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### Scientific Research

### An overview of the application of advanced non-thermal technologies in the food industry

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#### ABSTRACT

Food processing is one of the most important industries, and it has undergone many changes due to the increasing demand for high-quality food. Attention to preserving nutrients and not changing the texture and color of products indicates the need to use technologies with lower temperatures because older technologies usually use high temperatures. Today, the health effects of food are among the most important factors in the acceptability of a product. In newer processes, it is possible to preserve all kinds of vitamins and the quality and color of the final product with less heat. Among these processes, we can mention membrane filtration, bacteriocins, microencapsulation, ultrasound, extrusion cooking, and irradiation. In addition to maintaining the quality and nutrients of the product, the above methods are also cost-effective and environmentally friendly, which clearly shows the need to pay more attention to them to maintain health, along with economic and environmental issues. Encapsulating nutrients also preserves the substances in ecological conditions and the digestive tract, which has led to this method receiving more attention from specialists today. In this article, various types of modern processing methods in the food industry have been investigated.

## 1- Introduction

Today, in developed countries, alternative processing methods have been sought to preserve nutrients, reduce environmental damage, reduce and prevent pollution, and minimize waste, which can maintain product safety with minimal processing to maintain a fresh appearance [1, 2]. Developing new functional foods requires technologies that preserve healthy and nutritious foods to produce healthier ones [3]. Thermal methods used to increase food preservation and destroy pathogenic microorganisms and inactivate enzymes are very time-consuming and consume high energy, which increases production costs. Also, using thermal methods has harmful effects such as reducing product quality, losing nutritional properties such as vitamins, oxidation, adverse effects on sensory properties, and protein denaturation, which increases the need for non-thermal methods that are also environmentally friendly [4]. The use of new techniques requires less time, energy, and water. Non-thermal methods include membrane filtration, bacteriocins, microencapsulation, ultrasound, extrusion cooking, and irradiation, which preserve nutrients and reduce damage to the product [5, 6]. One of the new methods is membrane filtration, which is mostly used to process milk, fruit juice, beer, and soft drinks. The membrane is made of natural and synthetic materials and acts as a selective permeability barrier to separate materials into two parts under pressure [7]. This method is used in the dairy industry to remove bacteria and spores from skim milk, separate casein micelles, separate and disintegrate fat globules from whole milk, concentrate whey, separate whey proteins, and desalt whey membrane processes. It is used in the brewing industry for clarification, and in the sugar industry for the purification of mineral salts [8]. Since bioactive substances have antioxidant, antimicrobial, and therapeutic properties, special attention is paid to the preservation and storage of these substances in the food industry today, and these compounds can be prevented from being destroyed by

microencapsulation. These compounds have their effects on the quality and stability of food products [8]. In microencapsulation, targeted release causes the stability of the compounds during processing, storage, and digestion. Also, by preserving the nutritional value of the product, it can be effective in preserving the taste, aroma, and smell of the substances. The substances that are placed inside the coating are called the core or internal phase, and the covering materials are called the membrane or shell, which are used from materials such as carbohydrates, gums, fats, and polymeric materials. Microencapsulation is used for probiotic bacteria and bioactive compounds such as vitamins, enzymes, and phenolic compounds [10, 11]. This method is also used to coat or enclose off-flavor materials, essential oils, acids, alkalis, and buffers for targeted release at a specific time to protect them from environmental factors such as oxygen, heat, and biological and chemical agents. In other words, this method creates a barrier between the bioactive materials and the environment, which protects them [12]. Another new processing method used for ready-to-eat foods such as snacks and pasta is extruding. In this method, various products are produced by applying various operations such as mixing, baking, kneading, cutting, molding, and shaping. This method has gained popularity due to the preservation of macronutrients and micronutrients, bioactive compounds that improve the nutritional and functional properties of the final product. This method uses high temperatures and a short time to convert agricultural products that are in the form of grains or powders into fully cooked food products and then expels them from the end of the device into various shapes [13]. Another method used in the food industry that uses ionizing radiation to improve safety, sanitation, and increase preservation is called irradiation. In this method, food is exposed to a precise amount of radiant energy. These rays have a wide range of applications, including the ability to break chemical bonds, destroy

harmful bacteria and microorganisms in seafood, poultry, and meat, disinfect spices, increase the shelf life of fresh fruits and vegetables, and prevent the germination of onions and potatoes [14]. The World Health Organization (WHO) has also considered irradiation as a safe and appropriate method for improving the safety, quality, and shelf life of food products. This method is an alternative method for increasing shelf life and is environmentally friendly, easy, and suitable for saving energy [15-17]. This article reviews recent developments in new processing methods, the type of mechanism of action, applications, advantages and disadvantages, and their impact on quality and preservation of nutritional value.

## 2- Membrane Filtration

Membrane filtration was developed in the 1960s with a wide range of applications, and the oldest and most well-known of these methods include desalination and reverse osmosis water purification. Membrane filtration is a gentle method of separation and clarification. Infiltration, porous anionic, cationic, and nonionic membranes are used that selectively act on different types of fluid. This separation depends on the size of the molecules, the type of food, the membrane material, and the pressure [2]. Membrane filtration is an evolving technology and is mostly used in the processing of milk, fruit juice, and soft drinks. The membrane is made of natural and synthetic materials and acts as a selective permeability barrier to separate materials into two compartments under pressure [7]. The phases include a solid phase such as suspended solids, organic solids, and inorganic solids, a liquid phase such as water, ethanol, and chloroform, and a gas phase such as air, nitrogen, and oxygen. Membrane processes are divided into five categories, 1. Microfiltration (MF), is a pressure filtration process for separating suspended solids into particles between 0.08 and 10 mm, and the hydraulic pressure applied in this method is 1-2 bar or 15-20. This method is most commonly used for separating solids

from water and the size of the solids. Ultrafiltration (UF) separates macromolecular solids under pressure, with particle sizes of 0.001 to 0.1 mm and pressures of about 1-7 bar. 3. Nanofiltration (NF), in which membranes in this group are polymer layer composites consisting of negatively charged chemical groups and are used to retain molecular solids such as sugar and multivalent salts such as magnesium sulfate, with solids sizes between 0.0005 and 0.007 mm. 4. Reverse Osmosis (RO) These membranes are mainly made of cellulose acetate and have pore sizes of 5 to 20-angstrom units and are used to remove salts and organics with particle sizes between 0.00025 and 0.003 mm. 5. Electrodialysis (ED) which uses voltage or current as the driving force to separate ionic solutes and the size of the solutes is between 0.00025 and 0.08 mm [2]. Consumer demand for healthy and quality beverages such as fruit and vegetable juices due to the presence of compounds such as carbohydrates, vitamins, and minerals is increasing. It has caused manufacturers to look for alternative methods to preserve their nutritional value and sensory quality. Thermal processing methods cause quality loss, loss of aroma, non-enzymatic browning, and reduction of polyphenols and ascorbic acid. The use of non-thermal alternative methods such as membrane filtration to preserve nutritional and sensory properties, and clarify and store fruit juice are very widely used. One of the major problems in fruit juice filtration is membrane fouling, where the sediment formed by the juice components accumulates on the membrane pores, reducing the diffusion pressure and reducing efficiency. Sedimentation reduces membrane life, reduces juice quality, and increases time and energy [7]. Clarification of carbonated beverages is done by MF and UF methods, concentration for fruit juice concentrate is done by RO method, and deacidification to reduce the acidity of fruit juice is done by ED method. The five types of deposits are membrane scaling, metal oxide deposits, colloidal deposits, biological deposits, and cleaning agent deposits. The most

important applications of membrane filtration include dairy product production such as full-fat cream and skim milk production using the MF method, cheese production using the UF method, powdered milk and bulk milk production, pasteurization, homogenization, candy, fruit juice, soft drinks, and separation of salts from water. In the dairy industry, microfiltration is used to remove bacteria, break down milk fat, and separate skim milk micellar casein and carrier proteins [2, 7].

### 3- Bacteriocins

Bacteriocins are peptides that are synthesized ribosomally and prevent the growth of spoilage bacteria in food and are a suitable method for increasing the shelf life of food [1]. Bacteriocins are antimicrobial compounds that are synthesized ribosomally by various bacterial species, especially lactic acid bacteria [18]. Some gram-positive and negative bacteria produce protein-structured substances with antimicrobial activity called bacteriocins during their growth, which are used as natural preservatives in the food industry. Despite the idea of being antibiotics, bacteriocins cannot be considered antibiotics due to their activity and effect on strains close to them and due to their synthesis and production in a ribosomal manner. Bacteriocins have a low molecular weight that rarely exceeds 10 kDa and are easily degraded by proteolytic enzymes. Due to their high lysine and arginyl residue content, they are cationic and amphipathic molecules. They are unstructured in aqueous solutions but form helical structures when exposed to solvents such as trifluoroethanol, reinforcing the structure [19]. Bacteriocins are easy to produce and are generally safe [20]. Methods for its separation include chromatography and aqueous two-phase separation (ATPS) [21]. Most lactic acid bacteriocins have small cationic peptides, are heat-stable, membrane-permeable, and have greater antibacterial activity at lower pH. Some bacteriocins have low adsorption properties, but the cell wall of Gram-positive bacteria allows the passage of relatively large molecules. Bacteriocins are divided into three groups, including

lantibiotics, small heat-stable bacteriocins, and large heat-sensitive bacteriocins. Lantibiotics are peptide substances containing the polycyclic amino acid thioether lanthionine with methyllanthionine and the unsaturated amino acids dehydroalanine and 2-aminoisobutyric acid. Lantibiotics are of two types based on structural similarity: Type A consists of relatively elongated and coiled molecules, positively charged, amphipathic, flexible, and with a molecular mass of 2 to 4 kDa, which act through the formation of pores and membranes. Type B has a spherical structure and interferes with cellular enzymatic reactions. Their molecular mass is 2 to 3 kDa and they have a net negative charge or no net charge [12, 18, 19]. The disadvantages of this method include high separation and purification costs, limited activity, enzyme degradation, and low stability and solubility. The most important of them are nisin and pediocin [1].

### 4-Microencapsulation

Microencapsulation is one of the techniques for preserving the quality of sensitive materials and is a suitable method for producing materials that retain their nutritional properties and values [22]. Today, this processing method is widely used and the active ingredient to be encapsulated is called the core or internal phase and the coating material is called the shell or membrane, which is used to protect sensitive compounds and ensure their safe delivery [23]. Microencapsulation is an effective method for sensitive bioactive compounds and preserving them in small capsules to increase stability and maintain morphological properties [24]. This method is used to improve the transport of bioactive compounds and protect and control the release of food ingredients. It is also used to better transport compounds such as vitamins, fatty acids, antioxidants, fibers, food, drugs, probiotic bacteria, flavors, colors, enzymes, nutrients, and minerals present in food, which are generally sensitive to temperature, stomach acid, pH, and light, which can be protected by this method [25-27]. The most common methods for improving nutritional value are the addition of active ingredients such as probiotic

bacteria, B vitamins, linoleic acid, and proteins that are unstable when exposed to heat, acid, oxygen, and light, which can be protected by microencapsulation [28]. This method has many applications in the food industry and biotechnology, by which solid, liquid, and gas particles and droplets can be trapped in a membrane and released at a controlled rate and at a specific time [29, 30]. Water-soluble and fat-soluble vitamins can be encapsulated using different technologies. The most important reasons for encapsulating vitamins are to increase their shelf life and protect against oxidation [31]. This method is used to develop functional food products, reduce fat content, and improve sensory properties in various foods such as meat, dairy, fruit juices, and cereals [26]. This method is suitable for minimizing the loss of sensitive materials and materials that have little stability to degradation, heat, diffusion, or leakage of core materials. Microencapsulation can be effective in dairy products that are susceptible to oxidation or is used to mask the undesirable taste and aroma of some ingredients before they are incorporated into any food [32]. The materials to be encapsulated are solid or liquid and include materials such as drugs or active ingredients, additives such as diluents and stabilizers, and the coating material is an inert material that covers the core with the desired thickness and is compatible with the main materials, which can be flexible, brittle, hard or thin [33]. The coating material in microencapsulation must be such that it can form a coherent layer on the core and give it cohesion. It must also be impermeable, non-reactive with the core, not produce a specific taste, and can release the core at a specific point and time, which will protect the core materials [22, 35]. The use of nanocapsules leads to improved sensory properties and greater transparency and is widely used in the beverage industry [34]. The wall components can be 1. Waxes and lipids including beeswax, candelilla waxes, carnauba, glycerol stearate, phospholipids, and stearic acid 2. Proteins include gelatin, whey protein,

zein, soy protein, gluten, and albumin 3. Carbohydrates include starches, maltodextrin, chitosan, sucrose, glucose, ethyl cellulose, cellulose acetate, carboxymethyl cellulose, methylcellulose, alginates, carrageenan or 4. Polymers include polypropylene, polyvinyl acetate, polystyrene, and polybutadiene [33]. The most important benefits of microencapsulation include stabilization of enzymes and microorganisms, protection against ultraviolet radiation, heat, oxidation, acids, bases, improved shelf life due to prevention of destructive reactions, taste and odor masking, improved processing, reduced wastage of ingredients, use of liquids as solids, reduced core reaction to environmental factors (light, oxygen and water), increased demand for nutritious foods, increased marketing by improving the visual aspect and the ability to mix unusual ingredients [33,35]. Depending on the physical and chemical properties of the core, wall composition, and encapsulation method used microcapsule particles can be in the form of simple spheres, spheres with uniform thickness coating, irregularly shaped cores, multi-walled capsules, and multiple cores with the same capsule [23]. Various techniques are used to form capsules, including spray drying, spray cooling or spray cooling, coating extrusion, fluid bed coating, liposome entrapment, and extrusion [10]. The most widely used method is spray drying, which is one of the most common and oldest methods due to its low cost in microencapsulating food materials and producing efficient and high-quality microcapsules. This method is based on reducing water activity, reducing microbial growth of the product, increasing product quality, reducing storage and transportation costs, and protecting the product. The advantages of this method include cost-effectiveness, use for various encapsulating agents, flexibility, and applicability to various food materials [23]. The disadvantages of this method include the destruction of some materials due to thermal stability, lack of particle size control, and the need for side

processes such as agglomeration [36]. This method is widely used in various industries such as food, pharmaceutical, and chemical industries due to its high production and low operating cost. This method is widely used for encapsulating fragrances, dyes, oils, active food molecules, and probiotics. In recent years, consumers have turned to natural foods. The use of natural pigments is of great interest because color is one of the most popular indicators of food quality and acceptability, and consumers purchase the product by observing and evaluating it. Carotenoids are yellow, orange, and red pigments found in fruits, vegetables, mushrooms, and algae and have many health functions. Carotenoids are unstable and have low resistance to heat, light, and pH, so they need protection, which can be achieved by microencapsulation using a spray dryer [37]. In this method, the core and wall materials are atomized and converted into dust inside the chamber by hot air [23]. In the spray drying method, the core particles are dispersed in a polymer solution in a heated chamber, and the initial dissolution and dispersed emulsification of the core composition in carrier material solutions are carried out, which are sprayed in a hot chamber, then the evaporation of the solvent and the coating of the wall materials around the core lead to the formation of multi-core or matrix type microcapsules. Therefore, this technique involves atomizing an emulsion that carries the core and recovering the dried microcapsules [9]. Other techniques used for encapsulation include emulsification, in which a discontinuous phase is added to the continuous phase. To create a water-in-oil emulsion, homogenization is carried out with the help of a surfactant, and the insoluble gel beads formed in the oil phase are separated from the liquid solution by filtration or centrifugation [36, 38]. As mentioned, one of the applications of microencapsulation is to protect probiotics, which are live microorganisms that, when consumed in sufficient quantities, can make a big step forward in the treatment of intestinal dysfunctions such as lactose intolerance,

constipation, and cancer prevention [39,40]. Probiotics can also act as antibiotics and control infections, prevent allergic disorders, and treat inflammatory and respiratory diseases [41]. Among the most important probiotic microorganisms are lactic acid bacteria (LAB), which are the final product of sugar fermentation and are rod-shaped, gram-positive, non-spore-forming, cytochrome-free, anaerobic, air-resistant, and fermentative. The most important of them are *Lactobacillus acidophilus*, *Lactobacillus amyloporos*, *Lactobacillus casei*, *Lactobacillus delbrueckii*, *Lactobacillus rhamnosus*, and *Lactobacillus crispatus*. Other common probiotic microorganisms include bifidobacteria, which are Gram-positive, rod-shaped, and anaerobic [42]. Microencapsulation is an important new technology for maintaining viability during storage, and food consumption, and for developing new food carriers, and its potential for protecting probiotics in the gastrointestinal tract has been demonstrated [43]. Due to the sensitivity of probiotics to pH, oxygen, temperature, and physical factors, methods such as microencapsulation and nanoparticles can be used to improve their viability and performance to protect them from harsh conditions in the digestive tract and product storage time and prevent damage to probiotics [44, 45]. In a study conducted by Afshari *et al* (1402) on the staleness and organoleptic properties of baguette bread, they stated that nanocapsules containing date kernel extract at a concentration of 40% and a rate of 1% increased moisture, increased volume, increased phenolic compounds, and reduced staleness [12]. Shoaie *et al* (2022) studied the viability of *Lactobacillus plantarum* encapsulated with sodium alginate and gum arabic in rose jam and its storage for 90 days. The results showed that under simulated digestive conditions, the survival of probiotic bacteria increased, and in all samples containing capsules, the number of bacteria was higher than the permissible limit ( $10^6$  CFU/g) [46].



## 5-Ultrasound

Another emerging sustainable method that increases process speed and efficiency and maintains product quality and safety is ultrasound. This technology is stable, fast, non-thermal, low-cost, and non-destructive, while maintaining quality, preserving volatiles, increasing shelf life, improving sensory and appearance, and has many benefits for the manufacturer and consumer [11, 47-50]. Waves that exceed the human audible range are called ultrasound or infrasound, which include waves greater than 20 kHz. For greater efficiency, these waves can be combined with temperature (thermal sound) or pressure (mono sonication). These waves are divided into two categories based on intensity and frequency: low-intensity and high-intensity ultrasound. Low-intensity or high-frequency waves are waves with a frequency of 100 kHz and an intensity of less than 1 W/cm<sup>2</sup> [51]. This method can be used in fermentation, emulsification, extraction, reaction kinetics, and emulsification processes. Ultrasonic extraction is based on the principle of cavitation and involves damage to the plant cell wall and the release of bioactive compounds [6, 52]. The mechanism of action of ultrasound waves is based on two modes: cavitation and free radical formation. When ultrasound waves oscillate through the medium, they create a large expansion and density in the medium, and by increasing the gap between molecules and overcoming adhesion, the liquid is broken and cavities are created, and in sonic decomposition, free radicals with high reactivity are produced. High-intensity, low-frequency ultrasound waves have a frequency between 20 and 100 kHz and their intensity is in the range of 10 to 1000 watts per square centimeter and can affect the physical, biochemical, and mechanical properties of products. Its application is in foaming, emulsification, protein functional properties, acoustic crystallization, modification of texture properties in fatty products, and regulation of microstructures. This method is also used in freezing, drying, softening, melting, cooking,

sterilization, disinfection, and concentration. In high-pressure ultrasound, energy is released by inducing acoustic cavitation due to bubbles' production, growth, and implosion [51, 53, 54]. With the help of ultrasound, it is possible to accelerate freezing by increasing ice nucleation and improving the rate of mass and heat transfer. The use of ultrasound in freezing preserves the microstructure, reduces droplet loss, preserves quality characteristics, and reduces changes in the color and texture of food. In the melting process, the physical effects of ultrasound convert sound energy into heat and cause the formation of high-speed jets. This method increases the rate of melting heat transfer, prevents spoilage caused by microorganisms and enzymes, and preserves the characteristics of the food [55]. Research conducted on ultrasound in corn showed that the use of these waves preserves product quality and destroys aflatoxin B1 (AFB1) and zearalenone (ZEA) [56]. In a study, Hernández-Falcón *et al* (2018) investigated the effect of ultrasound on the level of aflatoxin M1, the physicochemical, and microbiological properties of milk. Experiments were performed on days 1, 7, and 14 with 20 kHz waves for 10 or 15 minutes and an amplitude of 95% on homogenous and non-homogeneous milk. The results showed that ultrasound waves, without changing the color of the milk, preserved phenolic compounds, maintained physicochemical and microbiological quality, and could reduce the amount of aflatoxin in milk. The lowest AFM1 level was observed in non-homogeneous milk treated for 10 minutes and one day after storage with  $0.15 \pm 0.05$  pg AFM1E/mL [57].

## 6-Extrusion

Extrusion comes from the Latin word *Extrudere*, which means to push or expel. Today, legumes are of great interest because they are an important source of gluten-free foods and a healthy diet with a source of protein, fiber, minerals, and vitamins. Their place in the household food basket can be increased by proper processing and creating

variety and various forms. On the other hand, studies have shown that high consumption of meat and meat products causes problems such as type 2 diabetes, high blood pressure, obesity, and cardiovascular disease, which can be prevented by consuming more legumes as a food with nutritional benefits and environmentally friendly [13,56]. Extrusion is a processing system that uses one or more screws to force food materials through a small opening. When the material is forced into the extruder, it is cooked by high pressure, high shear, and high temperature, and when it exits, it often puffs up as the pressure is released and the water turns into steam. Because the process is continuous, it is done in a short time, and the most common extruders are the single-screw and twin-screw systems, which are more flexible [57]. This method uses physical and chemical processes to force the material through a small opening to form products. By using mechanical shear, heat, and pressure, food materials that contain moisture, protein, and starch can be processed. High-temperature short-time cooking (HTST) is a method that uses high temperatures for a short time and is mostly used for breakfast cereals, cereal-based snacks, pasta, dietary fiber, baby food, pre-cooked flours, and pet food. This method comes in two forms: low-pressure extrusion at temperatures below 100°C and high-pressure extrusion at temperatures around 200°C. Cereals and starches undergo physical and chemical changes during extrusion cooking, and the extent of molecular degradation depends on parameters such as temperature, moisture, speed, and food composition. In cereal-based products, the degree of starch processing is very important to maintain quality, taste, texture, appearance, and digestibility. The most important benefits of this method include high product quality, diverse product shapes, production of new products, inactivation of anti-nutritional factors, versatility, low cost, high productivity, and compatibility with the environment [58, 59-61]. Nowadays, due to the simultaneous use of a single operation in extrusion cooking, which includes mixing, kneading, cooking, and

shaping using high temperature in a short time and high shear, it is used for the optimal use of food waste for raw material management and prevention of material waste, as well as for helping the environment. One of the most important advantages of extrusion is the minimization of nutritional losses due to the short time used in this method. In the high-temperature extrusion method, anti-nutritional compounds such as phytates inhibitors such as trypsin and enzymes such as lipase and lipoxidases are destroyed [62]. Along with the benefits such as starch gelatinization, destruction of anti-nutritional factors, increase in soluble fiber, reduction of lipid oxidation and contaminating microorganisms, and preservation of color and flavor of food products, this method has disadvantages such as the Maillard reaction, which reduces the nutritional value of protein, and also the destruction of heat-sensitive vitamins [63].

#### 7-Irradiation

Irradiation is used as an alternative method to inactivate microbes and extend the shelf life of a product. Irradiation is the processing of food using electromagnetic waves and can destroy pathogenic microorganisms by damaging their DNA. Irradiation can be used on a wide range of dry foods such as spices and seasonings, high-moisture foods such as meat and poultry, as well as fresh, refrigerated, and frozen foods. Fruits and vegetables are very beneficial for health because they are rich in essential nutrients and reduce chronic diseases such as obesity and diabetes, which can be disinfected without the use of chemicals and heat. In irradiation, food is exposed to a specific dose of non-ionizing radiation such as UV, visible light, infrared, and radio waves, or ionizing radiation such as gamma rays, X-rays, and electrons. The unit of dose consumed is the gray (GY) and the kilogray (KGY) which is referred to as the amount of energy absorbed per unit mass of food products. Based on the dose used, the type of food, and the purpose of this method, irradiation is divided into three types: radicalization, radicalization, and radiparitization. The most important



advantages of this method are non-thermal, preservation of nutritional value, delay in ripening of fruits, stopping the germination of agricultural products such as potatoes and onions, no waste production, destruction of microorganisms, delaying the growth of fungi, applicability for fresh, frozen and packaged materials, and also the destruction of insects and pests in agricultural products. This method causes disadvantages such as softening of some fruits and vegetables, oxidation and rancidity in fats, creating an undesirable taste in milk due to high sensitivity to oxidation, and creating undesirable taste and color in meat. Also, this method alone cannot prevent enzyme activity and blanching must be performed before irradiation [5, 15, 17, 64].

### 8-Conclusion

The increasing attention of food consumers to the use of healthy and nutritious food has caused manufacturers to seek to replace newer methods. The advantage of new methods, which are generally carried out at low temperatures, is the preservation of nutrients and vitamins, color, and flavor. In addition to making products safe and germ-free, these methods also have the above advantages, which are generally reduced in older methods due to high processing temperatures. Therefore, the attention of manufacturers to the use of new processes and the development of equipment related to them in line with the general health of the community is well understood. Given the many advantages of new methods, along with the lower cost and environmental compatibility of these methods, further development and research are important to replace these methods with conventional methods.

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### مقاله علمی-پژوهشی

#### مروری بر کاربرد تکنولوژی‌های پیشرفته غیرحرارتی در صنایع غذایی

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صنعت فرآوری مواد غذایی یکی از مهم‌ترین صنایع می‌باشد که امروزه با توجه به درخواست روز افزون مواد غذایی با کیفیت دچار تحولات بسیاری گشته است. توجه به حفظ مواد مغذی و عدم تغییر بافت و رنگ محصولات لزوم استفاده از فناوری‌هایی با دمای پائین‌تر را به خوبی مشخص می‌گرداند چرا که در فناوری‌های قدیمی‌تر معمولاً از دمای بالا استفاده می‌گردید. امروزه اثرات سلامت بخشی غذاها از جمله مهم‌ترین فاکتورهای مقبولیت یک فرآورده می‌باشد که در فرآوری‌های جدیدتر می‌توان با حرارت کمتر، باعث حفظ انواع ویتامین‌ها و کیفیت و رنگ محصول نهایی گشت. از جمله این فرآوری‌ها می‌توان به فیلتراسیون غشایی، باکتریوسین‌ها، میکروکپسولاسیون، فراصوت، پخت اکستروژن و پرتودهی اشاره نمود. روش‌های فوق علاوه بر حفظ کیفیت و مواد مغذی محصول، مقرون به صرفه و سازگار با محیط زیست نیز می‌باشد که لزوم توجه بیشتر به آن‌ها برای حفظ سلامتی و در کنار مسائل اقتصادی و زیست محیطی را به خوبی آشکار می‌سازد. کپسوله نمودن مواد مغذی باعث حفظ مواد در شرایط محیطی و دستگاه گوارش نیز می‌گردد که باعث شده امروزه این روش بیشتر مورد توجه متخصصین قرار گیرد. در این مقاله به بررسی انواع روش‌های نوین فرآوری در صنعت غذا پرداخته شده است.