	To analyze the microbiological, sensorial, and physical aspects of bay leaf and green tea extract marinades on anchovy	Green tea and bay leaf extracts lowered the microbial load, TVB-N concentration, and TBARS (thiobarbituric acid reactive substance) level, despite the undesirable dark color it produced	(Bilgin Fıçıcılar et al., 2018)
Rosemary, oregano, sage leaf, hop, licorice root, curcuma, clove bud, oregano leaf, and ajwain seed	To investigate the impact of plant extracts high in carbon dioxide on the oxidation of triacylglycerol in Atlantic salmon during cooking and storage	Marination with plant extracts could increase the fish shelf life, alongside positive impact of variety of plants as marinade components	(Tarvainen et al., 2015)
Hibiscus	To investigate the feasibility of preventing the formation of heterocyclic aromatic amines (HAAs) in fried beef patties by employing marinades with varying concentrations of hibiscus extract	Marinating meat using hibiscus extracts prior to frying may inhibit the formation of PhIP and MeIQx without negative impact to organoleptic characteristics	(Gibis & Weiss, 2010)

3 MARINATION/MARINADES: BRIEFS ON PREPARATION AND APPLICATIONS

To reiterate, the purpose of marination of meat products has traditionally been to improve flavor/tenderness as well as enhance product shelf life. Marination importantly targets to increase raw meat yield, which could provide advantages to consumers/producers, especially in attaining a juicier meat texture alongside reduced water loss during cooking (Alvarado & McKee, 2007). Herbs/spices and water are the two primary functional components of plant-based marinades. Improving the appearance and quality of meat products with a range of flavors and aromas remains crucial when incorporating plants and herbs into marinade solutions. In addition, the antioxidant and antibacterial properties would vary with marinade compositions. To achieve this, extracting the precise concentrations from herbs and spices by adding water can be challenging. Furthermore, the addition of water prior to marination compensates for the anticipated weight loss during cooking, thereby maximizing product juiciness/yield (Xiong, 2005). Indeed, water acts as a carrier and dispersant for salt, phosphates, sugar, and water-soluble flavoring and coloring agents in the marinade (Zhang et al., 2022). When applied to the surface of meat in high concentrations, salt acts as a preservative by improving the flavor, increasing the amount of moisture that is retained, acting as a synergist with sodium tripolyphosphate to extract salt-soluble proteins, dehydrating the meat, and inhibiting the outgrowth of *Clostridium botulinum* (Keeton & Osburn, 2001).

Major preparation steps for making a marinade are shown in Figure 1. These preparation steps, from assembly/collection of the herbs/spices from the source through separation/sorting to the refrigerated storage, would vary depending on factors such as location, culture/traditions, the meat type to be marinated, availability of supporting ingredients/flavors, and the period of use. Huffstetler (2020) demonstrated that despite the availability of bottled marinades found in various stores, consumers can make their own. Capably, the enzymes in marinades help to break down fibers, tenderize meat, as well as add flavor to meat products. Largely, the marinating process could resemble brining, wherein the latter has a much lower acid level. Also, the marinating process would resemble pickling, wherein the latter requires longer periods. Major proportions of marinade constituents are shown in Figure 2. Besides the acid- and oil-based marinades, there is the culinary perspective that marinade ratios are necessary. Alongside, marinades are dependent on flavor profiles, which are guided by such key components like oils, chili peppers, condiments, wine, vinegar, dairy, fruits, and herbs/spices. Marinade times are also essential; from a culinary perspective, meats like beef and lamb could be as short as 2 h and as long as 24 h, whereas poultry chicken/turkey could also be as short as 2 h but as long as 6 h (The Culinary Pro, 2022).

Table 2 contains information on marinating techniques, mechanisms of action, benefits, and drawbacks. In the meat industry, there are a range of marinating techniques, including

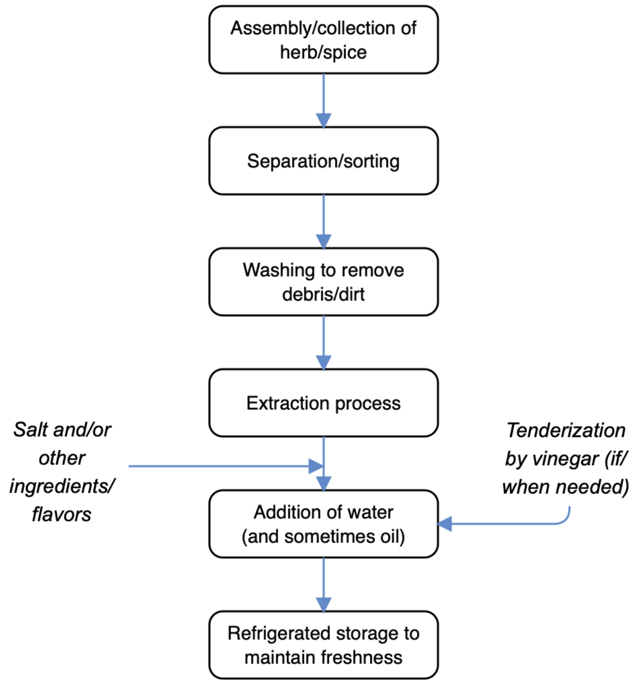

Figure 1. Major preparation steps of making a marinade.

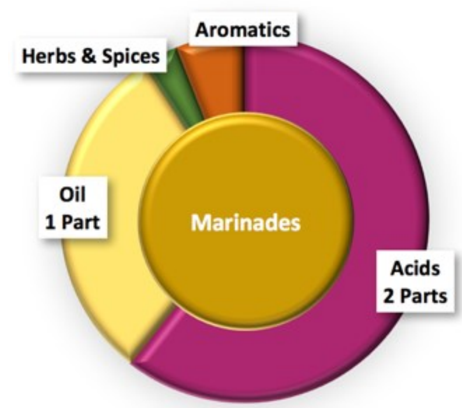

Figure 2. Major proportions of marinade constituents (Courtesy of The Culinary Pro).

Table 2. Marinating methods, merits, and demerits.

Methods	Mechanism of action	Merits	Demerits	References
Immersion or soaking	Completely immersing the substrate in the marinade and enabling the liquid to permeate the meat through diffusion over a time period	Most affordable technique of marinating; no sophisticated equipment needed; suitable for home or small businesses	No uniformity in ingredient distribution, time-consuming, and a lower and slower marinade absorption rate	(Yusop et al., 2010)
Injection	As the probes or needles are removed, the marinade is injected, distributing the marinade throughout the meat product	More relevant to the meat sector, better control over the marinating process by providing a precise amount of marinade solution, shorter time, and possibility to utilize the remaining marinade	Higher cooking losses, may create holes in the meat and allowing for leakage, a probable diminution in the meat's ability to retain water, and an increase in purging. Expensive equipment, not practical or desirable for tiny meat portions	(Yusop et al., 2012)
Tumbling	Marinating poultry meat to provide a ready-to-cook, value-added product, which involves massaging and tumbling to bring about extraction of protein exudates, at either the food processing plant or the supermarket or butcher shop	Protein coagulates upon heating to improve binding properties. The extracted protein acts as a sealer, which facilitates the retention of moisture contained within the meat tissue	Increased initial equipment expenses, may tear fragments with poor size or utility, more aggressive to the muscle	(Alvarado & McKee, 2007)
Injection/tumbling combination	Injection process followed by tumbling process	Delivers the highest level of overall product improvement and the highest throughput of completed products in the shortest length of time. Optimizes yields and weight gain while minimizing solution loss. Sensory quality improvement	Increased cost of equipment, increased manpower for product transfer and handling, can increase bacterial numbers	(Oyetunji, 2009; Williams, 2012).

immersion, multi-needle injection, and tumbling, that are used to enhance the absorption of marinade into meat products. Specifically, each marination technique has specific benefits and drawbacks and should be selected depending on the manufacturer's demands and the intended final product (Yusop et al., 2010). For instance, immersion or soaking requires the complete immersion of substrate in the marinade to enable the liquid to permeate the meat through diffusion over time, which may help achieve a greater quality enhancement of the product, like in poultry (Yusop et al., 2010). The needle injection approach requires a strategy such that, as probes or needles are removed, the marinade is injected and, as such, distributed throughout the meat product (Yusop et al., 2012). The tumbling approach requires the marinating of poultry meat so as to provide a ready-to-cook yet value-added output product. This involves the massaging and tumbling that bring about the extraction of protein exudates. The tumbling process leads to products with enhanced juiciness and allows for improved slicing attributes (Alvarado & McKee, 2007). There could be a combination of injection process followed by tumbling process, which allows for the highest level of overall product improvement together with throughput of completed products in the shortest length of time (Oyetunji, 2009; Williams, 2012).

4 SOME THERMAL PROCESSES APPLIED TO MARINATED MEAT PRODUCTS

4.1 Sous-vide

The cooking procedure is considered one of the ultimate factors in determining the final quality of meat products. An adequate choice of final thermal processing is crucial for beef tenderness, flavor, and juiciness, and it should be selected uniquely for each (Guzek et al., 2015; Liu et al., 2020). Sous-vide cooking involves subjecting raw materials with intermediate foods to controlled conditions involving specific temperature and time (the low-temperature long-time cooking method) within heat-stable vacuumized pouches (Schellekens & Martens, 1992). Meat would be cooked at temperatures ranging between 55 and 95°C for many hours or days, depending on its type, thickness, and connective tissue composition, and then rapidly cooled (Ayub & Ahmad, 2019; Baldwin, 2012; Ortuño et al., 2021).

Sous-vide preserves sensory quality, reduces lipid oxidation, extends shelf life, eliminates cooking losses, and increases the process yield by reducing material, labor, and storage expenses (Thathsarani et al., 2022). Sous-vide processing alone might not be sufficient to ensure the quality and safety of meat products for consumers. However, when combined with non-thermal processes like marination, the results of sous-vide cooking could further excel. This was proved by a number of workers (Haskaraca et al., 2019; Hong et al., 2016; Karyotis et al., 2017; Lee et al., 2021; Tkacz et al., 2021, 2022), who combined marination with sous-vide cooking to improve the quality and safety of different meat products. For instance, Haskaraca et al. (2019) proposed that marination with grapefruit seed extract in sous-vide-processed Doner Kebabs would increase the microbiological safety of these goods by inactivating *Listeria monocytogenes*, thereby protecting public health. The addition of the marinade boosted the pathogen's sensitivity to heat throughout this phase. Another instance is Karyotis et al. (2017), who demonstrated that sous-vide cooking effectively eliminated *Listeria monocytogenes* and *Salmonella* spp. from marinated chicken breast.

Sous-vide applied to chicken breast with lime juice (as a marinade) enhanced the meat quality by suppressing the pink discoloration and bacterial development (Hong et al., 2016). Probably, lime juice marinade might have contributed to preventing the pink coloration of cooked sous-vide chicken breasts by preserving their refrigerated freshness for up to 14 days. More so, the use of a marinating process prior to the application of sous-vide cooking could improve the flavor, tenderness, and juiciness of beef meat (Tkacz et al., 2021). Red pepper, garlic, onion, and tomato-based marinades facilitated beef steak production with promising quality attributes, such as high sensory scores as well as reduced shear force and cooking loss. Additionally, marinating would positively influence the fatty acid content of beef, thereby enhancing the production of ready-to-eat meat products (Tkacz et al., 2021).

4.2 Boiling/steam cooking

Steaming, air-steaming, and superheated steaming are steam-based cooking procedures commonly employed in the meat sector (Barbanti & Pasquini, 2005; Bowker et al., 2018; Cho & Choi, 2021; Choi et al., 2016; Modzelewska-Kapituła et al., 2019; Mudalal et al., 2014; O'Neill et al., 2019a). Steam cooking has been modified from the normal oven cooking process by injecting steam into the oven chamber to produce juicier meat products. Steam cooking occurs at a higher temperature than sous vide, ranging from 100 to 240°C (Isleroglu et al., 2015), wherein the meat is cooked to the necessary temperature within a certain time period (Modzelewska-Kapituła et al., 2019). Steam cooking marinated pork chops under high pressure, examined by O'Neill et al. (2019a), showed improved physicochemical (cook loss, moisture content, WBSF, and n-6:n-3 PUFA ratio) and sensory (texture, tenderness, juiciness, and OSA) attributes. Kougiagka et al. (2022) examined the qualitative attributes of boiled snail fillets marinated with acids, salt, different oils, and spices. The hardness of the cylindrical mid-posterior region of the boiled snail fillet signaled the presence of the flesh's fat and carbohydrate contents.

Elsewhere, Jiao et al. (2020) analyzed the nutritional and safety characteristics of Hengshan goat leg meat, wherein processes like steaming, boiling, and braising produced meats were shown to enhance the balanced nutrients and reduce the carcinogens. Combining steam injection with air convection in the oven chamber can help increase the tenderness and decrease the cooking losses of meat muscle (Murphy et al., 2001). Besides superheated steam and hot smoking (Cho & Choi, 2021) and microwave heating and steaming (Jantaranikorn et al., 2023), the combined use of marinating and air-steaming processing techniques for chicken breast meats, which result in minimal cooking loss and tenderized flesh, appear promising (Barbanti & Pasquini, 2005) and potentially improve proximate composition. Moreover, the extra sensible heat that comes from superheated steam can help elevate the anticipated temperature to surpass the saturation point at a given pressure (Cenkowski et al., 2007; Choi et al., 2016). Besides, several cooking techniques on marinated chicken steak were evaluated, and it was found that chicken steak cooked with superheated steam had enhanced textural features and reduced cooking loss, as well as a greater overall acceptance than other cooking methods.

4.3 Grilling

Grilling, whether charcoal or oven grill type, involves significant quantities of direct as well as radiant dry heat transferred by conduction (Ježek et al., 2020; Liao et al., 2010; Schröder, 2003), which, when applied to animal meat products, produce a considerable range of compounds that confer specific aroma, taste, and flavor (Bassam et al., 2022; Tkacz & Modzelewska-Kapituła, 2022). Like from a typical oven grill, such direct/radiant heat would produce relatively high temperatures capable of facilitating fat and juiciness loss (Beckett, 2012), as well as reducing the cooking time of any given meat slice (Ježek et al., 2020; Schröder, 2003). Largely, oven-grilling is considered healthier than the charcoal type and is increasingly of research food processing interest, particularly for animal/meat food products (Okpala et al., 2022). Additionally, there is increasing evidence that the oven-grill approach appears to be increasingly employed across households in various parts of the globe, which suggests this facility is commercially and widely available. Hence, one would consider the application of oven grilling to animal meat products as recommendable (Okpala et al., 2023).

Previous studies on grilling marinated animal meat products have ranged from establishing the formation of heterocyclic amine carcinogens (Salmon et al., 1997), PAHs (Viegas et al., 2014), reduction of carcinogenic HAAs (Viegas et al., 2015), to effects on quality attributes like nutritional, physicochemical, microstructural, and organoleptic/sensory attributes (Komoltri & Pakdeechanuan, 2012; Okpala et al., 2022; Vidal et al., 2020). For instance, Viegas et al. (2015) investigated the effect of beer marinades on charcoal-grilled pork, specific to the formation of HAAs. These researchers showed beer marinades would mitigate the consumption impact of well-done grilled pork meat, thereby reducing the formation of cooking carcinogens. Moreover, Okpala et al. (2022) analyzed the antioxidant, organoleptic, and physicochemical changes in various marinated oven-grilled chicken breast meat samples. These workers showed that the oven-grilling method was capable of moderating the antioxidant, organoleptic, and physicochemical value ranges in the various marinated chicken breast meat samples. Recently, Okpala et al. (2023) equally applied the combination of marination and oven-grilling to pork neck meat. The results showed a wide range of quality attributes, from the physicochemical to sensorial standpoints.

4.4 Roasting and frying

During this cooking process of frying, there is a high temperature at normal air pressure and rapid heat transfer, which helps to make it efficient (Negara et al., 2021). Moreover, when considering frying, it can also improve the nutritional value, flavor, and sensory qualities of foods (Ziaiifar et al., 2008). Arcanjo et al. (2019) assessed the effect of wine marination on the degree of lipid and protein oxidation, volatile profile, and sensory qualities of roasted beef strip steaks. In general, wine-based marination had a positive impact on the sensory qualities of roasted beef, lowering lipid oxidation and rancidity and providing fragrant esters, alcohols, and lactones. Al-Dalali et al. (2022b) studied the impact of frozen storage on the volatile aldehydes, volatile alcohols, lipid oxidation, and fatty acid content of marinated roasted beef. Marination of beef enhanced the amount of fatty acids and thiobarbituric acid-reactive chemicals, while the roasting procedure primarily contributed to the formation of several volatile compounds.

Using chemical and sensory evaluations, Al-Dalali et al. (2022a) showed the marination would enable various plant recipes to influence the taste profile of roasted beef flesh. Various marinade formulas would improve the aroma profile of roasted beef, especially in (marinade) solution comprising water, 2% salt, 0.5% sugar, 0.5% soy sauce, and spices. In the manufacture of braised pigeon, Qian et al. (2021) showed marinating and frying were able to influence the taste of the flesh. By braising and frying, the amount and concentration of volatile compounds were significantly altered. In addition to some alkenes and alcohols detected in marinated pigeon flesh, the frying activity enabled the Maillard process and fat oxidation to increase the formation of essential meat taste compounds such as benzaldehyde, phenylacetaldehyde, octanal, nonanal, heptanal, e-2-octenaldehyde, and others.

4.5 Microwave and ohmic heating

Providing significant commercial potential in the food processing business (Guo et al., 2017), microwave utilizes a dielectric heating method alongside electromagnetic wave energy of between 0.3 and 300 GHz (Jiang et al., 2014). Food materials would absorb microwave energy, which would result in (microwave) attenuation (Xu et al., 2021). Indeed, the microwave concept has broad usage in the food sector, including cooking, pasteurization, drying, sterilizing, baking, etc. (Chandrasekaran et al., 2013). Recent studies have shown that microwaves can be combined with other processing methods and subsequently applied to marinated meat products (Jantaranikorn et al., 2023; Pankyamma et al., 2021; Wang et al., 2022). For instance, Wang et al. (2022) studied the flavor attributes of marinated pork belly cooked using conventional pan-heating, microwave heating, and microwave coupled with conduction heating. Microwave heating was shown to disrupt the integrity of the microstructure and increase cooking loss (50.33%) and sodium ion concentration (10.8 mg/g) by about 1.5 times that of microwave coupled with conduction heating. Also, microwave heating may expedite the breakdown of proteins and the thermal destruction of ribonucleotides, resulting in larger concentrations of free amino acids and nucleotides compared to conventional thermal heating. Pankyamma et al. (2021) investigated the effects of microwave power and drying techniques on the quality of tuna chunks marinated with salt, chili powder, turmeric powder, and pepper powder. The samples marinated and dried at 700 W displayed excellent rehydration capabilities and enhanced microbiological stability, although lipid oxidation was increased in the same samples.

Ohmic heating is a volume heating method that generates heat depending on the resistance of the material to the applied current (Zell et al., 2010). Also providing significant commercial potential in the food processing business, ohmic heating involves the conversion of dissipated electrical energy into heat that elevates the system's temperature, prompting considerable changes in food material components and microstructure, such as protein denaturation and water migration (Ángel-Rendón et al., 2020; Gavahian et al., 2019). Given its quick processing time, ohmic heating would inhibit lipid/protein oxidation (Kang et al., 2021). The efficiency of ohmic heating relies on the composition and physical features of the given food item, particularly its electrical conductivity (Varghese et al., 2014; Zell et al., 2009). By utilizing the benefits of ohmic heating, Kamonpatana and Sastry (2022) examined pretreatment methods aimed to both enhance and reduce the electrical conductivities of different solid particles, such as chicken chow mein ingredients. The electrical conductivity of chicken was most difficult to modify by blanching alone, necessitating marination in conductive fluids for the necessary durations. The impact of ohmic cooking on the water holding capacity, cooking loss, and color of marinated pork short shank was evaluated by Ángel-Rendón et al. (2019). Ohmic cooking of pork might have advantages in the culinary trade owing to the shorter cooking durations that can be used without substantially impacting essential parameters such as cooking loss, color, and water holding capacity.

4.6 High hydrostatic and ultrasound techniques

Alongside the marination process, the incorporation of supplemental strategies to assure quality and enhance marinade absorption would require the effective utilization of available procedures. Retention as well as uptake of marinade could improve by combining with other technologies such as ultrasounds (Shi et al., 2020; Xiong et al., 2020) and high hydrostatic and hydrodynamic pressure (Bowker et al., 2010; O'Neill et al., 2019b), the latter probably effective in enhancing the marination process yield (Xu et al., 2019). By testing the effectiveness of high hydrostatic pressure in accelerating pork chop marinade absorption, O'Neill et al. (2019b) demonstrated that 400 MPa could improve marinade absorption and hence enhance flavor acceptance. Depending on the pressure level used, the high hydrostatic pressure application improved the pork chops' shelf life; nevertheless, the texture was significantly impacted. Moreover, the marinade seemed to conceal the decolorization/whitening impact of high hydrostatic pressure on raw meat. The utilization of hydrodynamic pressure processing increased the assessment factors of the marinating process, as indicated by Bowker et al. (2010). The hydrodynamic pressure treatment of turkey breasts resulted in better textural qualities with no adverse impacts on muscle color or water retention. Additionally, hydrodynamic pressure treatment boosted marinade absorption, processing yield, and the tenderness of the final cooked product (Xiong et al., 2020). Besides, the major impact of ultrasound coupled with SB-assisted marination on chicken breast meat was the enhancement of meat tenderization, water holding capacity, and curing efficiency. Elsewhere, Shi et al. (2020) demonstrated that ultrasound coupled with a marination procedure (using potassium alginate) may tenderize aged chicken breast flesh. By evaluating the softness of cooked meats, these workers detected reduced shear force, which helped optimize the tenderness of aged chicken breast.

5 SOME QUALITY IMPLICATIONS OF THERMALLY PROCESSED MARINATED MEAT PRODUCTS

Typically, meat must be prepared before consumption. Thermal processes cause several positive effects on meat, including inactivation of anti-nutrient enzymes (Sobral et al., 2018), taste and flavor enhancement, microorganism destruction, shelf life extension, tenderness (Abdel-Naeem et al., 2021; Bognár, 1998), and improved digestibility (Rodriguez-Estrada et al., 1997; Sobral et al., 2018). However, they also produce some negative effects like aromatic polycyclic hydrocarbons (Onopiuk et al., 2021) and nutritional losses (Rodriguez-Estrada et al., 1997). HAAs and PAHs are potential and confirmed carcinogens (Pogorzelska-Nowicka et al., 2022). Cooking reduces the nutritional value of meat by destroying some vitamins and minerals, decreasing the meat's moisture content, denaturing muscle proteins, and altering the structure of myofibrillar and connective tissue (Abdel-Naeem et al., 2021). In addition, heating accelerates lipid oxidation, particularly for PUFA fats, which are abundant in rabbit meat (Lopes et al., 2015). The methods of thermal treatment, the cooking environment (dry or wet), cooking temperature, and cooking duration significantly affect the above-cited cooking changes (Combes et al., 2004). In this sense, red blood spots (RBS) may be caused by the insufficient denature of blood residues in blood arteries owing to inadequate heat transfer (Sturkie, 2012). Potentially, thermal processes may also affect the number of antioxidants originally present in marinated beef (Thomas et al., 2010).

5.1 Inhibitions of carcinogens

Both HCAs and PAHs are essential carcinogenic and poisonous substances that are mostly found in cooked protein-rich diets, particularly meat products (Hsu & Chen, 2020). Accordingly, plant-based marinades prior to cooking have been researched for their inhibiting effects (Bao et al., 2020; Gumus & Kizil, 2022; Khan et al., 2021, 2022; Macit & Kizil, 2022; Yu et al., 2023). For instance, Yu et al. (2023) examined the impact and principal constituents of coriander root and leaf extract marinades on the development and inhibition of PAHs in roasted duck wings. Coriander root extract was found to inhibit the development of PAHs in roasted duck wings more effectively than coriander leaf extract. Phenolic compounds in coriander marinades seemed most crucial in PAHs inhibition.

Khan et al. (2022) examined the impact of Za'atar marinades on the development of polar and non-polar HCAs in fried beef patties. The ideal marination durations seemed so when a decrease in HCA exposure happened, which provided healthier meat products as well as potential and novel food safety hazards. Production differences in HCAs seemed likely linked to natural antioxidants present in Za'atar, which boost oxidative activity and result in the reduction and/or synthesis of HCAs within the thermally processed meat. Bao et al.

(2020) investigated the mechanism of black pepper's effect on HAAs in tilapia fillets cooked at various temperatures. Black pepper, often employed to enhance food taste, might lend its use in preparing fish given the HAA limitations. The addition of 1.0% black pepper largely inhibited total HAAs in the fried fish fillets, thereby enhancing the quality/safety of fried aquatic muscle products. Moreover, olive leaf extract marinades (Macit & Kizil, 2022) and *Vaccinium myrtillus* L. extract marinades (Gumus & Kizil, 2022) possess significant inhibitory capacity on the formation of HAAs in pan-cooked salmon and chicken thigh meat, respectively.

5.2 Red blood spots

Consumers as well as relevant stakeholders in the animal meat industry consider the occurrence of RBS to be rare/unacceptable in commercially prepared food. This is largely because it indicates undercooked meat products (Bae et al., 2018; Smith & Northcutt, 2003). RBS is said to occur when a red blood spot is detected inside/within transverse meat cuts. The most likely cause of this defect is when blood lingers within the vessels post-slaughter. The ingredients employed in marinade solutions may alter the thermal denaturation of hemoglobin (Hb), hence influencing the color of blood residues in vessels after cooking (Jantaranikorn & Yongsawatdigul, 2020). Furthermore, to prevent apparition of RBS, marinated chicken breasts have to be cooked to an internal temperature of 85°C for at least 1 min (Jantaranikorn & Yongsawatdigul, 2020). Moreover, the potential reduction of RBS in cooked marinated chicken breasts can occur using a combination of microwave heating and steaming (Jantaranikorn et al., 2023). Accordingly, microwave pre-heating for 7 min, followed by steaming to a core temperature of 82°C, seems an effective heating technique for lowering RBS incidence, along with reasonable cooking loss. Consequently, heat processes may decrease RBS during the marination.

5.3 Loss of nutrients

Thermal processes may affect the nutritional composition of meat and fish, including water content, lipid profile, amino acids, and bioactive components such as vitamins and polyphenols, therefore impacting the quality of the final product (Ersoy & Özeren, 2009; Garcia-Segovia et al., 2007; Jensen et al., 2014). Preventing nutrient loss should be a target, and that appears to be a promising takeaway that the use of marinades/margination process provides when applied to meat products prior to thermal treatment. For instance, Xie et al. (2022b) studied the effects of tea polyphenol treatments (control, unmarinated, and marinated) on the lipid oxidation of scallop adductor muscle during hot air drying. Marinating scallops in tea polyphenols enhanced the antioxidant activity, prevented lipid oxidation, and preserved the scallops' nutritional content throughout drying. Another instance is the work of Xie et al. (2022a), which showed that marination with bamboo leaves might suppress lipoxygenase activity and interfere with free radical chain reaction. Moreover, Okpala et al. (2022) analyzed the antioxidant, organoleptic, and physicochemical changes in various marinated oven-grilled chicken breast meat. The oven-grilling method, by moderating the antioxidant, organoleptic, and physicochemical value ranges in the various marinated chicken breast meat samples, may well be controlling the loss of nutrients.

6 CONCLUDING REMARKS

This current treatise has provided relevant information about how the quality of animal meat products would be enhanced through a combination of plant-based marinations and thermal processes. Indeed, marination demonstrates great promise to increase the tenderness of meat as well as enhance its flavor and water-holding capacity. Moreover, the intention of novel thermal processing technologies remains to fulfill the expectations of customers, but only to a certain degree. From this synthesis, the addition of marinades (the marination process) was shown as a key to enhance the quality of meat products. Promisingly, the application of thermal processes would go further to strengthen the marinades' efficacy. The direction of future work could be further literature synthesis involving systematic or meta-analysis of animal meat products that have been subjected to a combination of marinades/marination with thermal processing. Conducting such systematic or meta-analysis would help reveal new understanding of the existing data, especially the effectiveness and efficacy of the combination of marinades/marination and thermal processing.

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REFERENCES

Abdel-Naeem, H. H. S., Abdelrahman, A. G., Imre, K., Morar, A., Herman, V., & Yassien, N. A. (2022). Improving the Structural Changes, Electrophoretic Pattern, and Quality Attributes of Spent Hen Meat Patties by Using Kiwi and Pineapple Extracts. *Foods*, *11*(21), 3430. https://doi.org/10.3390/foods11213430

Abdel-Naeem, H. H. S., Sallam, K. I., & Zaki, H. M. B. A. (2021). Effect of different cooking methods of rabbit meat on topographical changes, physicochemical characteristics, fatty acids profile, microbial quality and sensory attributes. *Meat Science*, 181, 108612. https://doi.org/10.1016/j.meatsci.2021.108612

Al-Dalali, S., Li, C., & Xu, B. (2022a). Evaluation of the effect of marination in different seasoning recipes on the flavor profile of roasted beef meat via chemical and sensory analysis. *Journal of Food Biochemistry*, *46*(6), e13962. https://doi.org/10.1111/jfbc.13962

Al-Dalali, S., Li, C., & Xu, B. (2022b). Insight into the effect of frozen storage on the changes in volatile aldehydes and alcohols of marinated roasted beef meat: Potential mechanisms of their formation. *Food Chemistry*, *385*, 132629. https://doi.org/10.1016/j.foodchem.2022.132629

Alvarado, C., & McKee, S. (2007). Marination to Improve Functional Properties and Safety of Poultry Meat. *Journal of Applied Poultry Research*, *16*(1), 113-120. https://doi.org/10.1093/japr/16.1.113

Ángel-Rendón, S. V., Filomena-Ambrosio, A., Cordon-Díaz, S., Benítez-Sastoque, E. R., & Sotelo-Díaz, L. I. (2019). Ohmic cooking: Application of a novel technology in pork and influences on water holding capacity, cooking loss and colour. *International Journal of Gastronomy and Food Science*, *17*, 100164. https://doi.org/10.1016/j.ijgfs.2019.100164

Ángel-Rendón, S. V., Filomena-Ambrosio, A., Hernández-Carrión, M., Llorca, E., Hernando, I., Quiles, A., & Sotelo-Díaz, I. (2020). Pork meat prepared by different cooking methods. A microstructural, sensorial and physicochemical approach. *Meat Science*, *163*, 108089. https://doi.org/10.1016/j.meatsci.2020.108089

Ankri, S., & Mirelman, D. (1999). Antimicrobial properties of allicin from garlic. *Microbes and Infections*, *1*(2), 125-129. https://doi.org/10.1016/S1286-4579(99)80003-3

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

Awuchi, C. G., & Okpala, C. O. R. (2022). Natural nutraceuticals, especially functional foods, their major bioactive components, formulation, and health benefits for disease prevention-An overview. *Journal of Food Bioactives*, *19*, 97-123. https://doi.org/10.31665/JFB.2022.18317

Ayub, H., & Ahmad, A., 2019. Physiochemical changes in sous-vide and conventionally cooked meat. *International Journal of Gastronomy and Food Science*, *17*, 100145. https://doi.org/10.1016/j.ijgfs.2019.100145

Bae, S. M., Cho, M. G., Hong, G. T., & Jeong, J. Y. (2018). Effect of NaCl Concentration and Cooking Temperature on the Color and Pigment Characteristics of Presalted Ground Chicken Breasts. *Korean Journal for Food Science of Animal Resources*, *38*(2), 417-430. https://doi.org/10.5851/kosfa.2018.38.2.417

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chemistry*, *99*(1), 191-203. https://doi.org/10.1016/j.foodchem.2005.07.042

Baldwin, D. E. (2012). Sous vide cooking: A review. *International Journal of Gastronomy and Food Science*, *1*(1), 15-30. https://doi.org/10.1016/j.ijgfs.2011.11.002

Banerjee, M., & Sarkar, P. (2003). Inhibitory effect of garlic on bacterial pathogens from spices. *World Journal of Microbiology and Biotechnology*, *19*, 565-569. https://doi.org/10.1023/A:1025108116389

Bao, X., Miao, J., Fan, Y., & Lai, K. (2020). The effective inhibition of the formation of heterocyclic aromatic amines via adding black pepper in fried tilapia fillets. *Journal of Food Processing and Preservation*, *44*(5), e14435. https://doi.org/10.1111/jfpp.14435

Barbanti, D., & Pasquini, M. (2005). Influence of cooking conditions on cooking loss and tenderness of raw and marinated chicken breast meat. *LWT - Food Science and Technology*, *38*(8), 895-901. https://doi.org/10.1016/j.lwt.2004.08.017

Bassam, S. M., Noleto-Dias, C., & Farag, M. A. (2022). Dissecting grilled red and white meat flavor: Its characteristics, production mechanisms, influencing factors and chemical hazards. *Food Chemistry*, *371*, 131139. https://doi.org/10.1016/j.foodchem.2021.131139

Beckett, F. (2012). *Sausage & Mash*. Bloomsbury.

Bilgin Fıçıcılar, B., Gençcelep, H., & Özen, T. (2018). Effects of bay leaf (Laurus nobilis) and green tea (Camellia sinensis) extracts on the physicochemical properties of the marinated anchovies with vacuum packaging. *CyTA - Journal of Food*, *16*(1), 848-858. https://doi.org/10.1080/19476337.2018.1485747

Bognár, A. (1998). Comparative study of frying to other cooking techniques influence on the nutritive value. *Grasas y Aceites*, *49*(3-4), 250-260. https://doi.org/10.3989/gya.1998.v49.i3-4.746

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

Bowker, B. C., Maxwell, A. D., Zhuang, H., & Adhikari, K. (2018). Marination and cooking performance of portioned broiler breast fillets with the wooden breast condition. *Poultry Science*, *97*(8), 2966-2970. https://doi.org/10.3382/ps/pey144

Cadun, A., Kışla, D., & Çaklı, Ş. (2008). Marination of deep-water pink shrimp with rosemary extract and the determination of its shelf-life. *Food Chemistry*, *109*(1), 81-87. https://doi.org/10.1016/j.foodchem.2007.12.021

Cenkowski, S., Pronyk, C., Zmidzinska, D., & Muir, W. E. (2007). Decontamination of food products with superheated steam. *Journal of Food Engineering*, *83*, 68-75. https://doi.org/10.1016/j.jfoodeng.2006.12.002

Chandrasekaran, S., Ramanathan, S., & Basak, T. (2013). Microwave food processing: a review. *Food Research International*, *52*(1), 243-261. https://doi.org/10.1016/j.foodres.2013.02.033

Chen, C., Liu, C.-H., Cai, J., Zhang, W., Qi, W.-L., Wang, Z., Liu, Z.-B., & Yang, Y. (2018). Broad-spectrum antimicrobial activity, chemical composition and mechanism of action of garlic (Allium sativum) extracts. *Food Control*, *86*, 117-125. https://doi.org/10.1016/j.foodcont.2017.11.015

Cheok, C. Y., Chin, N. L., Yusof, Y. A., Mustapa Kamal, S. M., & Sazili, A. Q. (2011). Effect of marinating temperatures on physical changes of traditionally marinated beef satay. *Journal of Food Processing and Preservation*, *35*(4), 474-482. https://doi.org/10.1111/j.1745-4549.2010.00490.x

Cho, W.-H., & Choi, J.-S. (2021). Sensory quality evaluation of superheated steam-treated chicken leg and breast meats with a combination of marination and hot smoking. *Foods*, *10*(8), 1924. https://doi.org/10.3390/foods10081924

Choi, Y.-S., Hwang, K.-E., Jeong, T.-J., Kim, Y.-B., Jeon, K.-H., Kim, E.-M., Sung, J.-M., Kim, H.-W., & Kim, C.-J. (2016). Comparative Study on the Effects of Boiling, Steaming, Grilling, Microwaving and Superheated Steaming on Quality Characteristics of Marinated Chicken Steak. *Korean Journal of Food Science and Animal Resources*, *36*(1), 1-7. https://doi.org/10.5851/kosfa.2016.36.1.1

Cobos, Á., & Díaz, O. (2015). Chemical composition of meat and meat products. In P. C. K. Cheung & B. M. Mehta (eds.), *Handbook of Food Chemistry* (pp. 471-510). Springer-Verlag. https://doi.org/10.1007/978-3-642-36605-5_6

Combes, S., Lepetit, J., Darche, B., & Lebas, F. (2004). Effect of cooking temperature and cooking time on Warner–Bratzler tenderness measurement and collagen content in rabbit meat. *Meat Science*, *66*(1), 91-96. https://doi.org/10.1016/S0309-1740(03)00019-6

Ersoy, B., & Özeren, A. (2009). The effect of cooking methods on mineral and vitamin contents of African catfish. *Food Chemistry*, *115*(2), 419-422. https://doi.org/10.1016/j.foodchem.2008.12.018

Farhadian, A., Jinap, S., Faridah, A., & Zaidul, I. S. M. (2012). Effects of marinating on the formation of polycyclic aromatic hydrocarbons (benzo[a]pyrene, benzo[b]fluoranthene and fluoranthene) in grilled beef meat. *Food Control*, *28*(2), 420-425. https://doi.org/10.1016/j.foodcont.2012.04.034

Fellenberg, M. A., Carlos, F., Peña, I., Ibáñez, R. A., Vargas-Bello-Pérez, E. (2020). Oxidative quality and color variation during refrigeration (4 °C) of rainbow trout fillets marinated with different natural antioxidants from oregano, quillaia and rosemary. *Agriculture and Food Science*, *29*(1), 43-54. https://doi.org/10.23986/afsci.87078

Fu, Q., Shi, H., Hu, D., Cheng, J., Chen, S., & Ben, A. (2022). Pork longissimus dorsi marinated with edible mushroom powders: Evaluation of quality traits, microstructure, and protein degradation. *Food Research International*, *158*, 111503. https://doi.org/10.1016/j.foodres.2022.111503

Garcia-Segovia, P., Andres-Bello, A., & Martinez-Monzo, J. (2007). Effect of cooking method on mechanical properties, color and structure of beef muscle (M. pectoralis). *Journal of Food Engineering*, *80*(3), 813-821. https://doi.org/10.1016/j.jfoodeng.2006.07.010

Gavahian, M., Tiwari, B.K., Chu, Y.-H., Ting, Y., & Farahnaky, A. (2019). Food texture as affected by ohmic heating: Mechanisms involved, recent findings, benefits, and limitations. *Trends Food Science Technology*, *86*, 328-339. https://doi.org/10.1016/j.tifs.2019.02.022

Gazwi, H. S. S., Mahmoud, M. E., & Hamed, M. M. (2020). Antimicrobial activity of rosemary leaf extracts and efficacy of ethanol extract against testicular damage caused by 50-Hz electromagnetic field in albino rats. *Environmental Science and Pollution Research*, *27*, 15798-15805. https://doi.org/10.1007/s11356-020-08111-w

Gibis, M., & Weiss, J. (2010). Inhibitory effect of marinades with hibiscus extract on formation of heterocyclic aromatic amines and sensory quality of fried beef patties. *Meat Science*, *85*(4), 735-742. https://doi.org/10.1016/j.meatsci.2010.03.034

Gibis, M., & Weiss, J. (2012). Antioxidant capacity and inhibitory effect of grape seed and rosemary extract in marinades on the formation of heterocyclic amines in fried beef patties. *Food Chemistry*, *134*(2), 766-774. https://doi.org/10.1016/j.foodchem.2012.02.179

Gokoglu, N., Yerlikaya, P., & Topuz, O. K. (2012). Effects of Tomato and Garlic Extracts on Oxidative Stability in Marinated Anchovy. *Journal of Food Processing and Preservation*, *36*(3), 191-197. https://doi.org/10.1111/j.1745-4549.2011.00576.x

Golden, K. D., & Smith-Marshall, J. (2012). Characterization of Bromelain from *Morinda citrifolia* (Noni). *Journal of Scientific Research*, *4*(2), 445. https://doi.org/10.3329/jsr.v4i2.8125

Gumus, D., & Kizil, M. (2022). Reduction of heterocyclic aromatic amines formation in chicken thigh meat by Vaccinium myrtillus L. extract. *Journal of Food Processing and Preservation*, *46*(11), e17119. https://doi.org/10.1111/jfpp.17119

Guo, Q., Sun, D.-W., Cheng, J.-H., & Han, Z. (2017). Microwave processing techniques and their recent applications in the food industry. *Trends in Food Science & Technology*, *67*, 236-247. https://doi.org/10.1016/j.tifs.2017.07.007

Guzek, D., Glabska, D., Gutkowska, K., Wierzbicki, J., Wozniak, A., & Wierzbicka, A. (2015). Influence of cut and thermal treatment on consumer perception of beef in Polish trials. *Pakistan Journal of Agricultural Sciences*, *52*(2), 521-526.

Haskaraca, G., Juneja, V.K., Mukhopadhyay, S., & Kolsarici, N. (2019). The effects of grapefruit seed extract on the thermal inactivation of Listeria monocytogenes in sous-vide processed döner kebabs. *Food Control*, *95*, 71-76. https://doi.org/10.1016/j.foodcont.2018.07.006

He, F.-Y., Kim, H.-W., Hwang, K.-E., Song, D.-H., Kim, Y.-J., Ham, Y.-K., Kim, S.-Y., Yeo, I.-J., Jung, T.-J., & Kim, C.-J. (2015). Effect of Ginger Extract and Citric Acid on the Tenderness of Duck Breast Muscles. *Korean Journal of Food Science and Animal Resources*, *35*(6), 721-730. https://doi.org/10.5851/kosfa.2015.35.6.721

Hiemori-Kondo, M., Ueta, R., & Nagao, K. (2022). Improving deer meat palatability by treatment with ginger and fermented foods: A deer meat heating study. *International of Journal of Gastronomy and Food Science*, *29*, 100577. https://doi.org/10.1016/j.ijgfs.2022.100577

Hong, G.-E., Mandal, P. K., Kim, J.-H., Park, W.-J., Oh, J.-W., Lim, K.-W., & Lee, C.-H. (2016). Influence of Lime Juice on the Pink Discoloration and Quality of Sous-Vide Processed Chicken Breast During Refrigerated Storage. *Journal of Food Quality*, *39*, 726-731. https://doi.org/10.1111/jfq.12230

Hsu, K.-Y., & Chen, B.-H. (2020). Analysis and reduction of heterocyclic amines and cholesterol oxidation products in chicken by controlling flavorings and roasting condition. *Food Research International*, *131*, 109004. https://doi.org/10.1016/j.foodres.2020.109004

Huffstetler, E. (2020). *How to Make Your Own Marinade*. Condiments & Sauces. Retrieved from: https://www.thespruceeats.com/make-your-own-marinade-1388463

Hui, Y. H. (ed.) (2012). *Handbook of Meat and Meat Processing* (2nd ed.). CRC Press.

Isleroglu, H., Kemerli, T., & Kaymak-Ertekin, F. (2015). Effect of Steam-Assisted Hybrid Cooking on Textural Quality Characteristics, Cooking Loss, and Free Moisture Content of Beef. *International Journal of Food Properties*, *18*(2), 403-414. https://doi.org/10.1080/10942912.2013.833219

Istrati, D., Simion Ciuciu, A. M., Vizireanu, C., Ionescu, A., & Carballo, J. (2015). Impact of Spices and Wine-Based Marinades on Tenderness, Fragmentation of Myofibrillar Proteins and Color Stability in Bovine *Biceps Femoris* Muscle. *Journal of Texture Studies*, *46*(6), 455-466. https://doi.org/10.1111/jtxs.12144

Jantaranikorn, M., Thumanu, K., & Yongsawatdigul, J. (2023). Reduction of red blood spots in cooked marinated chicken breast meat by combined microwave heating and steaming. *Poultry Science*, *102*(1), 102317. https://doi.org/10.1016/j.psj.2022.102317

Jantaranikorn, M., & Yongsawatdigul, J. (2020). Effect of marinating ingredients on temperature-induced denaturation of hemoglobin and its relation to red blood spot formation in cooked chicken breast. *Journal of Food Science*, *85*(8), 2398-2405. https://doi.org/10.1111/1750-3841.15308

Jayasena, D. D., & Jo, C. (2013). Essential oils as potential antimicrobial agents in meat and meat products: A review. *Trends in Food Science & Technology*, *34*(2), 96-108. https://doi.org/10.1016/j.tifs.2013.09.002

Jensen, I.-J., Dort, J., & Eilertsen, K.-E. (2014). Proximate composition, antihypertensive and antioxidative properties of the semi-membranosus muscle from pork and beef after cooking and in vitro digestion. *Meat Science*, *96*(2 Part A), 916-921. https://doi.org/10.1016/j.meatsci.2013.10.014

Ježek, F., Kameník, J., Macharáčková, B., Bogdanovičová, K., & Bednár, J. (2020). Cooking of meat: Effect on texture, cooking loss and microbiological quality—A review. *Acta Veterinaria Brno*, *88*(4), 487-496. https://doi.org/10.2754/avb201988040487

Jiang, H., Zhang, M., Mujumdar, A. S., & Lim, R.-X. (2014). Comparison of drying characteristic and uniformity of banana cubes dried by pulse-spouted microwave vacuum drying, freeze drying and microwave freeze drying. *Journal of Science Food and Agriculture*, *94*(9), 1827-1834. https://doi.org/10.1002/jsfa.6501

Jiao, Y., Liu, Y., & Quek, S.Y. (2020). Systematic evaluation of nutritional and safety characteristics of Hengshan goat leg meat affected by multiple thermal processing methods. *Journal of Food Science*, *85*(4), 1344-1352. https://doi.org/10.1111/1750-3841.15087

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

Kamonpatana, P., & Sastry, S. K. (2022). Electrical conductivity of foods and food components: The influence of formulation processes. *Journal of Food Process Engineering*, *45*(4), e13992. https://doi.org/10.1111/jfpe.13992

Kang, D., Zhang, W., Lorenzo, J. M., & Chen, X. (2021). Structural and functional modification of food proteins by high power ultrasound and its application in meat processing. *Critical Reviews in Food Science and Nutrition*, *61*(11), 1914-1933. https://doi.org/10.1080/10408398.2020.1767538

Karyotis, D., Skandamis, P. N., & Juneja, V. K. (2017). Thermal inactivation of Listeria monocytogenes and Salmonella spp. in sous-vide processed marinated chicken breast. *Food Research International*, *100*(Part 1), 894-898. https://doi.org/10.1016/j.foodres.2017.07.078

Keeton, J. T. & Osburn, W. N. (2001). Formed and emulsion products. In A. R. Sams (ed.), *Poultry Meat Processing* (pp. 195-226). CRC Press.

Khan, M. R., Busquets, R., & Azam, M. (2021). Blueberry, raspberry, and strawberry extracts reduce the formation of carcinogenic heterocyclic amines in fried camel, beef and chicken meats. *Food Control*, *123*, 107852. https://doi.org/10.1016/j.foodcont.2020.107852

Khan, M. R., Samdani, M. S., Alam, M. G., Alammari, A. M., Azzam, M. A., Ali, H. M., Alsohaimi, I. H., Azam, M., Ouladsmane, M., Alam, P. (2022). Inhibitory effect of culinary herbs Za'atar (blend of thyme, sesame seeds and sumac) marinades on the formation of polar and non-polar heterocyclic amines carcinogen in fried beef patties: Determination by SPE/UPLC-MS/MS. *Journal of King Saud University – Science*, *34*(2), 101821. https://doi.org/10.1016/j.jksus.2022.101821

Kim, Y. J., Jin, S. K., Park, W. Y., Kim, B. W., Joo, S. T., & Yang, H. S. (2010). The effect of garlic or onion marinade on the lipid oxidation and meat quality of pork during cold storage: effect of garlic or onion marinade on pork quality. *Journal of Food Quality*, *33*, 171-185. https://doi.org/10.1111/j.1745-4557.2010.00333.x

Komoltri, P., & Pakdeechanuan, P. (2012). Effects of marinating ingredients on physicochemical, microstructural and sensory properties of golek chicken. *International Food Research Journal*, *19*(4), 1449-1455.

Kougiagka, E., Apostologamvrou, C., Hatziioannou, M., & Giannouli, P. (2022). Quality characteristics and microstructure of boiled snail fillet meat. *Journal Food Processing and Preservation*, *46*(11), e17079. https://doi.org/10.1111/jfpp.17079

Lawrence, M. T., & Lawrence, T. E. (2021). At-home methods for tenderizing meat using blade tenderization, lime juice and pineapple puree. *Meat Science*, *176*, 108487. https://doi.org/10.1016/j.meatsci.2021.108487

Lee, B., Park, C. H., Kim, J. Y., Hyeonbin, O., Kim, D., Cho, D. K., Kim, Y. S., & Choi, Y. M. (2021). Effects of Astragalus membranaceus, Adenophora triphylla, and Ulmus pumila Extracts on Quality Characteristics and Storage Stability of Sous-Vide Cooked Chicken Breasts. *Food Science of Animal Resources*, *41*(4), 664-673. https://doi.org/10.5851/kosfa.2021.e24

Lee, S. Y., Yim, D. G., Lee, D. Y., Kim, O. Y., Kang, H. J., Kim, H. S., Jang, A., Park, T. S., Jin, S. K., & Hur, S. J. (2020). Overview of the effect of natural products on reduction of potential carcinogenic substances in meat products. *Trends in Food Science & Technology*, *99*, 568-579. https://doi.org/10.1016/j.tifs.2020.03.034

Lešnik, S., Furlan, V., & Bren, U. (2021). Rosemary (Rosmarinus officinalis L.): extraction techniques, analytical methods and health-promoting biological effects. *Phytochemistry Reviews*, *20*, 1273-1328. https://doi.org/10.1007/s11101-021-09745-5

Liao, G., Wang, G., Xu, X., & Zhou, G. (2010). Effect of cooking methods on the formation of heterocyclic aromatic amines in chicken and duck breast. *Meat Science*, *85*(1), 149-154. https://doi.org/10.1016/j.meatsci.2009.12.018

Liu, Y., Duan, X., Zhang, M., Li, C., Zhang, Z., Liu, A., Hu, B., He, J., Wu, D., Chen, H., & Wu, W. (2020). Cooking methods effect on the nutrients, bioaccessibility and antioxidant activity of Craterellus cornucopioides. LWT, *131*, 109768. https://doi.org/10.1016/j.lwt.2020.109768

Loon, Y. K., Satari, M. H., & Dewi, W. (2018). Antibacterial effect of pineapple (Ananas comosus) extract towards Staphylococcus aureus. *Padjadjaran Journal of Dentistry*, *30*(1), 1-6. https://doi.org/10.24198/pjd.vol30no1.16099

Lopes, A. F., Alfaia, C. M. M., Partidário, A. M. C. P. C., Lemos, J. P. C., & Prates, J. A. M. (2015). Influence of household cooking methods on amino acids and minerals of Barrosã-PDO veal. *Meat Science*, *99*, 38-43. https://doi.org/10.1016/j.meatsci.2014.08.012

Lorenzo, J. M., Pateiro, M., Domínguez, R., Barba, F. J., Putnik, P., Kovačević, D. B., Shpigelman, A., Granato, D., & Franco, D. (2018). Berries extracts as natural antioxidants in meat products: A review. *Food Research International*, *106*, 1095-1104. https://doi.org/10.1016/j.foodres.2017.12.005

Macit, A., & Kizil, M. (2022). Effect of olive leaf extract marination on heterocyclic aromatic amine formation in pan-fried salmon. *Journal of Science Food and Agriculture*, *102*(9), 3908-3915. https://doi.org/10.1002/jsfa.11740

Mahrour, A., Caillet, S., Nketsa-Tabiri, J., & Lacroix, M. (2003). Microbial and sensory quality of marinated and irradiated chicken. *Journal of Food Protection*, *66*(11), 2156-2159. https://doi.org/10.4315/0362-028X-66.11.2156

Martínez, L., Castillo, J., Ros, G., & Nieto, G. (2019). Antioxidant and Antimicrobial Activity of Rosemary, Pomegranate and Olive Extracts in Fish Patties. *Antioxidants*, *8*(4), 86. https://doi.org/10.3390/antiox8040086

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

Modzelewska-Kapituła, M., Pietrzak-Fiećko, R., Tkacz, K., Draszanowska, A., & Więk, A., (2019). Influence of sous vide and steam cooking on mineral contents, fatty acid composition and tenderness of semimembranosus muscle from Holstein-Friesian bulls. *Meat Science*, *157*, 107877. https://doi.org/10.1016/j.meatsci.2019.107877

Mudalal, S., Petracci, M., Tappi, S., Rocculi, P., & Cavani, C. (2014). Comparison between the Quality Traits of Phosphate and Bicarbonate-Marinated Chicken Breast Fillets Cooked under Different Heat Treatments. *Food and Nutrition Sciences*, *5*(1), 35-44. https://doi.org/10.4236/fns.2014.51005

Murphy, R. Y., Johnson, E. R., Duncan, L. K., Clausen, E. C., Davis, M. D., & March, J. A. (2001). Heat Transfer Properties, Moisture Loss, Product Yield, and Soluble Proteins in Chicken Breast Patties

During Air Convection Cooking. *Poultry Science*, *80*(4), 508-514. https://doi.org/10.1093/ps/80.4.508

Nakatani, N., & Inatani, R. (1984). Two Antioxidative Diterpenes from Rosemary (Rosmarinus officinalis L.) and a Revised Structure for Rosmanol. *Agricultural and Biological Chemistry*, *48*(8), 2081-2085. https://doi.org/10.1080/00021369.1984.10866436

Negara, B. F. S. P., Tirtawijaya, G., Cho, W.-H., Harwanto, D., Sohn, J.-H., Kim, J.-S., & Choi, J.-S. (2021). Effects of Frying Processes on the Nutritional and Sensory Characteristics of Different Mackerel Products. *Processes*, *9*(9), 1645. https://doi.org/10.3390/pr9091645

Nurwantoro, Bintoro, V. P., Legowo, A. M., Purnomoadi, A., & Setiani, B. E. (2015). Garlic Antioxidant (Allium Sativum L.) to Prevent Meat Rancidity. *Procedia Food Science*, *3*, 137-141. https://doi.org/10.1016/j.profoo.2015.01.014

Okpala, C. O. R., Juchniewicz, S., Leicht, K., Korzeniowska, M., & Guiné, R. P. F. (2022). Antioxidant, Organoleptic and Physicochemical Changes in Different Marinated Oven-Grilled Chicken Breast Meat. *Foods*, *11*(24), 3951. https://doi.org/10.3390/foods11243951

Okpala, C. O. R., Juchniewicz, S., Leicht, K., Skendrović, H., Korzeniowska, M., & Guiné, R. P. F. (2023). Quality attributes of different marinated oven-grilled pork neck meat. *International Journal of Food Properties*, *26*(1), 453-470. https://doi.org/10.1080/10942912.2023.2166952

O'Neill, C. M., Cruz-Romero, M. C., Duffy, G., & Kerry, J. P. (2019a). Comparative effect of different cooking methods on the physicochemical and sensory characteristics of high pressure processed marinated pork chops. *Innovative Food Science & Emerging Technologies*, *54*, 19-27. https://doi.org/10.1016/j.ifset.2019.03.005

O'Neill, C. M., Cruz-Romero, M. C., Duffy, G., & Kerry, J. P. (2019b). 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*, *21*, 100350. https://doi.org/10.1016/j.fpsl.2019.100350

Onopiuk, A., Kołodziejczak, K., Szpicer, A., Wojtasik-Kalinowska, I., Wierzbicka, A., & Półtorak, A. (2021). Analysis of factors that influence the PAH profile and amount in meat products subjected to thermal processing. *Trends in Food Science & Technology*, *115*, 366-379. https://doi.org/10.1016/j.tifs.2021.06.043

Ortuño, J., Mateo, L., Rodríguez-Estrada, M. T., & Bañón, S. (2021). Effects of sous vide vs grilling methods on lamb meat colour and lipid stability during cooking and heated display. *Meat Science*, *171*, 108287. https://doi.org/10.1016/j.meatsci.2020.108287

Oyetunji, O. T. (2009). *Evaluation of the effect of marination processes on the quality and safety of pork products*. Doctoral dissertation, University of Georgia, Georgia.

Pankyamma, V., Madhusudana Rao, B., Debbarma, J., & Pallela Panduranga Naga, V. (2021). Physicochemical, microstructural, and microbial qualities of dehydrated Tuna chunks: Effects of microwave power and drying methods. *Journal of Food Processing and Preservation*, *45*(5), e15426. https://doi.org/10.1111/jfpp.15426

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

Petroman, C., Petroman, I., Negruţ, V., Marin, D., Ciolac, R., & Văduva, L. (2013). Frequency of Consumption of Meat and Meat Products in Timis County. *Scientific Papers: Animal Science & Biotechnologies/Lucrari Stiintifice: Zootehnie si Biotehnologii*, *46*(2), 405-408.

Phan, A., Netzel, G., Chhim, P., Netzel, M., & Sultanbawa, Y. (2019). Phytochemical Characteristics and Antimicrobial Activity of Australian Grown Garlic (Allium Sativum L.) Cultivars. *Foods*, *8*(9), 358. https://doi.org/10.3390/foods8090358

Pogorzelska-Nowicka, E., Atanasov, A. G., Horbańczuk, J., & Wierzbicka, A. (2018). Bioactive compounds in functional meat products. *Molecules*, *23*(2), 307. https://doi.org/10.3390/molecules23020307

Pogorzelska-Nowicka, E., Kurek, M., Hanula, M., Wierzbicka, A., & Półtorak, A. (2022). Formation of Carcinogens in Processed Meat and Its Measurement with the Usage of Artificial Digestion—A Review. *Molecules*, *27*(14), 4665. https://doi.org/10.3390/molecules27144665

Putra, A. A., Wattanachant, S., & Wattanachant, C. (2019). Sensory-related Attributes of Raw and Cooked Meat of Culled Saanen Goat Marinated in Ginger and Pineapple Juices. *Tropical Animal Science Journal*, *42*(1), 59-67. https://doi.org/10.5398/tasj.2019.42.1.59

Qian, M., Zheng, M., Zhao, W., Liu, Q., Zeng, X., & Bai, W. (2021). Effect of marinating and frying on the flavor of braised pigeon. *Journal of Food Processing and Preservation*, *45*(3), e15219. https://doi.org/10.1111/jfpp.15219

Rababah, T. M., Ereifej, K. I., Alhamad, M. N., Al-Qudah, K. M., Rousan, L. M., Al-Mahasneh, M. A., Al-u'datt, M. H., & Yang, W. (2011). Effects of Green Tea and Grape Seed and TBHQ on Physicochemical Properties of Baladi Goat Meats. *International Journal of Food Properties*, *14*(6), 1208-1216. https://doi.org/10.1080/10942911003637327

Rashidaie Abandansarie, S. S., Ariaii, P., & Charmchian Langerodi, M. (2019). Effects of encapsulated rosemary extract on oxidative and microbiological stability of beef meat during refrigerated storage. *Food Science & Nutrition*, *7*(12), 3969-3978. https://doi.org/10.1002/fsn3.1258

Rodriguez-Estrada, M. T., Penazzi, G., Caboni, M. F., Bertacco, G., & Lercker, G. (1997). Effect of different cooking methods on some lipid and protein components of hamburgers. *Meat Science*, *45*(3), 365-375. https://doi.org/10.1016/S0309-1740(96)00123-4

Salmon, C. P., Knize, M. G., & Felton, J. S. (1997). Effects of marinating on heterocyclic amine carcinogen formation in grilled chicken. *Food and Chemical Toxicology*, *35*(5), 433-441. https://doi.org/10.1016/S0278-6915(97)00020-3

Schellekens, W., & Martens, T. (1992). *Sous Vide Cooking Part I: Scientific Literature Review*. Commission of the European Communities Directorate General XII. Research And Development.

Schröder, M. J. (2003). *Food Quality and Consumer Value: Delivering Food that Satisfies*. Springer.

Sengun, I. Y., Kilic, G., & Ozturk, B. (2020). The effects of koruk products used as marination liquids against foodborne pathogens (Escherichia coli O157:H7, Listeria monocytogenes and Salmonella Typhimurium) inoculated on poultry meat. *LWT*, *133*, 110148. https://doi.org/10.1016/j.lwt.2020.110148

Sengun, I. Y., Yildiz Turp, G., Cicek, S. N., Avci, T., Ozturk, B., & Kilic, G. (2021). Assessment of the effect of marination with organic fruit vinegars on safety and quality of beef. *International Journal of Food Microbiology*, 336, 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. (2018). Inhibitory effect of mixture herbs/spices on formation of heterocyclic amines and mutagenic activity of grilled beef. *Food Additives & Contaminants: Part A*, *35*(10), 1911-1927. https://doi.org/10.1080/19440049.2018.1488085

Shen, X., Huang, X., Tang, X., Zhan, J., & Liu, S. (2022). The Effects of Different Natural Plant Extracts on the Formation of Polycyclic Aromatic Hydrocarbons (PAHs) in Roast Duck. *Foods*, *11*(14), 2104. https://doi.org/10.3390/foods11142104

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

Siroli, L., Baldi, G., Soglia, F., Bukvicki, D., Patrignani, F., Petracci, M., & Lanciotti, R. (2020). Use of essential oils to increase the safety and the quality of marinated pork loin. *Foods*, *9*(8), 987. https://doi.org/10.3390/foods9080987

Sivam, G. P. (2001). Protection against Helicobacter pylori and Other Bacterial Infections by Garlic. *Journal of Nutrition*, *131*(3), 1106S-1108S. https://doi.org/10.1093/jn/131.3.1106S

Smith, D. P., & Northcutt, J. K. (2003). Red Discoloration of Fully Cooked Chicken Products. *Journal of Applied Poultry Research*, *12*(4), 515-521. https://doi.org/10.1093/japr/12.4.515

Sobral, M. M. C., Cunha, S. C., Faria, M. A., & Ferreira, I. M. (2018). Domestic Cooking of Muscle Foods: Impact on Composition of Nutrients and Contaminants. *Comprehensive Reviews in Food Science and Food Safety*, *17*(2), 309-333. https://doi.org/10.1111/1541-4337.12327

Sokołowicz, Z., Augustyńska-Prejsnar, A., Krawczyk, J., Kačániová, M., Kluz, M., Hanus, P., & Topczewska, J. (2021). Technological and Sensory Quality and Microbiological Safety of RIR Chicken Breast Meat Marinated with Fermented Milk Products. *Animals*, *11*(11), 3282. https://doi.org/10.3390/ani11113282

Sturkie, P. D. (2012). *Avian Physiology*. Springer Science & Business Media.

Tarvainen, M., Nuora, A., Quirin, K.-W., Kallio, H., & Yang, B. (2015). Effects of CO2 plant extracts on triacylglycerol oxidation in Atlantic salmon during cooking and storage. *Food Chemistry*, *173*, 1011-1021. https://doi.org/10.1016/j.foodchem.2014.10.125

Testa, B., Lombardi, S.J., Macciola, E., Succi, M., Tremonte, P., & Iorizzo, M., 2019. Efficacy of olive leaf extract (Olea europaea L. cv Gentile di Larino) in marinated anchovies (Engraulis encrasicolus, L.) process. *Heliyon*, *5*(5), e01727. https://doi.org/10.1016/j.heliyon.2019.e01727

Thathsarani, A. P. K., Alahakoon, A. U., & Liyanage, R. (2022). Current status and future trends of sous vide processing in meat industry; A review. *Trends in Food Science and Technology*, *129*, 353-363. https://doi.org/10.1016/j.tifs.2022.10.009

The Culinary Pro (2022). Marinades. Retrieved from https://www.theculinarypro.com/marinades

Thomas, R. H., Bernards, M. A., Drake, E. E., & Guglielmo, C. G. (2010). Changes in the antioxidant activities of seven herb- and spice-based marinating sauces after cooking. *Journal of Food Composition and Analysis*, *23*(3), 244-252. https://doi.org/10.1016/j.jfca.2009.08.019

Tkacz, K., & Modzelewska-Kapituła, M. (2022). Marinating and Grilling as Methods of Sensory Enhancement of Sous Vide Beef from Holstein-Friesian Bulls. *Applied Sciences*, *12*(20), 10411. https://doi.org/10.3390/app122010411

Tkacz, K., Modzelewska-Kapituła, M., Petracci, M., & Zduńczyk, W. (2021). Improving the quality of sous-vide beef from Holstein-Friesian bulls by different marinades. *Meat Science*, *182*, 108639. https://doi.org/10.1016/j.meatsci.2021.108639

Tkacz, K., Tylewicz, U., Pietrzak-Fiećko, R., & Modzelewska-Kapituła, M., 2022. The Effect of Marinating on Fatty Acid Composition of Sous-Vide Semimembranosus Muscle from Holstein-Friesian Bulls. *Foods*, *11*(6), 797. https://doi.org/10.3390/foods11060797

Vandendriessche, F. (2008). Meat products in the past, today and in the future. *Meat Science*, *78*(1-2), 104-113. https://doi.org/10.1016/j.meatsci.2007.10.003

Varghese, K. S., Pandey, M. C., Radhakrishna, K., & Bawa, A. S. (2014). Technology, applications and modelling of ohmic heating: a review. *Journal of Food Science and Technology*, *51*, 2304-2317. https://doi.org/10.1007/s13197-012-0710-3

Vidal, N. P., Manful, C., Pham, T. H., Wheeler, E., Stewart, P., Keough, D., & Thomas, R. (2020). Novel unfiltered beer-based marinades to improve the nutritional quality, safety, and sensory perception of grilled ruminant meats. *Food Chemistry*, *302*, 125326. https://doi.org/10.1016/j.foodchem.2019.125326

Viegas, O., Amaro, L. F., Ferreira, I. M., & Pinho, O. (2012). Inhibitory effect of antioxidant-rich marinades on the formation of heterocyclic aromatic amines in pan-fried beef. *Journal of Agricultural and Food Chemistry*, *60*(24), 6235-6240. https://doi.org/10.1021/jf302227b

Viegas, O., Moreira, P. S., & Ferreira, I. M. (2015). Influence of beer marinades on the reduction of carcinogenic heterocyclic aromatic amines in charcoal-grilled pork meat. *Food Additives & Contaminants: Part A*, *32*(3), 315-323. https://doi.org/10.1080/19440049.2015.1010607

Viegas, O., Yebra-Pimentel, I., Martinez-Carballo, E., Simal-Gandara, J., & Ferreira, I. M. (2014). Effect of beer marinades on formation of polycyclic aromatic hydrocarbons in charcoal-grilled pork. *Journal of Agricultural and Food Chemistry*, *62*(12), 2638-2643. https://doi.org/10.1021/jf404966w

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. (2021). Influence of Marination with Aromatic Herbs and Cold Pressed Oils on Black Angus Beef Meat. *Foods*, *10*(9), 2012. https://doi.org/10.3390/foods10092012

Wang, C., Xie, Y., Qi, J., Yu, Y., Bai, Y., Dai, C., Li, C., Xu, X., & Zhou, G. (2018). Effect of Tea Marinades on the formation of polycyclic aromatic hydrocarbons in charcoal-grilled chicken wings. *Food Control*, 93, 325-333. https://doi.org/10.1016/j.foodcont.2017.12.010

Wang, X., Feng, T., Wang, X., Xia, S., Yu, J., & Zhang, X. (2022). Microwave heating and conduction heating pork belly: Non-volatile compounds and their correlation with taste characteristics, heat transfer modes, and matrix microstructure. *Meat Science*, *192*, 108899. https://doi.org/10.1016/j.meatsci.2022.108899

Williams, J. B. (2012). Marination: Processing technology. In Y. H. Yui (ed.), *Handbook of meat and meat processing* (pp. 495-504). CRC Press.

Xie, H., Chen, H., Yuechen, L., & Fan, F. (2022a). Effects of Different Antioxidants of Bamboo Leaves Treatments on Lipid Oxidation of Scallop (Argopecten irradians) Adductor Muscle During Hot Air Drying. *Journal of Aquatic Food Product Technology*, *31*(9), 939-950. https://doi.org/10.1080/10498850.2022.2119910

Xie, H., Yue, C., & Fan, F. (2022b). Different tea polyphenol treatments on lipid oxidation of scallop (Argopecten irradians) adductor muscle during hot air drying. Journal of Food Processing and Preservation, *46*(6), e16534. https://doi.org/10.1111/jfpp.16534

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

Xiong, Y. L. (2005). Role of myofibrillar proteins in water-binding in brine-enhanced meats. *Food Research International*, *38*(3), 281-287. https://doi.org/10.1016/j.foodres.2004.03.013

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

Xu, J., Zhang, M., Wang, Y., & Bhandari, B. (2021). Novel Technologies for Flavor Formation in the Processing of Meat Products: A Review. *Food Reviews International*, *39*(2), 802-806. https://doi.org/10.1080/87559129.2021.1926480

Yu, Y., Cheng, Y., Wang, C., Huang, S., Lei, Y., Huang, M., & Zhang, X. (2023). Inhibitory effect of coriander (Coriandrum sativum L.) extract marinades on the formation of polycyclic aromatic hydrocarbons in roasted duck wings. *Food Science and Human Wellness*, *12*(4), 1128-1135. https://doi.org/10.1016/j.fshw.2022.10.038

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

Yusop, S. M., O'Sullivan, M. G., Kerry, J. F., & Kerry, J. P. (2012). Influence of processing method and holding time on the physical and sensory qualities of cooked marinated chicken breast fillets. *LWT - Food Science Technology*, *46*(1), 363-370. https://doi.org/10.1016/j.lwt.2011.08.007

Zell, M., Lyng, J. G., Cronin, D. A., & Morgan, D. J. (2009). Ohmic heating of meats: Electrical conductivities of whole meats and processed meat ingredients. *Meat Science*, *83*(3), 563-570. https://doi.org/10.1016/j.meatsci.2009.07.005

Zell, M., Lyng, J. G., Cronin, D. A., & Morgan, D. J. (2010). Ohmic cooking of whole beef muscle — Evaluation of the impact of a novel rapid ohmic cooking method on product quality. *Meat Science*, *86*(2), 258-263. https://doi.org/10.1016/j.meatsci.2010.04.007

Zhang, J., Bowker, B., Yang, Y., Pang, B., Yu, X., Tasoniero, G., & Zhuang, H. (2022). Water properties and marinade uptake in broiler pectoralis major with the woody breast condition. *Food Chemistry*, *391*, 133230. https://doi.org/10.1016/j.foodchem.2022.133230

Ziaiifar, A. M., Achir, N., Courtois, F., Trezzani, I., & Trystram, G. (2008). Review of mechanisms, conditions, and factors involved in the oil uptake phenomenon during the deep-fat frying process. *International Journal of Food Science and Technology*, *43*(8), 1410-1423. https://doi.org/10.1111/j.1365-2621.2007.01664.x