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Introduction and Applications of Ultra High Pressure in Food Technology

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Abstract: In recent years, ultra high pressure (UHP) technology has gained high prominence in the food processing industry, which can meet the growing requirement of consumers of high-quality food. This article reviews the history of the ultra high pressure (UHP) process and introduces the principles connected with UHP processing and the methods we used in UHP processing. Also, this paper talks about applications like extracting bioactive peptides and inactivating bacteria through recent examples. Finally, this study combines specific research results to demonstrate the advantages of UHP, it is an advanced processing technique responding to market requirements, and is quite promising for the area of storing perishable food products. UHP treatment can also be widely applied in products' rapid freezing to get high-quality food with longer shelf life in order to meet consumers' requirements. In the future, some more advanced concepts and cutting-edge technologies, such as computer modeling can be applied to the field of UHP processing.

Keywords: UHP, Food processing, Sterilization, Food preservation

1. Introduction

In the past few years, the demand for high-quality food products has risen rapidly. New technologies, such as ultra high pressure (UHP) for food processing and preservation, are used in the food industry. This technology has a good connection with the food industry because it provides a way to replace conventional methods of thermal processing, which often hurt foods and hamper the balance between high quality (color, flavor, and functionality) and safety. As an emerging non-thermal technology, UHP can not only guarantee food safety requirements but also satisfy consumers' requirements for high-quality and high-nutrient products, and its applications and advantages are always discussed [1].

According to the consumers, they are now in great demand for mildly processed food because consumers who care about health consider food as a nutrient delivery. In a consumer-driven market, the wellness of consumers and the quality of the products are now becoming strict problems for food manufacturers [2]. Facing the challenges, researchers are studying and developing food processing methods that can give consideration to both food safety and quality. The effects of ultra high pressure processing, such as inactivating microbial in fruit or other vegetable beverages [3] have often been studied in recent years. This review summarizes the basic principles, methods, devices, applications, and advantages of UHP compared with thermal processing, which can facilitate researchers' understanding of this technology.

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2. The overview of UHP used in the food process

2.1. The principle of UHP processing used in the food processor

UHP processing is a physical process that mainly follows two principles when processing food [4].

2.1.1. Pascal's principle

In accordance with Pascal's principle, during high-pressure food processing, the pressure is transmitted to all fluid particles in the medium fluid in all directions at the same value. So, the food is uniformly pressurized, the pressure transmission speed is breakneck, and the shape and volume of the food are irrelevant. Also, there is no pressure gradient [5].

2.1.2. Le Chatelier's principle

This principle means that the reaction equilibrium will be carried out to reduce the influence of the external force exerted on the system [6]. That is, UHP treatment will make the physical and chemical reactions in the food components in the direction of the maximum compression state so that the reaction balance, reaction rate, and molecular conformation change in the food [7].

2.2. The method of UHP processing used in the food process

UHP refers to a food processing method that changes the activity or gelatinization of enzymes, starches, proteins, and other biological macromolecules in food at room temperature or low temperature, and at the same time kills bacteria and other microorganisms. The realization of UHP technology is to use water or other liquid media as a medium to transmit pressure, then put the processed food in vacuum-sealed packaging and pressurize it at a specific temperature [8]. Also, UHP can destroy the cell membrane structure and accelerate the outflow of substances in cells, so it can be used to assist in extracting some substances.

2.3. The device of UHP processing used in the food process

A high-pressure system consists of a pressure generation pump, a high-pressure vessel and its closing device, a temperature control device, and a material handling system. Once loaded, the pressure-transmitting medium fills the vessel. Air is removed by a low-pressure fast-fill-and-drain pump, together with an automatic deaeration valve; in this way, high pressure is generated [9].

Generally, the hydraulic press uses the piston in the high-pressure cylinder to press the workpiece through the movable workbench. The oil pressure in the high-pressure cylinder is variable depending on the tonnage and diameter of the equipment. The workpiece is pressed and formed between the workbenches. The food ultrahigh pressure hydrostatic press is a special hydraulic press. The workpiece is formed in the liquid medium in the high-pressure cylinder. The liquid pressure depends on the characteristics of sterilization and is a process parameter that must be reached. Generally, the oil pressure in the cylinder is 100-600 Mpa. Since the pressure inside the high-pressure cylinder is equal, it is called isostatic pressure.

Also, the heating of the pressurized medium uses the pressure medium to expand with the increase of temperature to produce high pressure. Therefore, extremely accurate temperature management over the pressure vessel's whole interior volume is necessary when high pressure and high temperature are combined [10]. Depending on the application, the isostatic pressure system can be operated as a warm isostatic pressure system, a cold isostatic pressure system, or a hot isostatic pressure system [11].

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3. Applications of UHP in the food industry

UHP can be used in a large variety of situations in food processing, ranging from bacteria inactivation to pretreatment of protein. There are a lot of examples and studies that reveal the applications and advantages of UHP in recent years.

3.1. UHP application of bacteria inactivation

UHPH, known as UHP homogenization, is an advanced technology that is commonly used in the food processing process. Despite the principle of UHPH technology and traditional homogenizers, a novel design and the use of valve structural materials have successfully achieved UHPs of 350-400 MPa cc. As a branch of UHP processing, UHPH can reduce the particle size, increase the service life, andraise a good efficiency and ability in microorganism inactivation. with minimal effects on the sensory characteristics and nutritional value. According to the novel research, UHPH can achieve a significant inactivation for bacterial spores when combined with low-temperature heat treatment. The commonly used method to inactivate spores nowadays is ultra-high temperature treatment, which may cause a deduction of the nutrient value [12].

3.2. UHP application of pretreating to prepare bioactive peptide

Bioactive peptides are an important classification of chemical compounds with diverse properties that benefit human health. Bioactive peptides are effective substitutes for nutraceuticals and functional food ingredients because of their high bioactivity and minimal side effects. These characteristics prove the increasing demand for various specific bioactive dietary compounds. Enzymatic hydrolysis (EH) is considered one of the most famous technologies that can be used to prepare active substances, including bioactive peptides. After its long-time consumption and low hydrolysis rate, its industrial application is limited [13]. The protein structure will be changed by appropriate treatments. In this way, enzymatic hydrolysis efficiency improves. We now modify protein structures mainly through chemical, physical, enzymatic, and bioengineering methods [14], and the physical method like UHP is considered the most suitable method to treat food products because of its properties of convenience and environmentally friendly [15].

What’s more, UHP can be operated to extract bioactive peptides through food materials. For example, bioactive peptides can be extracted from mushrooms, while the degree of hydrolysis and highest soluble protein content were achieved at a pressure of 400 MPa [16]. This result shows that with the help of UHP, the degree of protein hydrolysis and the content of soluble protein can be changed, which helps us create the best environment to obtain high-quality and high-quantity peptides. Those two applications proved that UHP processing is highly developed and still promising in the area of preparing bioactive peptides.

4. The advantages of UHP and specific examples

4.1. UHP takes advantage because of the low temperature

The UHP treatment has recently been applied widely in food production, especially in food preservation [17]. Because of the replacement of high temperature by UHP to inactivate microorganisms, people can avoid a lot of disadvantages during high-temperature processing [18]. In conclusion, UHP treatment can reduce the decomposition of proteins, improve quality, and maintain the primary structure of nutrients like polysaccharides and proteins when satisfying the requirement of sterilization standards. In this part, specific examples will be given to demonstrate the advantages of UHP of staple food retaining texture, appearance, flavor, and shelf life.

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4.2. Effects of UHP on the texture and appearance

According to several pieces of research results, the UHP treatments that have a pressure equal to or greater than 400 MPa will show positive effects on the texture and appearance of stored food. We will focus on the research carried out by Dea-Hun Part to study the effects of UHP in the 30-day chilled storage of salmon.

In the study, fresh-caught salmon flesh was cut into similar pieces of (50*30*7mm, 25g in weight), then subjected to UHP at 0, 200, 400, or 600 MPa, and then stored at 4°C for 30 days. Then the research group studied the color and texture of the pieces in different conditions. In the study on color, the color was tested by the parameters of L-value, a-value, and b-value, and a CM 3500d spectrophotometer was used to perform the measurement. In the study of texture, the group used a Compac-100 II rheometer with a 20-mm-dia. probe, with a cross-head speed of 1 mm/s and specimens of 50% compressed. In this way, the texture indexes such as chewiness, hardness, and cohesiveness were shown in the data.

In the color measurement, the change of b-value showed the color shift towards blue was significantly observed in samples treated at relatively low-pressure treatments. As the level of UHP increased, the samples became brighter. Considering the results of the texture indexes shown in the diagram, the hardness of samples treated by UHP of ⩾400 MPa became greater compared to those of ≦200 MPa. After UHP treatment of >400 MPa, fillets became harder than at all other tested pressures. For the chewiness, the index had a positive correlation to pressure, especially at 400 and 600 MPa fillets. In conclusion, the UHP treatment will do well for the storage of shelf food; people can consider the UHP treatment a useful method [17,18].

4.3. The effects of UHP on the shelf life of food.

According to several studies, UHP treatments will significantly increase the shelf life of certain food. In this part, the research taken by Sergei Tikhonov will be provided as a specific example and help people testify to the conclusion. The group carried out a study regarded to the shelf life of chilled meat. For the research, the chilled beef was divided into two groups, and each group contains five 300g samples. One of the groups was treated with UHP, which was the experimental group (treated with a 800 MPa pressure for 6 minutes), while the other one was the control group (without UHP treatment). Both of them were stored at 4°C for 60 days. In the study, several indicators were used to determine the shelf life of the sample such as protein content (tested by Keldahl), microbiological indicators (determined by GOST R 54353-2011 Requirements), and the acid number of fat, (according to GOST R 55480-2013). The experiment was carried out for five times, and the results are provided.

The results showed that the control group samples after 60 days didn't meet the requirement of Technical Regulation of the Customs Union TR CU 034/2013 by microbiological indicators. And the KMAFAnM indicator was 3.4*105 CFU/g; yeast was at the 5.1*105 level. While the experimental group was at 1.0*104 CFU/g and 1*103 CFU/g levels. It was a piece of strong evidence that the UHP treatment can make a contribution to microbiology inactivation. Also, the acid number could tell the same conclusion. The acid numbers of the samples demonstrated that the control group, after 30 and 60 days of storage, has a greater level, which is at 1.2 and 3.6mg KOH, while the levels of the experimental group are at 0.2 and 0.6mg KOH.

In conclusion, the shelf life of chilled food is prolonged as a result of UHP treatments. With the treatment, the protein content, organoleptic characteristics, such as color, smell, texture, stability, and microbiological safety are all significantly increased [18].

5. Conclusion

Nowadays, consumers require more convenient food with more abundant nutrition. With the continuous development of food-producing methods, the quality of food raw materials plays a more and more important role for those producers. Among those advanced food processing techniques, UHP is an advanced processing technique responding to market requirements. It is quite promising for the area of storing perishable food products, as in this process food products can preserve their initial properties of the products, such as color, flavor, taste, nutritional value, and so on. Moreover, Because ice crystals can be very small and do not harm the cellular structures of biomass in this situation, UHP treatment can also be widely employed in the field of rapid product freezing. This technology's primary goal is to meet consumer demands by producing food that is of superior quality and has a longer shelf life. Simultaneously, the food UHP process has not been well researched, the required equipment is costly, and integrating UHP equipment into an automated technological process presents challenges for all manufacturing operations. In the future research process, some more advanced concepts and cutting-edge technologies can be applied to the field of UHP processing, such as computer modeling to reduce the cost and make the process concrete, which is quite promising in the food industry.

References

[1] *Wang, C. Y., Huang, H. W., et al. (2016). Recent Advances in Food Processing Using High Hydrostatic Pressure Technology. Critical Reviews in Food Science and Nutrition, 56(4), 527–540. https://doi.org/10.1080/10408398.2012.745479*

[2] *Balasubramaniam, V. M., Martíinez-Monteagudo, S. I., Gupta, R. (2015). Principles and Application of High Pressure-Based Technologies in the Food Industry. In Annual Review of Food Science and Technology, Vol. 6, pp. 435-462.*

[3] *Daher, D., Gourrierec, S. L., Perez-Lamela, C. (2017). Effect of high pressure processing on the microbial inactivation in fruit preparations and other vegetable based beverages. Agriculture, 7(9), 72. doi:https://doi.org/10.3390/agriculture7090072*

[4] *B. Crossland. (1995) The development of high pressure processing, in High Pressure Processing of Foods, Nottingham University Press, Nottingham, pp. 7.*

[5] *K. Heremans. (1995) High pressure effects on biomolecules, in High Pressure Processing of Foods, Nottingham University Press, Nottingham, pp. 81.*

[6] *B. Tauscher. (1995) Pasteurization of food by hydrostatic pressure: chemical aspects, Z. Lebensm. Unters. Forsch. 200:3.*

[7] *R. van Eldik, T. Asano, W. J. Le Noble. (1989) Activation and reaction volumes in solution. Chem. Rev. 89:549.*

[8] *N. Homma, Y. Ikeuchi, and A. Suzuki. (1994) Effect of high pressure treatment on the proteolytic enzymes in meat. Meat Sci. 38:219.*

[9] *G. Deplace and B. Mertens. (1992) The commercial application of high pressure technology in the food processing industry, in High Pressure and Biotechnology, Colloque INSERM, Vol. 224, France, pp. 469.*

[10] *G. V. Barbosa-Cánovas, B. P. Swanson, U. R. Pothakamury, and E. Palou. (1997) Nonthermal Preservation of Foods. Marcel Dekker, New York.*

[11] *B. Mertens and G. Deplace. (1993) Engineering aspects of high pressure technology in the food industry. Food Technol. 47(6):164.*

[12] *Nutraceuticals Market Size & Share Report, 2021–2030. (2021). https://www.grandviewresearch.com/industry-analysis/nutraceuti cals-market.*

[13] *Georget E., Miller B., et al. (2014) (Ultra) high pressure homogenization for continuous high pressure sterilization of pumpable foods - a review. Front Nutr. Aug 19;1:15.*

[14] *Wen, C., Zhang, J., Zhang, H., Duan, Y., Ma, H. (2020). Plant pro tein-derived antioxidant peptides: Isolation, identification, mechanism of action and application in food systems: A review. Trends in Food Science & Technology, 105, 308–322.*

[15] *Tsumura, K., Saito, T., et al. (2005). Functional properties of soy protein hydrolysates obtained by selective proteolysis. LWT - Food Science and Technology, 38(3), 255–261.*

[16] *Chen, M., Wang, L., Xie, et al. (2022). Effects of high-pressure treatments (ultra-high hydrostatic pressure and high-pressure homogenization) on bighead carp (aristichthys nobilis) myofibrillar protein native state and its*

hydrolysate. Food and Bioprocess Technology, 15(10), 2252-2266. doi:https://doi.org/10.1007/s11947-022-02878-1

[17] Li H, Gao J, Zhao F, Liu X, Ma B. Bioactive Peptides from Edible Mushrooms—The Preparation, Mechanisms, Structure—Activity Relationships and Prospects. Foods. 2023; 12(15):2935. https://doi.org/10.3390/foods12152935

[18] Zhou, Y., He, Q., Su, D., Huang, H. (2016). Effects of UHP Tenderizing Treatment on the Quality Characteristics of Venison. Journal of Food Process Engineering, 39(2), 196–203.

[19] Tikhonov, S., Tikhonova, N., Lazarev, V., Samokhvalova, E., Minukhin, L., Pischikov, G. (2020). UHP Chilled Meat Processing: A Promising Storage Method. E3S Web of Conferences, 176. https://doi.org/10.1051/e3sconf/202017603022