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Chapter

Introductory Chapter: A Global Presentation on Trends in Food Processing

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1. Introduction

Nowadays food processing has reached a level that is hard to imagine. Food processing is almost omnipresent. Almost all food consumed in almost all settings is now processed in some way. Varied types of food processing have beneficial or even negative effects on food, diet quality, and human health [1].

A range of new food processing technologies has been investigated and developed to modify or replace traditional food processing techniques so that better quality and more consumer preference-oriented foods can be manufactured [2]. The focus has been on quality over the last decade, enhancing the process efficiency, safety, productivity, and stability of food products in a healthier way [3].

The nutritional quality of food is influenced by factors such as quality of raw material, transportation, processing techniques, packaging, storage, and the whole food chain (farm to fork) [4, 5].

Several existing methods and techniques included in food processing are used in order to transform raw material ingredients into food for people's consumption. Food processing implies the use of clean, butchered, and harvested components to manufacture food products for the market demand. There are numerous ways to produce food [6, 7].

Nowadays, an impressive displacement process is taking place worldwide within alimentary production patterns and systems, with regard to the ready-for-consumption food, which replaces traditional food based on fresh meals. However, not much attention is being paid to food processing, when it comes to dietary guidelines, classifications of food products, or epidemiology studies [8].

Scientists in this industry regard food processing in various ways. Certain processes such as drying, nonalcoholic fermenting, skimming, pasteurization, freezing, and vacuum-packing are rightly considered as beneficial in the food industry. However, other processes are regarded as less beneficial or even harmful for human health, namely, charring, hydrogenation, carbon dioxide addition, alcoholic fermenting, salt-pickling, and sugaring [1, 7].

Nowadays, a drastic change has been noticed in how compliance and its consequences are approached. Due to regulatory requirements, and to a much less tolerant and most knowledgeable public, the industry has been in the critical public eye and placed under a much more thorough scrutiny and examination than ever before. As a consequence, at the local and state levels, there has been an increasing demand of documentation, in terms of legislation. It is very difficult to make a mistake and have no one find out about it. In the end, we are actually all consumers and expect safe food. Legislation is seeing a lot of issues related to allergens, organics, and package labeling [9–11].

Food safety technology has greatly interfered with and changed the way food industry specialists identify, react to, and communicate on specific food safety issues. Thus, the Internet and social media have impacted the industry by allowing an instant information exchange, which, at times, can include true or even false data, hence rightly entitling food companies to have a correspondingly adequate reaction. The legislation regarding the food industry attempts to regulate the management of pests, sanitation, and contamination with fewer toxic materials. Having said that, there will always be people trying to "beat" any law or system; consequently it is extremely important to plan for that by being able to identify issues with strong systems and processes. The trap, however, lies in believing that laws or government can control food safety. For managing the hazards involved and the control over food safety, the legislation needs to constantly improve alongside with its enforcement, according to the Hazard Analysis Critical Control Points (HACCP) model [12, 13].

Services, processes, or innovations, understood as new products, are recognized as an important instrument for companies belonging to the food industry to stand out from competitors and to satisfy consumer expectations [14, 15].

Notwithstanding, nowadays, consumers' preferences for food have changed significantly; in fact, consumers believe that food should directly contribute to their health [15, 16].

In these circumstances, the demands of consumers are no longer limited to satisfying hunger. Food should provide the necessary nutrients while at the same time preventing nutrition-related diseases and improving physical and mental well-being [17].

Recent food industry innovations mainly regard new technical and scientific approaches in food processing, as well as the implementation of new food products on the market. In this respect, due to the constantly rising cost of healthcare, the steady increase in life expectancy, and the necessity for the elderly to enjoy an improved life quality, functional food plays a major role in the consumers' demand nowadays. As such, researchers agree in stating that functional food represents one of the most rewarding and gratifying areas of research and innovation in the food industry [18, 19].

The food industry is a key branch in the global economy. As a consequence, many authors highlighted its relevance for employment and economic output [9, 11, 14].

2. New trends in food processing

Nowadays, a major trend in food manufacturing has been influenced by the consumers' demand of functional or health-promoting foods. According to the Food and Nutrition Board of the Conform Institute of Medicine, functional foods are defined as "any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains." The term "functional food" was first used in Japan in the mid-1980s, and it refers to processed nutritious foods containing supplementary ingredients that give support to specific functions of the human body [1, 7, 20].

In the year 2000, Sloan presented another option for the definition of functional food, namely, "a food or beverage that imparts a physiological benefit that enhances overall health, helps prevent or treat a disease/condition, or improves physical or mental performance via an added functional ingredient, processing modification, or biotechnology" [21, 22].

Señorans et al. in 2006 classified health-promoting foods into three different categories, according to the types of food processing and their influence on human health, as follows: (1) those with specific functionalities, (2) foods fortified with natural ingredients providing a wanted functionality (foods enriched with natural ingredients), and (3) probiotics and prebiotics [7]. This classification is topical nowadays, but it is constantly innovating.

2.1 Functional foods

The major processes based on biotechnology are mainly used in the production of foods with specific functionalities. In this respect, genetic engineering constitutes an important support. Consequently, the industry's final objective of obtaining new foods of specific composition, with new and better functional properties, can be achieved, as these new biotechnologies can alter the genes contained in certain cells [23, 24].

The raw materials with modified composition constitute another promising area for producing foods with enhanced nutritional value. For example, foods having improved nutritional value began to appear 20 years ago, such as tomatoes with higher lycopene content or corn with higher oleic acid content [25] and white wines with a higher concentration of resveratrol [26], hypoallergenic foods, in which a specific protein or peptide has been removed [27], etc.

Functional food products have also been produced by the wide use of enzymes. Hence, new advances in this area have been used/are being used such as techniques of enzyme and cell immobilization or new developments in bioreactors. For example, milk protein concentrate with a decreased content of lactose [28] and fats with a controlled content of fatty acids [29] can be produced using the abovementioned techniques.

Another important technique is the application of membrane technology, which is used in modifying the composition of foods and their functionality [30]. This process lends itself mostly to foods in a liquid medium. For example, this method has proven its usefulness by allowing separation and concentration of milk components without the proteins, bioactive substances, and flavor being altered [31]. In addition, various processes have been developed in the dairy industry, for instance, ultrafiltration [32], nanofiltration [33], electrodialysis [34], and lactoferrin [35].

Another technological process is the removal of antinutrients by means of supercritical fluid extraction. Antinutrients are compounds which are thought of as negative or non-healthy ones, such as fats, caffeine, cholesterol, etc. [36]. This technology has been mainly used since the 1990s, for the elimination of caffeine from coffee [37] (this improved technique is still used today [38]), alcohol from cider [39] and wine [40], and fat from foods such as French fries, onion rings, and snack foods [41]. This improved technique is used today for extraction of raspberry seed oil [42], extraction of oleoresins and plant phenolics [43], bioactive compounds from plants [44], and food quality and food safety evaluation [45].

2.2 Foods enriched with natural ingredients

The addition of iron to bread or vitamin A and D to milk is an old and well-known procedure called "food fortification." The loss of nutrients while food is being processed has been overcome lately by supplementing health-promoting ingredients or nutraceutical ingredients to food products [24, 25].

The most important elements used for food fortification are iron, vitamin A, iodine, folate (vitamin B9), vitamin B12, other B vitamins (thiamine, riboflavin, niacin, and vitamin B6), vitamin C, vitamin D, calcium, selenium, fibers, proteins, and fatty acids [46].

In this respect, consumers generally require to be offered "all-natural" foods, and in order to provide them with this type of products, "natural ingredients" have been manufactured by biotechnological, membrane technology, and supercritical fluid extraction [24, 25].

2.3 Probiotics and prebiotics

Probiotics and prebiotics are part of the so-called foods that promote health. They are considered to be major nutrients that influence the physiology and gastrointestinal function [47].

According to the FAO/WHO definition, probiotics are defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host." Probiotics have beneficial effects on health through mechanisms of action, such as preventing colonization or pathogen adhesion, metabolism production, and immune system modulation by producing antibodies to immunoglobulins [48].

Probiotics, according to Gipson, are "a substrate that is selectively used by host microorganisms that confer a health benefit" [50]. The most used probiotic compounds are inulin, fructo-oligosaccharides, fructans, lactulose, and galacto-oligosaccharides [51].

3. Thermal technologies

3.1 Radio frequency heating

Radio frequency heating (dielectric heating) is a process by which a high-frequency radio wave is created using a generator for heating a dielectric material. Heat is quickly generated in the center of the food [52].

Each food product has specific dielectric properties, and these depend on the viscosity, temperature, chemical composition, and other physiological properties of the food [53]. It is applied in the food industry for continuous and batch heat processes [54]; rapid defrosting of frozen fish, meat, and other processed materials or foodstuff [55]; baking, disinfecting, and sanitizing dry food products (seeds, cereals, dried fruits, legumes); and sterilizing solid or viscous packaged foods [53, 54].

3.2 Microwave heating

Microwave heating is a thermal process that is performed with electromagnetic microwave radiation (1–100 GHz) and heat transfer. Any food that is exposed to the microwave is heated due to the electric and magnetic fields that generate heat [56].

The dielectric and magnetic properties of foods influence microwave activity. Due to the presence of water, microwave-treated liquid foods absorb electromagnetic energy very quickly [57].

Foods heat faster outside than indoors. Microwave heating is not uniform and results in nutrient losses due to the high temperature of the heated surface [58]. Microwave heating is used at home and at industrial level. At the household level, it is used for heating and thawing food, because it is a very fast method. In the food industry it is used for food drying, baking of bread and biscuits, pre-preparation and cooking of foods (cereals, meat, and meat products), defrosting food, bleaching vegetables, and pasteurizing and sterilizing fast food/liquid food, meals, and other food products [56, 59, 60].

3.3 Ohmic heating

Ohmic heating is a process of Joule heating, electro-heating, or electro-conductive heating. Electricity flows through the food. This process compared to microwave and radio frequency heating has no penetration depth limitation. The heating is carried out evenly, without damaging the nutrients in the food [61, 62].

Ohmic heating's applied products are for liquid foods containing large particles: slices of fruit in syrups and sauces, stews, soups, and heat-sensitive liquids [61, 63]. Food products subjected to ohmic heating treatment are high-quality, value-added, and shelf-stable products. This process is also suitable for defrosting, pasteurization, sterilization, extraction, dehydration, fermentation, evaporation, peeling, bleaching, packaging, and heating of food at serving temperature [62, 64, 65].

3.4 Infrared heating

The infrared process is between the ultraviolet energy region and the microwave. Infrared radiation is normally classified based on its spectral spectrum, in near-infrared (700–1400 nm), mid-infrared (1400–3000 nm), and far-infrared (3000–10,000 nm) regions [52, 66].

The far infrared is considered to be the most useful region for food processing, as most food components are absorbed by radiation in this region [66, 67]. Infrared heating is an indirect way of heat. At this stage electromagnetic energy enters food, adsorbs to the surface, and then converts to heat [58, 67].

Heating by radiant energy depends on the characteristics and color of the food. IR radiation is used to change the quality of food by changing the flavor, aroma, and the color of the food surface [58, 67].

Infrared heating is used in the food industry for roasting, cooking, baking, dehydrating, drying, pasteurizing, peeling, bleaching, and food processing [66, 68, 69]. The process of heating by IR is used in the food industry successfully and for 32 inactivation of lipoxygenase, lipases, α amylases, and enzymes responsible for the development of aromas and for the damage of fruits and vegetable and inactivation of bacteria, spores, yeast, and mold in both liquid and solid foods [70, 71].

Infrared heating can be combined for processes such as dehydration, cooking, baking, and freeze-drying [69, 72].

4. Nonthermal technologies

The term "nonthermal processing" is very often used to describe efficient processes at ambient or sublethal temperatures [73].

Developing and optimizing the processes of novel food preservation have become a major trend in food processing nowadays. Thus, those used to obtain minimally processed foods stand out alongside the ones based on emerging physical techniques (high-pressure processing, pulsed electric field processing, cold plasma treatment, ultrasound processing, irradiation, UV and pulsed light). These processes enable engineers and scientists to produce more nutritive, fresher, less processed, and safer foods [1, 7].

Minimally processed products gained more attention due to health considerations, in the last decade. In comparison to thermal processing, nonthermal techniques are beneficial to maintain the freshness, nutritional properties, flavor, and color attributes, especially some thermal unstable compounds such as ascorbic acid and polyphenols. More than that, novel nonthermal processing techniques show a potential application in the reduction of food immunoreactivity [74].

This processing method involves a loss in food quality, though thermal preservation methods provide safer foods. Hence, minimizing the degradation of food quality by limiting the damage that heat can produce on the food constitutes the main objective of the nonthermal preservation methods. They also imply the inactivation of those microorganisms and enzymes that are responsible for food degradation [7, 73].

4.1 High-pressure processing

High hydrostatic pressure was first used in Japan in the 1990s. It has been improved over the years and is now used worldwide. It's basically a cold pasteurization, which is traditionally used in the destruction and inactivation of spoilage and pathogenic microorganisms while preserving the quality of food. This technology is an energy-efficient and rapidly acting technological aid used in today's food processing [75–78]. The aim of this process is to extract a considerable amount of bioactive compounds from foods and the enhancement of their bioavailability [79, 80]. Sensory, nutritional, and functional properties of fruit and vegetable beverages have been slightly modified by means of the nonthermal processes in whose development and design scientists showed a great interest, in recent years [81]. As compared to conventional methods, processing has become cheaper in some cases as it requires a lower energy input, although the HHP equipment involves considerable costs [82].

High hydrostatic pressure processing (100–1000 MPa) is a minimal thermal technology applied to food products, often at room temperature [83]. This technology has been primarily focused as a substitute technology for heat processing. Heat processing is used to destroy or inhibit the activity of damaged microorganisms or enzymes. It can be successfully used at room temperature, reducing the thermal energy required for heat processing, to make food products without unwanted changes, such as nutritional and sensory characteristics. As a minimal thermal process, high hydrostatic pressure can be applied to heat-sensitive foods to guarantee microbiological safety and quality characteristics in minimally processed products. Therefore, the application of this process can provide high-quality pasteurized food products. Thus, high-pressure processing may provide fruit and vegetable products with suitable shelf life that maintain characteristics similar to fresh products, which consumers demand [81, 84, 85].

The critical factors in HHP process are shown in **Table 1**, and their magnitude will depend on the microorganism or enzyme subject to inactivation [86] (**Table 2**).

High hydrostatic pressure process preserves the freshness and taste of the product at a higher level, has low processing losses, and thus has a high product yield [87].

This technology has been analyzed, with good results, on a number of foods: beverages, juices, vegetables, fruits, meat products, fish and seafood, and ready-to-eat foods [88–90]. The technology is successfully used to preserve meat products [88] or to increase the shelf life of goat cheese and yogurt and reduces the allergenicity of milk and decreases cheese ripening time [91–93].

Conclusion. Advantages, limitations, and commercial applications of high-pressure processing are presented in **Table 3**.

Lactobacillus	***Bifidobacterium***	**Others**
L. acidophilus NCFM	*B. adolescentis*	*Enterococcus faecium*
L. bulgaricus	*B. animalis*	*Pediococcus pentosaceus*
L. casei	*B. breve*	*Saccharomyces boulardii*
L. delbrueckii	*B. bifidum*	
L. kefiranofaciens M1,	*B. lactis*	
L. paraplantarum	*B. longum*	
L. paracasei	*B. pseudocatenulatum*	
L. plantarum		
L. reuteri		
L. rhamnosus		
L. salivarius		

Table 1.
The most frequently used probiotics [49].

Pressure
Time required to achieve the treatment pressure
Time at an specific pressure
Treatment temperature
Final decompression time
Vessel temperature distribution at pressure
Initial product temperature
Product composition
Product pH
Packaging material integrity
Product water activity

Table 2.
Factors influencing the high hydrostatic pressure process [7, 86].

4.2 Pulsed electric field processing

This technique uses high-intensity pulsed electric field and involves pulses of high voltage (typically 20–80 kV/cm), for short periods of time (less than 1 second), which pass through the product placed between a set of electrodes inside a chamber, which are applied to fluid foods [94–96].

This main microbial process is used in order to inactivate some enzymes. It is also used to reduce the heating time of foods, and thus the degradation in the sensory and physical properties of foods is minimized [7]. In **Table 4**, a description of the different factors that affect the microbial inactivation with pulsed electric field processing can be found.

Pulsed electric field has been used in several processes: food processing, bioprocessing, inactivation of microorganisms, or permeabilization of food cells without thermal effects. The application of the processes used has good results for liquid and semisolid food products. Satisfactory results were obtained for the processing and preservation of foods such as milk, fruit juices, cooked meat, liquid eggs, and soups [94–96, 98].

Advantages	Limitations	Commercial applications
• No evidence of toxicity	• Little effect on food enzyme activity	• Kills vegetative bacteria (and spores at higher temperatures)
• Colors, flavors, and nutrients are preserved	• Some microbes may survive	• Pasteurization and sterilization of fruits, vegetables, meats, sauces, pickles, yoghurts, and salad dressings
• Reduced processing times	• Expensive equipment	• Potential for reduction or elimination of chemical preservatives
• Uniformity of treatment throughout food	• Foods should have approx. 40% free water for antimicrobial effect	• Decontamination of high-risk or high-value heat-sensitive ingredients
• Desirable texture changes possible	• Limited packaging options	
• In-package processing possible	• Regulatory issues to be resolved	

Table 3.
Advantages, limitations, and commercial applications of high-pressure processing [1].

Pulse width
Electric field intensity
Treatment temperature
Treatment time
Type of microorganism
Pulse wave shapes
pH
Concentration and growth stage of microorganism
Medium conductivity
Presence or absence of antimicrobials and ionic compounds
Medium ionic strength

Table 4.
Factors affecting the microbial inactivation with pulsed electric fields [7, 97].

However, pulsed electric field processing does not perform well for solid food products without air bubbles that have very low electrical conductivity [99].

In food processing it is used successfully for several types of fruit. The analyses have shown that they cause a minimal negative effect on the physical and sensory properties but increase the shelf life and the functional and textural properties of the juices [95, 100].

The process is successfully used for the production of French fries to reduce the cutting force required. In this situation, it has been shown that it inactivates microorganisms, preserving the nutritional and sensory quality of foods [96, 99, 101].

Conclusion. Advantages, limitations, and commercial applications of pulsed electric field processing are presented in **Table 5**.

4.3 Cold plasma treatment

Cold plasma is considered a modern technology, with nonthermal activity, which has been used in food processing in microbial inactivation and in the

Advantages	Limitations	Commercial applications
• There are no records of toxicity	• Unidentified activity on spores and enzymes	• For liquid foods
• Flavors, colors, and nutrients are preserved	• Hard to use with conductive materials	• Pasteurization of fruit juices, soups, liquid egg, and milk
• The treatment time is relatively short	• Satisfactory activity only for liquids or liquid particles	• Accelerated thawing
	• Satisfactory results only in combination with heat	• Decontamination of heat-sensitive foods
	• Foods may be affected by process of electrolysis	• Inactivates vegetative cells
	• Safety worry in local processing environment	
	• Energy activity not yet certain	
	• Regulatory issues are not clarified	
	• Unsatisfactory results in the presence of bubbles	
	• Safety and operational issues	

Table 5.
Advantages, limitations, and commercial applications of pulsed electric field [1].

decontamination of products from the food industry. This technology has been used because the energy consumption is lower and the demands on temperature are lower when compared to conventional processing methods [102, 103].

The cold plasma processing system is supported by a ceramic electrode and a high-frequency plasma generator [104]. Plasma is, in fact, a partially ionized gas consisting of reactive species, such as ions, electrons, UV photons, molecules, free radicals, and excited atoms. Plasma components can interact with proteins and modify their conformations [102, 105, 106].

In the food industry, cold plasma is used as a powerful disinfection tool for decontamination in packaging and after packaging of food products. It is also used for dry disinfection of solid and liquid foods (meat, fish, dry milk, sprouted seeds, herbs, spices, grains, and fresh products) [107–109].

Cold plasma treatment is a fast technology and does not leave toxic residues or post-processing exhaust gases. Even if it has certain advantages, we must take into account the aspects regarding the nutritional content, the color, the texture, the chemical changes, and the general quality of the food. These aspects are influenced, cold plasma treatments are not yet widely used, and more studies are needed [103, 108, 110].

Conclusion. Advantages, limitations, and commercial applications of cold plasma treatment are presented in **Table 6**.

4.4 Ultrasound

Sound waves whose frequency exceeds the hearing limit of the human ear (∼20 kHz) are known as ultrasound. Ultrasound is one of the recently developed technologies in view of maximizing quality, minimizing processing, and ensuring the safety of food products. Ultrasound is applied in food processing in order to improve processes such as food preservation, mass transfer, manipulation of texture, assistance of thermal treatments, and food analysis [111].

Advantages	Limitations	Commercial applications
• Effective with temperature sensitive products	• There is no commercial tool available for disinfecting and sanitizing food products and packaging materials	• Disinfection of processing equipment. Shelf life extension
• Reduce cross-contamination and the establishment of biofilms on equipment	• Applied by various research organizations and universities, but not by industry	• Food processing equipment, food packaging, food contact surfaces, preservation
• Minimal effects on food quality and appearance of the product	• Interaction of electronically excited molecules with the food or packaging materials needs to be identified	• Inactivates surface spores and microflora on packaging food/materials surfaces
• No shadowing effect ensuring all parts of a product are treated	• Modification of food packaging polymers is expected	• Technology of decontamination for mild surface such as cut fresh meat and vegetables
	• No potential scale up to pilot plant level for food industry yet	• Irregularly shaped packages such as bottles can be effectively treated, contrary to technologies such as UV or pulsed light where shadowing occurs
	• Stability for large-scale commercial operations is not clear	
	• Spore inactivation mechanism is unknown	
	• Regulatory issues	

Table 6.
Advantages, limitations, and commercial applications of cold plasma treatment [1].

In food processing, ultrasound is applied for analysis and quality control, and given the frequency range, it can be divided into low and high energy.

Ultrasonic processing is successfully used for food processing and preservation processes. Also, ultrasound is used for crystallization, drying, emulsification, solubility, homogenization, dispersion, improving texture, or modifying the viscosity and fermentation process [112–116].

It is successfully used to increase microbial safety in fruit juices [117, 118]. The use of ultrasound for the extraction of bioactive compounds from seeds, plants, or food has shown an increase in extraction efficiency [113, 114].

Although, this technology has advantages in food preservation and extraction of some compounds, studies have shown that it diminishes the quality of food: nutritional value, aroma, and color [119, 120]. Consequently, it is necessary to deepen studies for large-scale use in food processing.

Conclusion. Advantages, limitations, and commercial applications of ultrasound processing are presented in **Table 7**.

4.5 Irradiation

Radiation is a process used to conserve food. This is a nonthermal process that lowers or eliminates microorganisms and does not destroy the properties of food. This process is considered by 55 countries to be safe [121, 122] if 1 of the 3 approved irradiation processes is used: gamma rays, X-rays, or electron beams [123].

Advantages	Limitations	Commercial applications
• Increased heat transfer	• Depth of penetration affected by solids and air in the product	• Effective against vegetative cells, spores, and enzymes
• Little adaptation required of existing processing plant	• Complex mode of action	• Effective tool for microbial inactivation
• Reduction of process times and temperatures	• Needs to be used in combination with another process (e.g., heating)	• Minimal effect on the ascorbic acid content during processing
• Can be used alone or in combination with heat and/or pressure	• Potential problems with scaling-up plant	• Enhances extraction yield
• Batch or continuous operation	• Possible damage by free radicals	• Fruit juices preservation
• Higher throughput and lower energy consumption	• Unwanted modification of food structure and texture	
• Achieves a desired 5 log for foodborne pathogens in fruit juices	• Negatively modify some food properties including flavor, color, or nutritional value	
	• Possible modification of food structure and texture	

Table 7.
Advantages, limitations, and commercial applications of ultrasound processing [1].

Advantages	Limitations	Commercial applications
• Reliable and energy efficient	• Localized risks from radiation	• Suitable for nonmicrobial applications (e.g., sprout inhibition)
• Excellent penetration into foods	• Poor consumer understanding	• Insecticidal
• Improvement in flavor in some foods	• High capital cost	• Suitable for sterilization
• Suitable for large-scale production	• Difficult to detect	• Packaging
• Little loss of food quality	• Higher doses may produce radiation-induced degradation products	• Appropriate for fruits, vegetables, herbs, spices, meat and fish preservation
• Negligible or subtle losses of bioactive compounds	• Changes in flavor due to oxidation	• Suitable for raw, dry foods or processed food
• Minimal modification in the flavor, color, nutrients, taste, and other quality attributes of food	• Formation of free radicals	
• No increase in food temperature during processing		

Table 8.
Advantages, limitations, and commercial applications of irradiation [1].

Gamma or X-rays rapidly enter food and inactivate microorganisms. They are high-frequency waves; they do not generate heat and thus the quality of the food remains intact [124–126].

Following irradiation, food undergoes minimal changes in the content of nutrients, aroma, color, and taste, considered insignificant [122, 127].

In the food industry, irradiation is used to reduce post-harvest losses, to preserve the color of meat, and to inhibit germ formation in products such as potatoes. It is also used to control post-packaging contamination for several types of foods (vegetables, fruits, spices, cereals, fish) [124, 128].

According to studies, not all foods are suitable for irradiation, for example, milk and foods that are high in lipids and vitamins [129]. There are contradictory studies on the influence of irradiation of food products and packaging; therefore it is a topical topic for new studies [125].

Conclusion. Advantages, limitations, and commercial applications of irradiation are presented in **Table 8**.

4.6 UV and pulsed light

Intense and short-duration pulses of broad spectrum "white light" (UV in the near-infrared region) are used in the method of pulsed and UV light, which has

Advantages	Limitations	Commercial applications
• No thermal effect, so quality and nutrient content are retained	• Pulsed light—mostly suitable for liquid foods and surface of solid foods, hence limiting its application	• Shelf life extension of ready-to-eat cooked meat products
• Can be applied with other nonthermal processing technologies	• Pulsed light—packaging materials for irradiation should be chemically stable	• Alternative treatment to thermal pasteurization of fresh juices
• Maintains food texture and nutrients	• Pulsed light—the material should be transparent in order to allow the light to pass into the food	• Bacterial inactivation in fruit juices and milk
• Unlike chemical biocides, UV does not alter the chemical composition, taste, odor, or pH of the product and leave no toxins or residues into the process	• Pulsed light—the mechanism by which pulsed light induces cell death is yet to be fully explained	• Surface decontamination of eggs and chicken
• Neither increases the temperature of the product nor produces undesirable organoleptic changes	• UV—dose response behavior of food pathogens in viscous liquid foods needs to be developed	• Decontamination of food powders
	• UV—more kinetic inactivation data for pathogen and spoilage microorganisms is required to predict UV disinfection rates on food surfaces	• Decontamination of food processing equipment
		• Decontamination of air and surfaces
		• Water sterilization and wastewater disinfection
		• Mitigation of allergen from food

Table 9.
Advantages, limitations, and commercial applications of UV and pulsed light [1].

been made use of lately in food preservation, For most applications, a high level of microbial inactivation is provided within a fraction of a second, just by applying some flashes onto the food products. Ultraviolet light and pulsed light are modern techniques used to increase food safety. These techniques are minimally invasive, maintain the nutritional qualities and sensory appearance of foods, and at the same time extend the shelf life [130–132]. UV technology uses shorter wavelength (100–380 nm) while pulsed light operates on a broad spectrum of light (180–1100 nm) [133].

Because of its poor penetration level, this technology has been used in sterilization and the reduction of microbial load on food processing equipment, food surfaces, or packaging materials. However, this method with UV light is also used in the pasteurization process of fruit juices [134].

The application of UV technology has been used for the first time in Europe to disinfect municipal drinking water as an alternative to chloride. It is now used globally for the treatment of drinking water, processing water, wastewater, and industrial water [132, 135]. This treatment is used as an alternative method for the thermal pasteurization of fresh juices. It is also used as a disinfection method in the food industry. Research has shown that it is effective against bacterial pathogens, does not increase the temperature of the treated products, and does not produce unwanted organoleptic changes [136, 137].

Pulsed light is a nonthermal technology and is probably the best alternative method for decontaminating surfaces in the food industry and food packaging. This technology has the role of sterilizing or inactivating microorganisms on work surfaces, equipment, packaging materials, and equipment [131]. According to studies, pulsed light inactivates bacteria, viruses, and fungi even faster and more effectively than continuous UV treatment [130, 133].

Conclusion. Advantages, limitations, and commercial applications of UV and pulsed light are presented in **Table 9**.

5. Conclusion

With the new trends of the modern world, food consumers come with new demands on food. They consider that a food is not enough to satisfy the need for hunger, but it must be as nutritious as possible and can prevent certain diseases. The processing methods used in the food industry, presented in this chapter, are the newest methods available. They try to be minimally invasive, to ensure food safety, and to maintain their nutritional, sensory, and structural qualities. The technologies presented are used in food processing, but they can be improved and require future studies to deepen the existing information.

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Conflict of interest

Author declares there is no conflict of interest.

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