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Historical Developments in Food Science and Technology

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Abstract

Food science aims to create and maintain a safe, abundant, and wholesome food supply based on fundamental science and engineering principles. The evolution of food science over the centuries has resulted in the development of various food processing technologies to ensure nutritious, fresh, and safe food. Recent decades have seen much attention paid to applying emerging technologies. By developing new food processing technologies, the overall processing time and energy consumption have been reduced compared to conventional methods, while ensuring food safety and providing benefits to the industry. This review provides an overview of the development and invention of technology to the present.

Keywords: Food science evolution; Emerging technologies; Food safety; Technological invention

1. Introduction

In the history of food technologies, progress has been accompanied by modernization, social evolution, and an overall improvement in the living standards of the population [1]. The practice of food processing is likely to have existed for a very long period among archaic humans from the early and middle Pleistocene periods [2]. Adapting food systems for a growing population from farm to fork is essential for ensuring nutrition and consumer satisfaction [3]. Food production and processing must be advanced to meet the evolving challenges of global food security and change in consumer perception [3,4].

Emerging technologies in the food processing industry address discrete consumer requirements for safer, healthier food with minimum processing [5]. Furthermore, these contemporary ideas lead to energy-efficient and sustainable food processing technologies that reduce water consumption and energy requirements while overcoming some of the limitations associated with current food processing methods. The knowledge of the control of complex processes and structure-function relationships makes it possible to develop tailor-made food based on the potential and opportunities of these new processes. These emerging food manufacturing techniques demonstrate scalability and flexibility by making use of cold plasma (CP), high hydrostatic pressure (HPP), ultrasonication (US), and pulsed electric field (PEF). This review explores briefly the historical development of food science and its technological advancements with respect to the previously mentioned aspects.

2. The history of technological development in food science

The history of food processing began with archaic humans, whose dietary quality was reported to be improved by non-thermal food processing, like sun drying, grinding, cutting, or pounding of animal-based foods [(2)]. As humans became more energy-demanding, thermal processing became increasingly important. There is evidence of opportunistic fire from 1.8 million years ago in Africa and Eastern Asia, albeit interpretations of the excavations are controversial [(2)]. Fire made raw meat more palatable, safe, and edible. Cooking legumes, tubers, grains, and other plant cereals improved dietary attributes and denaturation of antinutrients.

A socio-economic transition is considered to have driven the most rapid evolution of food processing over time. The way food is processed changed over the centuries, from Paleolithic stone tools, sun-drying, and bonfire grilling to industrial roller mills, spray drying, and electrical pressure cooking [(6)]. A transition from hunter-gatherers to pastoralism may have occurred between 15,000 and 10,000 years ago, followed by the transition to agriculture and livestock farming [(7)]. Consequently, dairy, cereals, and grains become more abundant in the human diet. Traditions to ferment food, bread, and cheese evolved along with grain cultivation and early milk production. There is archaeological evidence that beer brewing and bread making began approximately 14,000 years ago, while cheese making began approximately 8000 years ago in Europe [(8)]. Along with farming and crop cultivation, storage and preservation become a necessity. The first saltworks were established by prehistoric European and Chinese societies (5000–6000 BP) during the Neolithic period, which led to salt becoming a vital food preservative and commodity for millennia [(2)]. Milling technology advanced during the European Middle Ages, making bread a critical staple food. The Roman Empire made white bread a privilege for the rich and powerful; those living in the countryside and those with limited resources consumed dark bread made from mixed grains and legumes [(2)].

During the 18^{th} and 19^{th} centuries, the industrial revolution brought the food processing industry to a new level. There were a number of milestones in the history of the world. The introduction of electricity and steel, steam engines, internal combustion engines, and roller mills replaced hand manufacturing [(9)]. In 1810, Nicholas Appert invented canning, becoming a major advance in food science [(3)]. Napoleon Bonaparte found a need for thermally preserved food for his soldiers during lengthy sea voyages. He offered a reward to any scientist who could come up with a food preservation method. Nicholas Appert, a confectioner, became aware of this notice and began experimenting with other sorts of food and various bottles using his knowledge that sugar syrups were stored in stoppered glass bottles. His method was successfully demonstrated with products designed for the French army. Nicholas Appert won the prize in 1810 for his technique of hermetically sealed food products in glass jars [(3)].

As early as 1864, Louis Pasteur discovered that external microbial contamination causes food spoilage. In his search for a cure for wine spoilage, Pasteur discovered that yeasts are not the only microorganism responsible for wine spoilage; other microorganisms also played a part. The results of Pasteur's studies led him to recommend heating wine without air for a short period at 55 °C. This mild process, which conserved wine without changing its flavor, was eventually referred to as "pasteurization" [(2,3,10)]. Pasteur laid the foundation for contemporary "sterilization" techniques along with Charles Chamberland, who developed the first autoclave in 1876 [(3)]. In the same era, cold storage and refrigeration were developed and first used by the brewing industry. The first practical and portable compression refrigeration system was created by Carl von Linde in 1875 using methyl ether. It was improved to an ammonia compressor in 1876 and used in various nations [(11)].

The idea of hurdles has likely been applied practically for centuries, combining many preservation parameters (such as pH, water activity, salt concentration, storage temperature, etc.) to produce a synergistic preservation effect [(12)]. Leistner introduced the hurdle concept in the literature, and the same author published the hurdle technology in 1985 [(13)]. At the same time, packaging technology is constantly developing to meet commercial expectations, moving from outdated conventional methods to cutting-edge, automated systems. Paper, metal, plastics, and glass materials are widely applied in food packaging after 1950. There is a need for additional protection beyond transport and storage and the likelihood of shelf life for food and dietary supplements [(14)]. In recent years, an important issue to be considered is the effect of these packaging materials on the environment, thus making it necessary to adapt innovative, safe technologies such as biodegradable packaging materials [(15)]. For instance, a recent development in food packaging is edible packaging, which provides efficient ways to pack food safely and sustainably [(16)].

3. Emerging technologies

Prehistoric ages were marked by a competition for food that prompted the preservation of food. The concept of food processing has been raised to a minimally processed, environment-friendly, nutritionally advanced safe food concept. Based on earlier literature, food processing, manufacturing, and packaging have been advanced and rationalized to an unprecedented degree in food sectors[17–19]. Figure 1 schematically shows the most relevant events in the history of food science and technology. Thus, this section discusses emerging technologies, including CP, HPP, US, and PEF. These technologies are primarily aimed at reducing processing time, reducing energy consumption, and enhancing the food quality and shelf life.

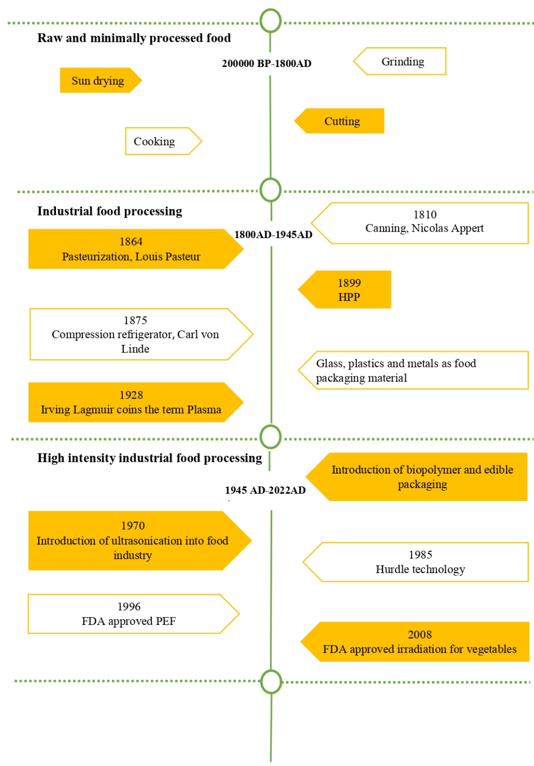

Fig 1. Major milestones in the development and history of food science and technology

3.1 Cold plasma (CP)

Globally, CP technology has drawn the attention of researchers as a non-thermal means of food processing[20]. Lewis Tonk first coined the term plasma, which was used by Langmuir in 1928 to define the fourth state of matter[21,22]. Plasma is a state of matter consisting of positive and negative ions, photons, electrons, gas atoms, free radicals, and molecules in the ground or excited state[23]. CP can be produced using different techniques, including plasma jet, dielectric barrier discharge, gliding arc discharge, and corona discharge. The conventionally used working gases are air, nitrogen, oxygen, argon, helium, and mixtures[24,25]. Initially, CP was used to enhance the printing and adhesion capabilities of polymers, raise material surface energies, and creating a range of electronic application domains. According to a recent research trend, CP is a powerful and successful technology for the food sector. The high efficiency and low-temperature property of plasma made the attention of food scientists towards its application in food technology[20]. CP offers numerous advantages, including the absence of hazardous residues or solvents, environmental safety, low impact on the material matrix, and higher microbial inactivation efficiency[26]. For instance, CP can be used to disinfect food surfaces, inactivate microorganisms, sterilize, disinfect, functionalize, inactivate enzymes, alter the hydrophobic/hydrophilic characteristics, and deposition or etching of thin films[27]. It was shown by Katsigiannis et al.[28] that CP reduces the microbial count on stainless steel food processing surfaces by 3.55 and 2.06 log for Listeria monocytogenes and Salmonella typhimurium. Furthermore, CP can be used to improve rheological properties of dough, enhance the functionality of whey protein, and seed germination[3]. Additionally, this approach has provided surface sterilization for packing materials and functional modification for their desirable properties[23]. However, a better understanding of plasma-matrix interactions, the safety of the gases used, and the development of secure food processing processes is still needed to use this technology in the future[27].

3.2 High hydrostatic pressure (HHP)

Food processing experts have described HHP technology as one of the best innovations of the last 50 years[11]. Food can be safely inactivated using HHP with minimal chemical reactions in food[29]. A level of HHP of 100 MPa and above is applied to food[29]. Historically, HHP has been associated with alloy production, ceramics, materials, and extrusion research. However, the most crucial work in food science was carried out in 1899. Hite's experiments showed that HHP at 600 MPa for 1 h to the raw milk extended its shelf life for 4 days[11]. He discovered that some bacteria could be inactivated using high pressure (689 MPa)[30]. Researchers in the early 1900s attempted to inactivate microorganisms in other food products using HPP, and jam was the first HHP processed commercial food in the 1990s[29,30]. Currently, this method is utilized globally for the pascalization of various food products, including meat, seafood, fruit juices, ready-to-eat foods, fruit-vegetable products, sauces, salads, and pet food[11]. Commercially, the product is pascalized under high pressure in the range of 400–600 MPa at room temperature and stored at 4–6 °C[30]. HHP is being developed both at the laboratory and industrial scale every year. Food industry innovation is underway in new product development and improved product quality and safety. A successful HPP test on juices and beverages containing *S. enterica*, *Escherichia coli*, and *L. monocytogenes* was conducted by Usaga et al.[31]. A 5 log reduction in microorganisms can be achieved by applying 600 MPa for 1.5 min. On the other hand, this technology still faces many challenges, including finding packaging materials with good barrier properties that prevent chemicals from being transferred to foods and vice versa, requiring high initial investments, and using batch operations[11,30].

3.3 Pulsed electric field (PEF)

PEF technology is one of the most emerging non-thermal technologies in food processing. Recent research studies focused on inactivating enzymes and microorganisms, drying, extraction, and diffusion of biological materials[32–34]. Early in the 20th century, ohmic heating was used to pasteurize milk, which marked the beginning of electricity in food processing. An engineer Heinz Doevenspeck from Germany patented PEF machinery in 1960[3]. The first comprehensive study on PEF-mediated microbial cell repair and inactivation was carried out in 1967[35,36]. Even at high-intensity fields, these authors found that bacteria, yeast, and spore suspensions were resistant to PEF treatment. Even though the number of research groups studying how PEF processing affects food products has increased continuously since 1990s, only a limited number of commercial and industrial systems can currently be found on the market. Howbeit, the application of PEF in the potato processing sectors showed greater potential in recent years. PEF can increase drying effectiveness and sugar leaching while obtaining french fries of outstanding quality[11]. Food is processed by applying high voltage pulses ranging from 20–80 kV/cm. PEF is widely applied in liquid food and has few applications in pre-processing meat and tuber crops[3]. For pumpable foods, pure pulse technologies developed the CoolPure® PEF process in 1995, which was approved by the US FDA . Misra et al.[3], Wiktor et al.[37] successfully applied PEF as a pre-treatment in drying carrots and apples by maintaining the bioactive compounds. Another study by Novickij et al.[38] demonstrated a synergistic effect between PEF and nisin-loaded pectin nanoparticles for improving the sensitivity of gram-negative bacteria to nisin. However, like HPP, the high equipment cost may be a concern based on energy requirements[3].

3.4 Ultrasonication (US)

The US is a physical treatment employing ultrasound waves at high intensity and low frequency ranges from 20 to 100 kHz with a power range of 110–1000 W cm^{-2} [39]. Ultrasound was founded in 1880 and was first commercially used in 1917 by Paul Langevin with echo-sounding technology[40]. The use of ultrasounds for cleaning and plastic welding was established in 1960[41]. The application of ultrasonics in agricultural acoustical technologies and methods is relatively new, particularly for evaluating fruit quality during pre- and post-harvest procedures[42]. Ultrasound sonotrodes were initially proposed in 1960 to lyse bacteria and for cleaning. Food industrial applications of ultrasound have been recognized since 1970, and technological advancements have been rapid since then[42]. The use of high-power ultrasound for chemical processes was further developed between 1970–1995, with sonotrodes operating up to 6 kW[43]. The food industry has studied and applied many processes over the past few decades, such as microbial inactivation, freezing and crystallization, homogenization/emulsification, deaeration, filtration, de-foaming, pickling, enzyme inactivation, drying, extraction, meat tenderization, brining, cleaning, cooking, and cutting assisted by ultrasound[33,43,44] found that ultrasound treatment prevented weight loss and preserved the biologically active compounds in pomegranate arils during storage.

The ultrasound technique enables the completion of fully reproducible food processes with minimum time, energy, and process costs, reduces work effort, improves the final product's purity, and eliminates post-treatment waste water compared to conventional techniques[18]. Cavitation phenomena and enhanced mass transfer are believed to contribute to the effects of ultrasound on food processes[18]. Despite, a limited number of manufacturers producing high-frequency transducer plates for industrial use, these technologies have recently found applications in the food industry[43]. High-frequency ultrasound standing waves have been utilized at an industrial scale for olive, palm, and coconut oil separation, and milk fat separation has also shown promising results[45]. The field of ultrasound technology in food technology has been extensively researched. Still, future research remains crucial to producing automated ultrasound systems that will reduce cost, labor, and energy while ensuring the maximum production of high-value and safe food products[43].

4. Conclusion

Technological development in food science always grows in parallel with the socio-economic growth in society. The performance of many traditional food processing techniques is reaches its maximum capacity during a time when consumer demands expand, and regulations related to food and environmental sustainability are increasingly strict. The "emerging technologies" concept encompasses the technology being used and the possibility of developing new applications. The potentiality of these technologies in food has only recently been realized and is successfully used to control enzymes, biochemical reactions, and microorganisms, develop new products, and reduce contaminants and packaging. At this point, it is possible to state that exploiting the novel applications based on these technologies is only at its initial stage. Several of these applications have not yet matured into industrial realities, and conventional methods will continue to be used in the food industry.

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