Chapter

Recent Advances and Innovation in Meat with Reference to Processing Technologies

Waseem Khalid, Zahra Maqbool and Muhammad Sajid Arshad

Abstract

This chapter discusses the recent advance in meat. Meat is usually a rich source of protein and is also composed of fats, vitamins, and minerals. The composition of these nutrients is different depending on the type of meat. Meat is basically divided into two categories: red and white. Due to high protein and fat content, the chances of oxidation are increased. The oxidation process causes meat spoilage. To protect the meat from spoilage, recent technologies and natural antioxidants are being used. Non-thermal processing techniques including gamma irradiation, e-beam irradiation, high-pressure processing, and pulsed electric field produce safe and quality meat because in recent technologies, conditions can be controlled. Conclusively, recent advances in meat and meat products play a role in improving product life and human health.

Keywords: meat, protein, antioxidants, shelf life, non-thermal processing

1. Introduction

Meat is an important part of most civilizations' diets. Meat is frequently viewed as the main food when planning meals because its protein has 70 percent biological availability in the body. As a result, it is frequently viewed as highly nutritive incentive sustenance. It is a concentrated supply of vitamin B complex, including vitamin B12, which is not found in plant foods. It is also a good source of metabolically active iron and enhances its absorption from other food sources. Its amino acid composition supplements the nutrition of many plant foods [1]. As a result, meat and meat products are favored to meet protein needs. Meat has a crucial role in human nutrition. Although this kind of protein has a lower biological value than egg albumin, it is a vital source of heme iron, vitamins, and minerals [2].

Farming technological advancements and animal agriculture intensification boost meat production volume and cost-efficiency. Beef is relatively inexpensive and available in developed countries. Intensive meat production is advantageous to consumer happiness and public health [3]. As a result, academic and industrial groups are striving to improve the sensory features of plant-based meat as well as researching fledgling approaches using cellular agriculture methodology. The benefits and challenges of plant-based and cell-based meat alternatives are studied with respect to production efficiency, product characteristics, and impact categories [4]. The application of meat-processing technologies to replace traditional energy-intensive meat processes has the potential to cut energy consumption and production costs and improve the meat sector's sustainability without requiring infrastructure upgrades [5]. The study gives a quick overview of four new food-processing methods. High-pressure processing (HPP) is used to ensure the safety and stability of packaged high-value products, resulting in longer shelf life. Due to the batch-based treatment technique, it has some restrictions. HPP equipment should be designed in the future to focus on improvements in energy efficiency. Meat tenderization is the primary goal of the shockwave (SW) or dynamic HPP development. The limited number of unique applications complicates the technology's broad research and comparison. However, if used on a small scale and aimed at replacing long aging processing, the technology appears to be more ecologically benign and economically effective [6]. Ohmic heating (OH) is a new direct electric heating technology for industrial meat processing [7]. Previous experiments and investigations have shown that it has the potential to be a cost-effective technique for treating meat products at a faster rate [8]. More technological advancements and commercial penetration are projected in the near future. Another processing method that uses direct electric energy is the pulsed electric field (PEF). It has a variety of applications in the meat-processing industry, but additional research is needed. Other possible PEF applications, such as PEF-assisted cooking, should be investigated since it could open up new prospects for improving and retaining the sensory quality of cooked meat, particularly for tough meat cuts, in both kitchens and food sectors. The industrial applicability of the assessed technology is still limited to specific use cases [9]. There are a variety of constraints that allow for the rapid and successful spread of technology on the market. They are concerned with batch-based processing systems in HPP and pulsed eclectic fields as well as the construction of appropriate industrial equipment in shockwave and OH. The majority of the issues might be resolved by increasing technological preparedness and developing new equipment. In addition, the design of HPP, PEF, OH, and SW equipment should be considered.

2. Categories of meat

Meat consumption is gradually growing, and its impact on health has piqued public interest, leading to epidemiological research on recent developments in understanding the impacts of meat or processed meat on human health as well as the mechanisms that underpin it. Individuals, populations, and geographies consume meat differently, with industrialized countries consuming more than underdeveloped countries. As human populations grow and income rises, meat consumption rises annually [10]. The meat production chain is divided into several stages, beginning with animal rearing utilizing various systems and feeds with optimum composition to promote animal development and ending with the production of meat with qualities that are aligned with consumer preferences [11]. Meat has played an important part in human evolution. The link between meat consumption and health is complex, and it requires further investigation, with special focus paid to the important differences that distinguish the impacts of various meat varieties, which have so far received little attention in the literature. White meat (poultry and turkey) and red meat (cows and calves, sheep, lamb, and pigs) have seen the greatest increase in consumption among the various types of meat available in markets. Red meat (beef and sheep meat) consumption adds to the intake of many vital elements in the human diet, including

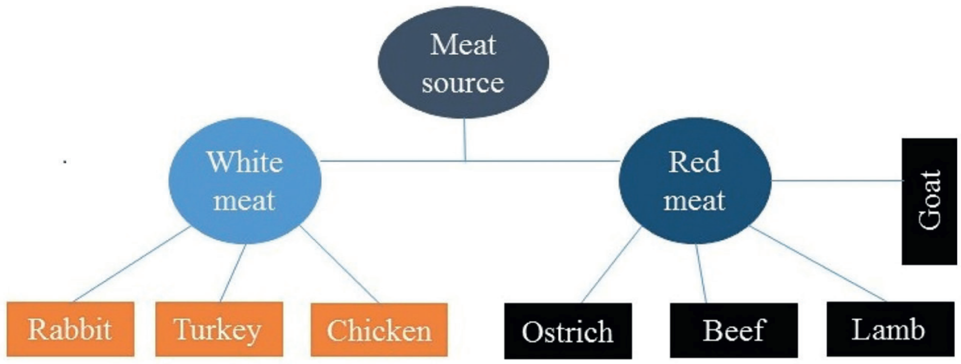

Figure 1.
Different types of meat sources.

protein, essential fatty acids, vitamins, and trace minerals, with high iron content, especially in meats with high myoglobin concentration. [12]

Red meat is also good for humans. It's a popular food group that's eaten throughout the world. This necessitates the development of red meat products that are appealing to and meet the needs of people in their eighties [13]. White meat differs from various food alternatives in that it has a low energy concentration and, as a result, a high nutritional density. White meat, like other meats, is a good source of protein with a high biological value (20–22 percent). The introduction of nutrient-dense, value-added white meat has significantly expanded the scope of functional foods for human health. Recently, there has been a surge in interest in the possible application of nanomaterials in meat nutrition. The most common application of nanotechnology in white meat (poultry) is the use of nano-mineral elements, which can reduce antagonistic behavior in the gastrointestinal system that is common with standard inorganic minerals as well as increase bioavailability and lower effective doses [14]. As a result, a growing number of people around the world prefer white meat products, which have fewer calories. Furthermore, these meats are lower in fat and cholesterol, making them ideal for people who want to eat a healthy and balanced diet. **Figure 1** shows the different types of meat.

3. Recent advances in meat

The world's population, which is currently at 7.3 billion people, is anticipated to exceed 9 billion by 2050. According to the Food and Agriculture Organization (FAO), more than 70 percent food will be required in 2050 to meet the expanding population's need. Even though meat consumption is dropping in affluent countries, it is rising worldwide. As these people begin to work full-time, they seek out more luxury products, such as meat and other animal products. Meat is one of the most popular agricultural products because it contains essential proteins, minerals, and vitamins for human nutrition and wellness [15]. Because of rising interest in economic creation, increasing amount, and medical issues, the meat industries have been on the rise. Consumers have always been on the search for high-quality meat products with an appealing appearance and nutritional value. People select meat from a variety of species, animals of varying ages, sizes, and cuts based on their religious beliefs, social status, origin, diverse cultures, previous experience, the volume of muscle and fat in the carcass, as well as the texture and flavor/aroma characteristics of the meat [16].

Food companies all over the world are creating novel methods and meat products in order to reach client demand. As a consequence, technological innovations such as nanotechnology can have a massive effect on the meat-handling sector by promoting the development of new utilitarian meats as well as novel packaging for those things. Nanomaterials in food have the potential to improve bioavailability, antimicrobial effects, sensory absorption, and bioactive chemical delivery. However, there are obstacles in the application of nanoparticles due to knowledge gaps in the processing of substances such as the stability of delivery systems in meat products, along with potential risks associated with the same features that provide benefits. Nanotechnology is used in meat processing in the form of nanomaterials that aid in food handling, financial matters and quality purpose [17]. Ultrasound has been effectively utilized across several fields of food technology to either replace or support traditional forms (cutting, degassing, and meat tenderization). However, more research is needed to improve the potential for efficient use of current processes by optimizing process conditions (scaling up ultrasound equipment). When coupled with ultrasound, quite a few technologies have demonstrated the ability to properly regulate food microbes. Ultrasonography does have the potential to contribute to breakthroughs in food safety, processing, and preservation as a result of these possibilities [18]. Because infrared (IR) light passes through multiple layers of tissue, different creators have assessed and disclosed strategies that focus on the use of representing approximately NIR spectroscopy for the investigation of a wide range of properties related to meat quality in either farm animals or carcass evaluation. According to recent evidence, a strategy based on the use of short frequencies (700–1100 nm) in the NIR region of the electromagnetic range can non-invasively gauge boundaries relevant to meat quality in live animals. Furthermore, this approach was said to be capable to remove tissues (such as fat and lean) measured through the skin. It is unknown that rapid and non-invasive methods depending on NIR spectroscopy can assess and analyze the value of meat quality in live animals [19].

Modern preserved food methods have a lot of weaknesses and restrictions when it comes to protecting food quality and reducing microbial load. As a result, non-thermal preservation techniques and alternative chemical compounds have been regarded as a high substitute for extending shelf life and cleanliness and generating low nutritional, physiological, and sensory change in fish and meat products. A food business that incorporates these strategies could be a suitable option. The previous review focuses on the most important aspects of meat and meat products' mechanisms of action under physicochemical, microbial, nutritional, and sensorial conditions as well as the potency of non-thermal preservation techniques (HPP, UV-C radiation, gamma irradiation, and ultrasound) and alternative chemical compounds (peracetic acid, essential oils, nanoparticles, and bacteriocins). Alternative chemical compounds and non-thermal preparation methods have a large capacity for microorganism eradication, leading to limited matrix modifications and reduced environmental impact [20]. Moreover, the various methodologies' application conditions, such as energy intensity, exposition time, and chemical compound concentration thresholds, must be continuously improved and specifically established for each matrix type to reduce nutritional, physicochemical, and sensorial changes to the greatest extent possible. Formation of advancement in meat by using non-thermal processing techniques is shown in **Table 1**.

Meat source	Plant source	Whole food/ extract	Non-thermal processing	Meat product	Improvement	Reference
Beef	—	Milk-derived bioactive peptides	—	Beef nuggets	Increase the stability and functional properties of beef nuggets	[21]
Ostrich & chicken	Kale	Kale leaf power	Gamma irradiation	Patties	Increase shelf life	[22]
Chicken	Moringa	Moringa leaf powder	Gamma irradiation	Meat balls	Reduce oxidation and improve amino acids	[23]
Duck	—	—	e-beam irradiation	Smoked duck meat	Improve the microbiological quality	[24]
Duck	—	—	e-beam irradiation	Frozen duck meat	Reduce microbe growth	[25]
Beef	Wheat	Wheat germ oil and wheat bran fiber	—	Beef patties	Produce low-fat beef patties	[26]
Chicken	Moringa	Moringa leaf powder	Gamma irradiation	Meat balls	Reduce the total aerobic bacteria and coliform counts	[27]
Duck	—	—	e-beam irradiation	Smoked duck meat	Change fatty acids and amino acids	[28]
Chicken	Turmeric	Turmeric powder	Gamma irradiation	Chicken patties	Enhance the stability and antioxidant status of chicken meat	[29]
Shrimp	Guava and papaya leaves	Extract	Ultrasound-assisted extraction	Shrimp patties	Shrimp patties enriched with guava leaf and papaya leaf show better antioxidant capacity, stability, and sensory characteristics	[30]
Meat	—	—	High hydrostatic pressure		HHP can influence meat protein conformation	[31]
Chicken	—	—	High hydrostatic pressure	White chicken meat	Improve the overall texture and quality of cooked chicken meat	[32]

Table 1.
Formation of advance meat by using non-thermal processing techniques.

3.1 Addition of plant-derived components in meat

People are being pushed to adapt more plant-based diets in order to reduce the negative impacts of the current food supply on human health. To meet this need, the food industry is developing a new generation of plant-based alternatives for cheese, meat, milk, fish, eggs, and yoghurt. The primary challenge in this area is to use healthy, affordable, and sustainable plant-derived elements such as proteins, lipids, and carbohydrates to imitate the desired texture, appearance, nutrition, mouthfeel, flavor, and utility of these commodities. Plant-derived molecules differ significantly from animal-derived components in terms of physicochemical and molecular characteristics. It is critical to comprehend the underlying properties of plant-derived compounds as well as the methods by which they can be formed into structures similar to those found in animal products [33]. Plant extracts are progressively being used in meat products and fresh meat as a source of bioactive components, which is a common strategy for improving quality and health-related properties. Polyphenols (flavonols, tannins, and anthocyanins) and essential oils are the major bioactive components of plant food that can be used by the meat industry (mostly made of terpenes). These chemicals can be found in seeds, leaves, and fruits. For example, black pepper is a common ingredient that is grown primarily in tropical climates [34].

In recent years, the meat sector has placed a significant emphasis on the development of healthier meat products, mainly for the positive use of eating. This goal could be achieved in two ways: by reducing harmful molecules and by increasing the proportion of useful bioactive components [35].

Nitrite is mostly exploited in meat production as a crosslinking agent, and it has been linked to health impacts. The impact of various methods for replacing synthetic nitrate and nitrite in order to obtain green-label meat products is outlined, also with their impact on various possible dangers [36]. Nitrites improve taste, flavor, and scent while preserving the meat's red-pinkish color and reducing the danger of bacterial infection, especially from *Clostridium botulinum*. Unfortunately, a recent study has revealed some of the flaws in this method. Most research groups are investigating the effects of nitrates and nitrites because some N-nitroso compounds have been connected to the development of stomach cancer. This one discusses the many food sources of nitrites and nitrates as well as the current legislative restrictions on their use in meat products [37].

Natural food preservatives are gaining popularity in the meat industry. Plants high in polyphenols that are used as natural food preservatives are the greatest option for partially or totally replacing synthetic preservatives. Fruits, olives, grapes, herbs, spices, vegetables, and algae are just a few examples of natural sources. The presence of one or more -OH groups on one or more aromatic rings determines the antibacterial and antioxidant properties of these phenolic compounds [34].

Plant extracts are gaining popularity in the food industry due to their antibacterial qualities, which aid in the prevention of off-flavors and improve color stability in ready-to-eat (RTE) meat products. They are appealing candidates to replace synthetic compounds, which are often thought to have carcinogenic and toxicological consequences, due to their natural character. Extracting these antioxidant chemicals from their natural sources, as well as assessing their usefulness in commercialized items, has proven to be a tremendous challenge for researchers and food chain contributors. Pathogenic and spoilage microorganisms are effectively suppressed by certain essential oils (such as thyme, clove, and cinnamon oils) [38].

Humans eat a lot of meat and meat-related goods. High biological value proteins; selenium; vital amino acids; zinc; B-complex vitamins, especially vitamin B12; and vitamins and minerals such as manganese and iron are all present in these meals [39]. Vegetables, fruits, by-products, and other plant materials can provide an inexpensive source of bioactive substances such as antioxidants and dietary fibers. In addition to lowering oxidative stress, antioxidants help prevent lipid and protein breakdown, limit the formation of toxins in meat products, and maintain color. Dietary fibers help beef products have better physicochemical qualities, and they are also good for preventing nutritional and diet-related diseases [40].

Meat-like sensory properties are achieved by a combination of processing methods and functional ingredients, which are essential to appeal to non-vegetarian customers. Sensory science is a broad field of study that encompasses customer preferences and is used to assess and analyze consumer reactions to product features. On a food-processing level, replicating the flavor and texture of muscle meat from plant proteins has proven problematic due to the generation of off-flavors that are generally created by legumes as well as a decreased saturated fat content, which is responsible for juiciness and softness. The umami and "meaty" flavor of plant proteins can be disguised or replicated using various flavoring agents and seasonings. Plant proteins can be used alone or combined with hydrocolloids to alter viscosity and generate a texture that resembles muscle structure. Understanding the physicochemical features of novel plant proteins is required to increase public acceptance of meat substitutes and make significant progress toward more sustainable and better diets [41].

3.2 Improve the nutritional status of meat

Nutrition is a broad and difficult topic to understand. Its primary goal is to ensure a child's healthy growth and development, adult performance and well-being, as well as the old and senile's health and lifetime. Nutrition is both a cause of pleasure and enjoyment and a critical medicinal agent. Meat was long regarded to be important for optimum growth and development because it is a concentrated dietary supply [42]. Nutrition is a serious ecological factor that has a consistent and diverse impact on the social and biological essence of the human body. A well-balanced diet is essential for optimum health and adds to enhanced lifespan and standard of living in the population. Meat products have a rapidly growing market. Because of clients' contemporary lifestyles and their desire for RTE foods, meat products and moderate goods production and consumption are on the rise. Despite the vast variety of food products accessible, the number of medicinal, preventative, and functional products is limited, despite the fact that the problem of nutritional imbalance remains a concern in modern society. The main goals for creating enriched foodstuffs are to prevent heart disease and fat, nitrates, and salt chloride levels while also improving the fatty acid profile and including physiologically active compounds [43]. As a result, food technologists, researchers, and nutritionists are attempting to enhance the levels of health-beneficial components in meat and meat products to improve the health image and impact of meat and animal products. Increased nutritional content and health benefits of these high-quality protein sources will expand distribution, consumer options, and accessibility, particularly among food-insecure people. As a result of its possible effects on human health and animal productivity, interest in conjugated linoleic acid (CLA) has grown in recent decades [44].

Iron-fortified products are a common part of anti-iron deficient diets. Despite the fact that meat and meat products are excellent sources of highly accessible iron, young iron-deficient women who consumed 80 g of fortified pork pate absorbed the iron (15 mg of iron). Other meat products have minerals like calcium, selenium, and iodine added to them, but their benefits in humans have yet to be established [45]. To boost the nutritional value of meat substitutes, fortification ingredients (amino acids, minerals, and vitamins) are added. Tocopherols, thiamine hydrochloride, zinc gluconate, pyridoxine hydrochloride, niacin, riboflavin, sodium ascorbate, and cobalamin are included to resemble the composition of meat while also meeting daily requirements. One of the most significant supplements that vegans require to achieve their daily requirements is vitamin B12. These additives can enhance storage, lipid oxidation, and meat analogue quality, in addition to their nutritional benefits. Vitamins and minerals, for instance, could be supplied as pure compounds or incorporated in matrices such as mushrooms, microalgae, or pulse flours [46].

Dietary fibers attained from cereals, vegetables, and fruits are used to improve meal preparations. Dietary fibers have functional properties that can help meats improve their quality and sensory attributes. These functional properties are determined by the types of dietary fibers included in products. The most important functional aspects of dietary fibers used in meat products are fat-binding and water-holding capacity, gel-forming ability, stiffness, and emulsification. The water-holding capacity of dietary fibers is influenced by the structure, chemical composition, and relative quantities of different types of fibers. The addition of fibers to meat products can improve emulsion stability, increase the water potential of minced meat, substitute fat, lower fat content, increase product yield, and improve meat texture [47].

It is also a great source of omega-3 fatty acids due to the higher quantity of linolenic acid [48]. Pumpkin and chia seeds in meat products not just create delicious food but also have medicinal properties. These ingredients help meat products have better gel strength, cooking output, and water retention. These additions boost the overall phenolic content of beef products, increasing their shelf life even further. The addition of these seeds raises the total dietary fiber content of the desired products, hence increasing the general health of the customers. As a consequence, the mixture of pumpkin and chia seeds produces meat products that are healthy, nutritious, and microbiologically safe [49].

3.3 Prevent oxidation

Worldwide, there is greater versatility in processed meat as compared to raw meat because of its long storage life. Overall, there is a high demand for meat products on the market; as a result, it is necessary to reformulate these items to incorporate new advantages. Oxidative responses and microbiological development are the two most common ways involved in the reduction in the quality of meat products, although using chemicals to improve shelf life is a common practice in the meat industry. Antioxidants such as butylhydroxytoluene (BHT), butyl hydroxyanisole (BHA), and start-butylhydroxyquinone (TBHQ) are often added to meat and meat products to prevent oxidation. In contrast to nitrates, the meat business has a variety of preservatives to choose from. Their safety, however, is doubtful, as they have been connected to asthma, hypersensitivity, skin irritation, allergies, cancer, and gastrointestinal issues [50]. Meat and meat products are perishable food that requires preservatives to avoid deterioration and assure the absence of potentially harmful bacteria and foodborne pathogens. One of the most common reasons for meat and meat product quality decline is lipid oxidation. Meat products lose nutritional value and sensory quality as a result of these procedures. Oxidation modifications can impair consumer acceptance (texture and color changes and also the development of rotting flavor and smell) and potentially the product's safety (harmful compounds). In this scenario, antioxidants are utilized to slow down the progression of these detrimental consequences [51].

Experts and specialists in the meat sector are now being encouraged to modify meat products in line with current market trends. Polyphenols are antibacterial and antioxidant compounds present in a wide range of vegetables, fruits, and plants. They could be used to create compounds and constituents for packaged foods to help meat products last longer [52]. A study showed that lipid oxidation in patties was controlled by using an ethanol extract of mesquite leaf (EEML). In this study, there was a substantial correlation between polyphenol content and total flavonoid content. The effects of two different amounts of mesquite leaf ethanol extract (0.05% and 0.1%) applied to meat patties on physicochemical parameters, total antioxidant capacity, lipid oxidation, and taste qualities during refrigerated storage were investigated [53].

Herbs (rosemary) and essential oils of herbs and spices (sage, thyme, oregano, and garlic) have all been used as natural antioxidants in beef preservation. Essential oils are plant-derived volatile and aromatic compounds. These oils have antioxidant, antifungal, and antibacterial properties. Thyme (Thymus vulgaris L.) is a fragrant herb with a flavor that is commonly used in meat, seafood, and prepared meals. Thyme essential oil (TEO) has antioxidant properties due to its phenolic components, such as carvacrol and thymol, as well as other flavonoids. As a result, scented oil packaging has been developed to minimize the acute changes caused by oil inclusion. The product lifetime is extended by a controlled release of these chemicals present in tiny amounts in the packing film [54]. Ground beef is treated with whey protein isolate (WPI)/cellulose nanofiber (CNF) nano-biopolymers films containing TEO in various percentages. The antioxidant activity of nano-biopolymers is assessed using beta-carotene and 2,2-diphenyl-1-picrylhydrazyl activity. TEO concentrations, along with thymol and carvacrol concentrations and antioxidant activity, all increased. The thiobarbituric acid reactive substances (TBARS) index and objective color evaluation were accomplished after storing ground beef samples at 41°C for 4 days. The oxidation of ground beef packaged in biodegradable sheets was lower than that of the positive control [55].

Moreover, because of significant consumer concerns about safety and quality, meat-processing studies are gaining traction. As a result, the meat business needs natural antioxidants to slow down artificial oxidation processes. Natural antioxidants are integrated into active films and coatings as well as other effects on biopolymer films' barrier, physical, optical, mechanical, bactericidal, and antioxidant capabilities. Natural antioxidants were also looked into for usage in meat packaging. Plant extract enhances the effectiveness of conserved meat products by avoiding lipid/protein oxidation and restricting microbial development. As a result, plant extracts may one day be a feasible option for producing environmentally friendly bioactive films in the meat industry [56].

3.4 Innovative processing technologies

Food manufacturing studies have recently centered on cutting-edge food-processing technology. These techniques offer significant benefits for preserving and improving the flavor of staple recipes as well as meeting the expanding challenges brought by globalization and a wide set of client needs. However, to ensure that the food business gives back the financial advantages of these breakthroughs, more adoption of novel technology is required [57]. The cost of commercialization and development, the relative advantage and related risks, as well as the degree of compliance and complexity all influence technology acceptance. With variable degrees of success, these non-thermal and thermal new technologies can be used to cause physical disruption to muscle structure, enhanced protein denaturation and getting older, and muscle protein denaturation and solubilization, resulting in texture and juiciness changes. The results of a meta-analysis are used to compare the impact of several technologies on meat tenderization. In the future, a combination of new and inventive technologies will be ideal for offering a variety of acceptable surfaces for meat products [58].

3.4.1 Irradiation

The procedure of introducing a medium- to low-level energy radiation is known as irradiation. Irradiation is an energy generation release to waves or ionizing moving particles such that there is enough energy to escape the electrons from the atom or molecule. Despite its creation to enhance microbiological food safety and usage in the space program, irradiation is not being used as extensively as its possible advantages would suggest. Researchers have been studying consumer acceptance of this technology since the 1980s, but few have delved into the issues it faces in the meat industry. As per experts, consumer education is crucial for the acceptability of food technologies such as irradiation. They proposed that trade associations, government organizations, and higher education programs use digital channels to support the use of lesser food technologies such as radioactivity [59].

Irradiation was once considered a promising green technique for assuring food microbiological safety. Food irradiation was assumed to be the main source of material changes since it used a continual source of radiation dose to activate atoms or molecules in food. Irradiation has proven successful in marinating meat, extending shelf life, and eradicating toxic, degrading bacteria. However, irradiation meat has undergone physicochemical and biochemical changes as a result of its use, lowering its nutrient benefit and textural properties. Moreover, coupling irradiated with freezing, low temperatures, and heating can assist in mitigating detrimental nutritional and sensory changes in food [60].

Food can be irradiated to store, preserve, and retain nutritional content, improve quality, and increase safety. Previous evidence showed that irradiation-induced pathogen reduction was most successful when applied after packaging. The FDA has confirmed that the meat packed in plastic bags is safe under the irradiation process. Irradiation's impact on the physiological and biological parameters of meat and its byproducts has made great progress. Irradiation is already being considered as a viable option for increasing the physicochemical quality of meat in some cases. However, a better understanding of the energy, effects, and mechanical methods of irradiation are still needed [59]. Recent research has shown that irradiation can be used to age fresh meat as well as for bacteriostasis, thawing, freezing, frying, and tenderization. The softness, water retention capacity, and flavor of cow tissue can all be affected by irradiation [60]. According to the World Health Organization (WHO), food safety is thought to be unaffected by irradiation doses of less than 10 kGy. Irradiation has also been demonstrated to reduce infections and extend its shelf life of various types of red meat (goat, beef, and camel meat). Irradiated meat's biological constituents have gotten a lot of interest. Irradiation can preserve the natural quality of meat, but changes in nutritional parameters occur, especially lipids and proteins [61].

Non-thermal processing method such as food irradiation has various advantages over traditional thermal treatment, particularly effectively antibacterial and antiparasitic effects and less nutrient loss. When compared to conventional processing technology, food irradiation does not cause a significant temperature increase (raise of 2.8°C/10 kGy) and is a new method that is easy, cost effective, and highly efficient. It's worth emphasizing that the irradiation of food generates no wastewater. As a consequence, food irradiation is an environmentally friendly method [62].

3.4.2 High-pressure processing

HPP has become the most widely used non-thermal processing method in the food sector, with animal products accounting for almost a quarter of all HPP items. The molecular effects of HPP on microbial and endogenous meat components such as protein molecules, myoglobin enzyme activities, meat color chemistry, and lipids led to the discovery of the mechanisms that cause the majority of the color, texture, and oxidative changes observed when meat is subjected to HPP [63].

For microbiological safety, commercially produced HPP chicken and beef are prepared at high pressures. According to research undertaken over the previous decade, HPP can be produced at high temperatures without compromising bacterial inactivation when blended with plant source essential oils (EOs) [64].

HPP inactivates oxidative enzymes and food pathogens. It extends the shelf life while reducing other activities and substances that degrade quality. HPP-treated RTE meat has a shelf life of 10 weeks, while basic RTE meat has a shelf life of 4 weeks [65]. HPP is a simple processing method that involves exposing meat to a pressure range of 350–600 MPa for a few minutes in order to improve microbiological safety and shelf life. Pressure is maintained isostatically, which means that as the pressure rises, the product's volume drops. At greater pressures, weaker ionic and hydrogen bonds are destroyed, denaturing the protein by modifying its quaternary structure, which is preceded by its tertiary structure. HPP has a small effect on the nutritional value of meat. Low molecular weight vitamins and flavor components are unaffected by pressure since covalent bonds are unaffected. High-pressure treatment to increase beef product digestibility has the potential to be a useful technology [66].

The most explored quality element in early studies was meat texture and softness, due to the interest in using some amount of pressure for meat tenderization. The effect of HPP on meat system product attributes and quality parameters such as smoothness, pigmentation, and lipid and protein oxidation are all explored in detail. In the meat business, HPP is currently employed as a cold pasteurization treatment and also a technique to tenderize fresh meat and enable the building of stable structures in the preparation of cured meats [67].

3.4.3 Pulsed electric field

Among electrical-based processing technologies, the PEF is a relative newcomer. In contrast to thermal electrical-based solutions like a moderate electrical field and ohmic heating, short electrical pulse at high voltages allows for limited thermal effect management. PEF is a promising strategy for destroying living cells in the food material without modifying the features of food items, particularly meat products, due to these properties [66]. PEF has also been shown to improve drying, speed up curing, and minimize the amount of microbial spoilage in meat, albeit careful processing is required. While meat safety, tenderization, and rapid curing appear to be areas where PEF could provide appealing possibilities in meat processing, more research is required before PEF can become a commercial reality in the meat industry. According to studies, PEF treatment improves uptake during drying and brining. Furthermore, improved water binding during cooking was due to better brine and water-binding agent micro-diffusion [69]. Pulsed voltage affects in vitro modeled gastrointestinal protein digestion of cooked beef. The samples were evaluated for protein digestibility, soluble protein, protein profile (SDS-PAGE), free amino acid analysis, and mineral profile. After PEF treatment, the levels of soluble protein and protein digestibility (percent) both increased significantly. PEF treatment changed the protein profile of the beef digests, which had a beneficial impact on in vitro digestion kinetics, leading to more and quicker protein digestion during in vitro GI simulations [9].

The meat industry's goal is to deliver goods of consistent and predictable quality. Consumers' initial purchase (color) and resale (tenderness and juiciness) choices are affected by color, tenderness, and meat juiciness. PEF results in softness and juiciness by changing the composition of the meat [70]. Although the efficiency of PEF processing is determined by PEF process conditions and meat quality, the technique offers great ability to improve the quality of numerous meat cuts, which could boost both the meat industry and customers. PEF is a low-energy food-processing procedure that can be used to replace inefficient processing techniques in the meat industry to enhance the quality of lower-value cuts [68].

4. Conclusion

It is concluded that recent advances in meat and meat products have played an important role in improving the product life, making safe and quality products, and have good impact on human health. Meat is usually a rich source of protein. It also contains some other nutrients including fats, vitamins, and minerals. During processing, novel processing plays an important role in maintaining the nutritional value of meat and meat products. On the other hand, natural antioxidants in the form of extracts and whole ingredients are added to meat for the purpose of enhancing the nutritional value and shelf stability of meat products.

Author details

Waseem Khalid, Zahra Maqbool and Muhammad Sajid Arshad*
Department of Food Science, Government College University, Faisalabad, Pakistan

*Address all correspondence to: sajid_ft@yahoo.com

References

[1] Cobos A, Díaz O. Chemical composition of meat and meat products. In: Handbook of Food Chemistry. Heidelberg, Berlin: Springer; 2015. pp. 1-32

[2] Ahmad RS, Imran A, Hussain MB. Nutritional composition of meat. Meat Science and Nutrition. 2018;**61**(10.5772):61-75

[3] Devendra C, Leng RA. Feed resources for animals in Asia: Issues, strategies for use, intensification and integration for increased productivity. Asian-Australasian Journal of Animal Sciences. 2011;**24**(3):303-321

[4] Rubio NR, Xiang N, Kaplan DL. Plant-based and cell-based approaches to meat production. Nature Communications. 2020;**11**(1):1-11

[5] Thangavelu KP, Kerry JP, Tiwari BK, McDonnell CK. Novel processing technologies and ingredient strategies for the reduction of phosphate additives in processed meat. Trends in Food Science & Technology. 2019;**94**:43-53

[6] Considine KM, Kelly AL, Fitzgerald GF, Hill C, Sleator RD. High-pressure processing–effects on microbial food safety and food quality. FEMS Microbiology Letters. 2008;**281**(1):1-9

[7] Engchuan W, Jittanit W, Garnjanagoonchorn W. The ohmic heating of meat ball: Modeling and quality determination. Innovative Food Science & Emerging Technologies. 2014;**23**:121-130

[8] Zell M, Lyng JG, Cronin DA, Morgan DJ. Ohmic heating of meats: Electrical conductivities of whole meats and processed meat ingredients. Meat Science. 2009;**83**(3):563-570

[9] Bhat ZF, Morton JD, Mason SL, Bekhit AEDA. Current and future prospects for the use of pulsed electric field in the meat industry. Critical Reviews in Food Science and Nutrition. 2019;**59**(10):1660-1674

[10] Xie Y, Ma Y, Cai L, Jiang S, Li C. Reconsidering meat intake and human health: A review of current research. Molecular Nutrition & Food Research. 2022;**66**(9):2101066

[11] Munekata PE. Improving the sensory, nutritional and physicochemical quality of fresh meat. Food. 2021;**10**(9):2060

[12] Juárez M, Lam S, Bohrer BM, Dugan ME, Vahmani P, Aalhus J, et al. Enhancing the nutritional value of red meat through genetic and feeding strategies. Food. 2021;**10**(4):872

[13] Holman BW, Fowler SM, Hopkins DL. Red meat (beef and sheep) products for an ageing population: A review. International Journal of Food Science & Technology. 2020;**55**(3):919-934

[14] Nabi F, Arain MA, Hassan F, Umar M, Rajput N, Alagawany M, et al. Nutraceutical role of selenium nanoparticles in poultry nutrition: A review. World's Poultry Science Journal. 2020;**76**(3):459-471

[15] Chriki S, Hocquette JF. The myth of cultured meat: A review. Frontiers in Nutrition. 2020;**7**:7

[16] Ponnampalam EN, Bekhit AED, Bruce H, Scollan ND, Muchenje V, Silva P, et al. Production strategies and processing systems of meat: Current status and future outlook for innovation–a global perspective. In: Sustainable Meat Production and Processing. United States of America: Academic Press; 2019. pp. 17-44

[17] Ramachandraiah K, Han SG, Chin KB. Nanotechnology in meat processing and packaging: Potential applications—A review. Asian-Australasian Journal of Animal Sciences. 2015;**28**(2):290

[18] Boateng EF, Nasiru MM. Applications of ultrasound in meat processing technology: A review. Food Science and Technology. 2019;**7**(2):11-15

[19] Chapman J, Elbourne A, Truong VK, Cozzolino D. Shining light into meat–a review on the recent advances in in vivo and carcass applications of near infrared spectroscopy. International Journal of Food Science & Technology. 2020;**55**(3):935-941

[20] Rosario DK, Rodrigues BL, Bernardes PC, Conte-Junior CA. Principles and applications of non-thermal technologies and alternative chemical compounds in meat and fish. Critical Reviews in Food Science and Nutrition. 2021;**61**(7):1163-1183

[21] Arshad MS, Hina G, Anjum FM, Suleria HAR. Effect of milk-derived bioactive peptides on the lipid stability and functional properties of beef nuggets. Scientific Reports. 2022;**12**(1):1-12

[22] Khalid W, Arshad MS, Yasin M, Imran A, Ahmad MH. Quality characteristics of gamma irradiation and kale leaf powder treated ostrich and chicken meat during storage. International Journal of Food Properties. 2021;**24**(1):1335-1348

[23] Nisar MF, Arshad MS, Yasin M, Arshad MU, Nadeem MT. Influence of irradiation and moringa leaf powder on the amino acid and fatty acid profiles of chicken meat stored under various packaging materials. Journal of Food Processing and Preservation. 2019;**43**(9):e14166

[24] An KA, Arshad MS, Jo Y, Chung N, Kwon JH. E-beam irradiation for improving the microbiological quality of smoked duck meat with minimum effects on physicochemical properties during storage. Journal of Food Science. 2017;**82**(4):865-872

[25] Arshad MS, Kwon JH, Ahmad RS, Ameer K, Ahmad S, Jo Y. Influence of E-beam irradiation on microbiological and physicochemical properties and fatty acid profile of frozen duck meat. Food Science & Nutrition. 2020;**8**(2):1020-1029

[26] Khalid A, Sohaib M, Nadeem MT, Saeed F, Imran A, Imran M, et al. Utilization of wheat germ oil and wheat bran fiber as fat replacer for the development of low-fat beef patties. Food Science & Nutrition. 2021;**9**(3):1271-1281

[27] Nisar MF, Arshad MS, Yasin M, Khan MK, Afzaal M, Sattar S, et al. Evaluation of gamma irradiation and moringa leaf powder on quality characteristics of meat balls under different packaging materials. Journal of Food Processing and Preservation. 2020;**44**(10):e14748

[28] Jo Y, An KA, Arshad MS, Kwon JH. Effects of e-beam irradiation on amino acids, fatty acids, and volatiles of smoked duck meat during storage. Innovative Food Science & Emerging Technologies. 2018;**47**:101-109

[29] Arshad MS, Amjad Z, Yasin M, Saeed F, Imran A, Sohaib M, et al. Quality and stability evaluation of chicken meat treated with gamma irradiation and turmeric powder. International Journal of Food Properties. 2019;**22**(1):154-172

[30] Yaqoob Z, Arshad MS, Khan MK, Imran M, Ahmad MH, Ahmad S, et al. Ultrasound-assisted extraction of guava and papaya leaves for the development of functional shrimp patties. Food Science & Nutrition. 2020;**8**(7):3923-3935

[31] Sun XD, Holley RA. High hydrostatic pressure effects on the texture of meat and meat products. Journal of Food Science. 2010;**75**(1):R17-R23

[32] Ros-Polski V, Koutchma T, Xue J, Defelice C, Balamurugan S. Effects of high hydrostatic pressure processing parameters and NaCl concentration on the physical properties, texture and quality of white chicken meat. Innovative Food Science & Emerging Technologies. 2015;**30**:31-42

[33] McClements DJ, Grossmann L. A brief review of the science behind the design of healthy and sustainable plant-based foods. NPJ Science of Food. 2021;**5**(1):1-10

[34] Beya MM, Netzel ME, Sultanbawa Y, Smyth H, Hoffman LC. Plant-based phenolic molecules as natural preservatives in comminuted meats: A review. Antioxidants. 2021;**10**(2):263

[35] Munekata PES, Rocchetti G, Pateiro M, Lucini L, Domínguez R, Lorenzo JM. Addition of plant extracts to meat and meat products to extend shelf-life and health-promoting attributes: An overview. Current Opinion in Food Science. 2020;**31**:81-87

[36] Bernardo P, Patarata L, Lorenzo JM, Fraqueza MJ. Nitrate is nitrate: The status quo of using nitrate through vegetable extracts in meat products. Food. 2021;**10**(12):3019

[37] Ferysiuk K, Wójciak KM. Reduction of nitrite in meat products through the application of various plant-based ingredients. Antioxidants. 2020;**9**(8):711

[38] Nikmaram N, Budaraju S, Barba FJ, Lorenzo JM, Cox RB, Mallikarjunan K, et al. Application of plant extracts to improve the shelf-life, nutritional and health-related properties of ready-to-eat meat products. Meat Science. 2018;**145**:245-255

[39] Ursachi CȘ, Perța-Crișan S, Munteanu FD. Strategies to improve meat products' quality. Food. 2020;**9**(12):1883

[40] Gagaoua M, Picard B. Current advances in meat nutritional, sensory and physical quality improvement. Food. 2020;**9**(3):321

[41] Fiorentini M, Kinchla AJ, Nolden AA. Role of sensory evaluation in consumer acceptance of plant-based meat analogs and meat extenders: A scoping review. Food. 2020;**9**(9):1334

[42] Lee HJ, Yong HI, Kim M, Choi YS, Jo C. Status of meat alternatives and their potential role in the future meat market—A review. Asian-Australasian Journal of Animal Sciences. 2020;**33**(10):1533

[43] Gabdukaeva, L. Z., Gumerov, T. Y., Nurgalieva, A. R., & Abdullina, L. V. (2021). Current trends in the development of functional meat products to improve the nutritional status of the population. In IOP Conference Series: Earth and Environmental Science (Vol. 624, No. 1, p. 012196). Western Siberia, Russian Federation: IOP Publishing.

[44] Ponnampalam EN, Mann NJ, Sinclair AJ. Effect of feeding systems on omega-3 fatty acids, conjugated linoleic acid and trans fatty acids in Australian beef cuts: Potential impact on human health. Asia Pacific Journal of Clinical Nutrition. 2006;**15**(1):21

[45] Beriain MJ, Gómez I, Ibáñez FC, Sarriés MV, Ordóñez AI. Improvement

of the functional and healthy properties of meat products. In: Food Quality: Balancing Health and Disease. United States of America: Academic Press; 2018. pp. 1-74

[46] Younis K, Yousuf O, Qadri OS, Jahan K, Osama K, Islam RU. Incorporation of soluble dietary fiber in comminuted meat products: Special emphasis on changes in textural properties. Bioactive Carbohydrates and Dietary Fibre. 2022;**27**:100288

[47] Zinina O, Merenkova S, Tazeddinova D, Rebezov M, Stuart M, Okuskhanova E et al. Enrichment of meat products with dietary fibers: A review. Eesti Maaulikool. 2019:1808-1822

[48] Rani R, Kumar S, Yadav S. Pumpkin and chia seed as dietary fibre source in meat products: A review. The Pharma Innovation Journal. 2021;**10**:477-485

[49] Fernández-López J, Viuda-Martos M, Pérez-Alvarez JA. Quinoa and chia products as ingredients for healthier processed meat products: Technological strategies for their application and effects on the final product. Current Opinion in Food Science. 2021;**40**:26-32

[50] Efenberger-Szmechtyk M, Nowak A, Czyzowska A. Plant extracts rich in polyphenols: Antibacterial agents and natural preservatives for meat and meat products. Critical Reviews in Food Science and Nutrition. 2021;**61**(1):149-178

[51] Pellissery AJ, Vinayamohan PG, Amalaradjou MAR, Venkitanarayanan K. Spoilage bacteria and meat quality. In: Meat Quality Analysis. United States of America: Academic Press; 2020. pp. 307-334

[52] Heck RT, Lorenzo JM, Dos Santos BA, Cichoski AJ, de Menezes CR, Campagnol PCB. Microencapsulation of healthier oils: An efficient strategy to improve the lipid profile of meat products. Current Opinion in Food Science. 2021;**40**:6-12

[53] Pateiro M, Domínguez R, Lorenzo JM. Recent research advances in meat products. Food. 2021;**10**(6):1303

[54] Aljabeili HS, Barakat H, Abdel-Rahman HA. Chemical composition, antibacterial and antioxidant activities of thyme essential oil (Thymus vulgaris). Food and Nutrition Sciences. 2018;**9**(05):433

[55] Carvalho RA, Santos TA, de Oliveira ACS, de Azevedo VM, Dias MV, Ramos EM, et al. Biopolymers of WPI/CNF/TEO in preventing oxidation of ground meat. Journal of Food Processing and Preservation. 2019;**43**(12):e14269

[56] Kumar Y, Yadav DN, Ahmad T, Narsaiah K. Recent trends in the use of natural antioxidants for meat and meat products. Comprehensive Reviews in Food Science and Food Safety. 2015;**14**(6):796-812

[57] Priyadarshini A, Rajauria G, O'Donnell CP, Tiwari BK. Emerging food processing technologies and factors impacting their industrial adoption. Critical Reviews in Food Science and Nutrition. 2019;**59**(19):3082-3101

[58] Warner RD, McDonnell CK, Bekhit AED, Claus J, Vaskoska R, Sikes A, et al. Systematic review of emerging and innovative technologies for meat tenderisation. Meat Science. 2017;**132**:72-89

[59] Feng Y, Ramos T, Shankar S, Bruhn C. Meat irradiation technology usage: Challenges and recommendations from expert interviews. Food Protection Trends. 2019;**39**(1):84-93

[60] Jia W, Wang X, Zhang R, Shi Q, Shi L. Irradiation role on meat quality induced dynamic molecular transformation: From nutrition to texture. Food Reviews International. 2022;**38**:1-23

[61] Jia W, Shi Q, Shi L. Effect of irradiation treatment on the lipid composition and nutritional quality of goat meat. Food Chemistry. 2021;**351**:129295

[62] Pi X, Yang Y, Sun Y, Wang X, Wan Y, Fu G, et al. Food irradiation: A promising technology to produce hypoallergenic food with high quality. Critical Reviews in Food Science and Nutrition. 2021;**66**(9):1-16

[63] Bolumar T, Orlien V, Sikes A, Aganovic K, Bak KH, Guyon C, et al. High-pressure processing of meat: Molecular impacts and industrial applications. Comprehensive Reviews in Food Science and Food Safety. 2021;**20**(1):332-368

[64] Chuang S, Sheen S. High pressure processing of raw meat with essential oils-microbial survival, meat quality, and models: A review. Food Control. 2022;**132**:108529

[65] Abera G. Review on high-pressure processing of foods. Cogent Food & Agriculture. 2019;**5**(1):1568725

[66] Gómez I, Janardhanan R, Ibañez FC, Beriain MJ. The effects of processing and preservation technologies on meat quality: Sensory and nutritional aspects. Food. 2020;**9**(10):1416

[67] Bolumar T, Orlien V, Bak KH, Aganovic K, Sikes A, Guyon C, et al. High-pressure processing (HPP) of meat products: Impact on quality and applications. In: Present and Future of High Pressure Processing. United States of America: Elsevier; 2020. pp. 221-244

[68] Gómez B, Munekata PE, Gavahian M, Barba FJ, Martí-Quijal FJ, Bolumar T, et al. Application of pulsed electric fields in meat and fish processing industries: An overview. Food Research International. 2019;**123**:95-105

[69] Kantono K, Hamid N, Oey I, Wang S, Xu Y, Ma Q, et al. Physicochemical and sensory properties of beef muscles after pulsed electric field processing. Food Research International. 2019;**121**:1-11

[70] Arshad RN, Abdul-Malek Z, Roobab U, Munir MA, Naderipour A, Qureshi MI, et al. Pulsed electric field: A potential alternative towards a sustainable food processing. Trends in Food Science & Technology. 2021;**111**:43-54