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Advancements in High-Pressure Processing for Food Preservation

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ABSTRACT

High-pressure processing (HPP) is a cutting-edge technique in the field of food preservation, offering a promising alternative to traditional thermal methods. This method involves subjecting food products to extremely high pressures, up to 600 MPa, in an effort to inactivate microbial pathogens and enzymes that contribute to food spoilage and degradation. The most significant advantage of HPP is its ability to extend shelf life and maintain the nutritional and sensory qualities of food, as it does not involve high temperatures that often alter taste, texture, and nutritional value. Recent advancements in HPP technology have broadened its application scope, making it suitable for a diverse range of food products, including fruits, vegetables, meats, seafood, and dairy products. One notable development is the reduction in processing times and costs, making HPP more accessible and efficient for large-scale operations. Additionally, innovations in packaging materials compatible with high-pressure environments have enhanced the safety and quality of HPP-treated foods. The environmental impact of HPP is another area of progress. Modern HPP systems are designed to be more energy-efficient and have a smaller carbon footprint compared to conventional preservation methods. This aligns with the growing consumer demand for sustainable and environmentally friendly food processing techniques.

1.Introduction

High-pressure food processing, also known as high hydrostatic pressure processing (HPP) or ultra-high pressure processing, is a method used in food preservation. This technology involves subjecting food to extremely high pressures, up to 600 MPa (megapascals), with or without the use of heat, to achieve microbial inactivation and to extend the shelf life of the product while maintaining its quality and safety. High-pressure food processing utilizes the principle of isostatic pressure transmission. This means the pressure is transmitted uniformly and

ISSN PRINT 2319 1775 Online 2320 787

 Journal Volume 11, Iss 02, 2022

instantaneously throughout the food product, regardless of its shape and size. The process typically involves placing food in flexible and water-resistant packaging, which is then subjected to high pressure using a pressure-transmitting medium (usually water).

The high pressure applied during HPP disrupts the cellular structure of microorganisms, such as bacteria, viruses, yeasts, molds, and parasites, leading to their inactivation. It also affects certain food enzymes which can cause spoilage or undesirable changes in food. However, the process does not significantly affect covalent bonds, thus preserving the food's flavor, color, and nutritional value. HPP is used for a wide range of food products, including fruits and vegetables, juices, meats, seafood, dairy products, and ready-to-eat meals. It's particularly useful for products where heat treatment would adversely affect texture, flavor, or nutritional content.

The main advantages of high-pressure food processing include extended shelf life, maintenance of freshness and nutritional quality, and the ability to inactivate foodborne pathogens and spoilage microorganisms without the use of high temperatures or chemical preservatives. Despite its many benefits, HPP can be expensive due to the high cost of equipment and the energy required to generate the pressure. Additionally, it is not effective against all types of microorganisms and does not completely replace traditional thermal processing methods in some cases. High-pressure processed foods must comply with food safety regulations and guidelines established by international and national food safety authorities. It's important to ensure that the process effectively inactivates pathogenic microorganisms without compromising the nutritional and sensory qualities of the food.

Research and development in HPP are ongoing, focusing on enhancing its efficiency, reducing costs, and expanding its applications. Innovations in packaging materials compatible with high-pressure processing are also a key area of development.

High-pressure food processing (HPP) is increasingly important in the food industry for several key reasons:

1. HPP effectively inactivates many of the microorganisms that cause food spoilage. This extends the shelf life of food products without the need for chemical preservatives, allowing for longer distribution times and reduced food waste.

ISSN PRINT 2319 1775 Online 2320 787

 Journal Volume 11, Iss 02, 2022

2. By inactivating pathogenic microorganisms like Listeria, Salmonella, and E. coli, HPP enhances food safety. This is crucial for ready-to-eat and minimally processed foods, where the risk of foodborne illnesses needs to be minimized.
3. Unlike traditional thermal processing, HPP does not significantly alter the nutritional and sensory properties of food. It preserves the taste, color, texture, and nutritional value, which are often compromised in heat-treated foods.
4. There is a growing consumer preference for "clean label" foods with fewer additives and preservatives. HPP allows food producers to meet this demand by providing a means to preserve food naturally.
5. HPP opens up possibilities for the development of new and innovative food products, particularly in the area of health and wellness. For instance, it allows for the production of high-quality, nutrient-rich juices and smoothies that have a fresh taste and long shelf life.
6. With increasing regulatory scrutiny on food safety and quality, HPP offers a way for food manufacturers to comply with stringent food safety standards.
7. As the food supply chain becomes more global, there is a need for preservation techniques that can ensure food safety and quality over long distances. HPP can play a critical role in this by extending the shelf life and maintaining the quality of exported and imported food products

2. Related works

Most food items, including fruits, vegetables, meat, poultry, seafood, milk, and their derivatives, tend to perish quickly due to their inherently short shelf life. The presence of moisture, along with environmental factors such as temperature and humidity [1-2], can initiate physical and chemical changes in stored food products, leading to microbial growth and, consequently, spoilage. Spoilage is characterized by unwanted transformations that make a product unfit for consumption due to physical, chemical, or microbiological alterations[3]. Physical alterations might involve the loss or gain of moisture in dried foods, or the occurrence of freeze burn. Often, these physical changes pave the way for chemical reactions and microbial proliferation. Unwanted chemical alterations include the staling of food, color changes (caused by enzymatic and non-enzymatic browning), and the development of off-flavors (often due to oxidation, resulting in rancidity)[4-6]. These chemical reactions are often catalyzed by specific

ISSN PRINT 2319 1775 Online 2320 787

 Journal Volume 11, Iss 02, 2022

enzymes such as lipases, peroxidases, polyphenol oxidases, and catalases, which diminish the food's quality and consumer acceptability, rendering it unsuitable for consumption[7].

Microbial spoilage is another major concern, arising when bacteria, mold, and yeast flourish in food, sometimes producing harmful toxins. The propensity for microbial growth is influenced not only by storage conditions like temperature and humidity but also by the food's composition [8]. Given that food is typically rich in nutrients and has high water activity, it provides an ideal breeding ground for microorganisms. The deterioration of food due to pathogenic microorganisms is particularly alarming. These pathogens have been linked to outbreaks related to fruits, vegetables, dairy, meat, and poultry products. For instance, the Taiwan Food Drug Administration reported over 2000 incidents of food poisoning caused by the accidental consumption of fresh fruits, vegetables, and seafood products contaminated with pathogenic microbes [9]. Therefore, processing food commodities to ensure their safety and extend their shelf life is crucial.

In recent times, nonthermal methods of food processing have gained popularity over traditional thermal techniques. These nonthermal methods include the use of pressure, short pulse electric fields, light, and sound waves[10-12]. The advantage of nonthermal processing is that it usually involves lower temperatures, resulting in minimal nutritional degradation during the food processing cycle [13-15]. In addition, there's a growing consumer preference for foods that are minimally processed and bear a "clean label," meaning they are free from artificial additives and preservatives[16]. Nonthermal techniques such as high-pressure processing (HPP), pulse electric fields, irradiation, cold plasma, and ultrasound are increasingly employed in the food industry.

Of these methods, HPP stands out due to its alignment with consumer preferences, offering products that are close to their fresh state, free from additives, convenient, and have a longer shelf life[17]. This technique is considered a promising form of cold pasteurization and is becoming increasingly important globally. It addresses the dual demands of food safety and quality, making it a valuable tool in modern food processing.

3. Methods on high pressure food processing

High-pressure food processing (HPP), also known as high hydrostatic pressure processing, involves a series of steps from preparation to packaging and processing.

ISSN PRINT 2319 1775 Online 2320 787

 Journal Volume 11, Iss 02, 2022

3.1 Raw Material Preparation:

The first step involves selecting and sorting the food materials. This ensures only high-quality, fresh ingredients are processed. Foods, especially fruits and vegetables, are thoroughly cleaned and washed to remove any dirt, debris, or microbial contaminants. If necessary, the food is cut or sized to ensure uniformity. This helps in achieving consistent processing results.

3.2 Pre-Packaging:

The choice of packaging material is crucial. It must be flexible and durable to withstand the high pressures used in HPP. Typically, materials like plastic pouches or bottles are used. The food is then placed into the packaging [18]. The packaging is sealed to prevent contamination and ensure that the pressure can be effectively applied to the food during processing.

3.3 High-Pressure Processing:

The packaged food products are loaded into the HPP vessel. This vessel is designed to withstand the extreme pressures used in the process. Water is commonly used as the pressure transmission medium. It surrounds the packaged food inside the vessel. The vessel is sealed, and high pressure is applied using a pump system [19]. Pressures can range from 100 to 600 megapascals (MPa), depending on the product and desired outcome. The pressure is maintained for a specific amount of time, usually a few minutes. The duration depends on the type of food and the intended results (e.g., microbial inactivation, enzyme deactivation). After the holding time, the pressure is quickly released. This rapid depressurization is a key feature of the HPP process.

3.4 Post-Processing Handling:

The processed products are removed from the HPP vessel. Quality control checks are conducted to ensure that the food has been processed correctly and meets safety and quality standards. Since HPP is a cold processing method, maintaining a cold chain during distribution and storage is crucial to preserve the quality and safety of the food. In some cases, additional packaging or labeling is required after HPP. The products are stored under refrigeration and distributed through cold chain logistics to maintain their quality and shelf life [20].

Throughout this process, maintaining hygiene and adhering to food safety standards is critical. HPP is a unique method that allows for the preservation of food while maintaining its freshness,

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 Journal Volume 11, Iss 02, 2022

nutritional value, and sensory qualities, which is why it's increasingly popular in the food industry.

4. Conclusion

In this reserach, high-pressure food processing (HPP) represents a significant advancement in the field of food technology, offering a robust solution to the challenges of food preservation while maintaining the quality and safety of the product. This method, characterized by its use of extreme pressure without the need for high temperatures, stands out for its ability to extend shelf life, ensure food safety, and preserve the nutritional and sensory properties of foods. The detailed preparation methods - from raw material selection, cleaning, and pre-packaging to the actual high-pressure treatment and post-processing handling - underscore the comprehensive nature of this technology. By employing flexible and durable packaging materials, applying pressure in a controlled manner, and maintaining a cold chain post-processing, HPP effectively inactivates harmful microorganisms and enzymes that cause food spoilage, without the use of chemical preservatives. Moreover, the growing consumer preference for minimally processed, clean label foods aligns well with the capabilities of HPP, making it a highly relevant technique in today's market. The method's ability to provide safe, high-quality, and long-lasting food products without compromising their fresh-like characteristics is a significant benefit.

As the food industry continues to evolve and face new challenges in food preservation and safety, HPP stands as a promising, innovative solution. Its increasing global importance is a testament to its effectiveness and alignment with current and future food industry trends and consumer demands.

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