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Impact of high-pressure processing on the nutritional and microbial quality of dairy products.

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Introduction

High-pressure processing (HPP) is an innovative non-thermal food preservation technique that has gained significant attention in the dairy industry. HPP involves subjecting food to extremely high pressures, typically ranging from 100 to 600 MPa, for a specified duration to achieve microbial inactivation while preserving the product's sensory and nutritional attributes. This method serves as an alternative to traditional thermal pasteurization, which can sometimes compromise the quality of dairy products [1].

HPP effectively inactivates spoilage microorganisms and pathogenic bacteria, thereby enhancing the microbial safety and shelf life of dairy products. Pathogens such as Listeria monocytogenes, Escherichia coli, Salmonella spp., and Staphylococcus aureus are highly susceptible to high-pressure treatment. Unlike conventional heat treatments, which may cause protein denaturation and undesirable flavor changes, HPP inactivates microorganisms by disrupting their cellular membranes, denaturing proteins, and interfering with enzyme activity without significantly increasing the product temperature [2].

The microbial reduction achieved through HPP depends on several factors, including pressure level, holding time, temperature, and the specific type of microorganism. Spore-forming bacteria such as Bacillus and Clostridium species demonstrate higher resistance to pressure and may require additional hurdles, such as combining HPP with mild heat, to achieve effective inactivation [3].

One of the primary advantages of HPP over thermal pasteurization is the superior retention of nutrients. Traditional heat treatments can degrade heat-sensitive nutrients, such as certain vitamins and bioactive compounds, thereby reducing the nutritional value of dairy products. In contrast, HPP preserves essential nutrients, including: The structure of dairy proteins, such as casein and whey proteins, remains largely intact under high pressure, preserving their functional and nutritional properties. HPP may induce minor modifications in protein structure, potentially enhancing digestibility and bioavailability [4].

Vitamins such as B2 (riboflavin), B12, and C are susceptible to heat degradation but are well-retained under HPP. This is particularly beneficial for fortified dairy products that aim to deliver maximum nutritional benefits. Responsible for the development of desirable flavors and textures in dairy products are less affected by HPP compared to thermal treatments, preserving their functionality. Additionally, HPP maintains bioactive peptides with antioxidant and antimicrobial properties.

HPP has a minimal impact on the taste, texture, and color of dairy products. Unlike thermal pasteurization, which may lead to cooked flavors in milk, HPP-treated dairy products retain a fresh taste and natural texture. This makes it particularly suitable for premium and organic dairy products

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where maintaining fresh sensory attributes is a priority.

Furthermore, HPP can improve the functional properties of dairy products by altering protein interactions and enhancing viscosity, which can be beneficial for yogurt and cheese production. However, excessive pressure may lead to undesirable changes in gelation and syneresis in some dairy applications [5].

Conclusion

High-pressure processing offers a promising alternative to traditional thermal pasteurization in the dairy industry. It effectively enhances microbial safety while preserving the nutritional and sensory qualities of dairy products. Despite its advantages, challenges such as the high cost of equipment and limited efficacy against bacterial spores remain. Continued research and technological advancements are expected to further optimize HPP for widespread dairy applications, ensuring safe, nutritious, and high-quality dairy products for consumers.

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