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Editorial

Non-Thermal Technologies for Food Processing

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This Special Issue covers the utilization of non-thermal technologies, specifically high pressure processing (HPP) or high hydrostatic pressure (HHP), pulsed electric field (PEF), ultrasound (US), and ultraviolet (UV) for food processing and preservation. The potential of HPP and US, either individually or in combination with heat, as an alternative to traditional food pasteurization methods has been thoroughly reviewed [1–3]. These innovative technologies exhibit the capability to effectively inactivate food-borne pathogens, spoilage microorganisms, and enzymes responsible for the deterioration of food quality, thereby extending the shelf life of various food products. By doing so, they contribute to the global pursuit of sustainable development goals established by the United Nations Member States in 2015, by reducing food losses and waste. Adopting these technologies for food pasteurization not only helps retain the original flavours, aromas, and delicate bioactive components of food due to lower heat application, but also ensures the production of safe and healthy clean-label foods, as no chemical preservatives are required. Beyond their preservation benefits, HPP, PEF, and UV-C also hold a great promise for enhancing specific quality attributes in diverse food items, such as pea and soy protein isolates [4], cassava flour [5], oat flour [6], and prickly pear cactus fruit juice [7].

In the review written by Silva and Evelyn entitled "Pasteurization of Food and Beverages by High Pressure Processing (HPP) at Room Temperature: Inactivation of *Staphylococcus aureus*, *Escherichia coli*, *Listeria monocytogenes*, *Salmonella*, and Other Microbial Pathogens" [1], significant insights were given regarding the effectiveness of HPP in eliminating various bacterial pathogens. The research indicated that *Staphylococcus aureus* required a minimum pressure level of 600 MPa or higher for successful inactivation. Conversely, bacterial strains such as *E. coli*, *L. monocytogenes*, and *Salmonella* spp. displayed a greater susceptibility to HPP treatment, with pressure ranges between 400 to 600 MPa resulting in six-log reductions. Other bacteria including *Vibrio* spp., *Campylobacter jejuni*, *Yersinia enterocolitica*, *Citrobacter freundii*, and *Aeromonas hydrophila* generally required lower pressures ranging from 300 to 400 MPa for effective inactivation [1]. It is important to note that the specific microbial species, strain, and composition of the food itself influence the extent of microbial reduction achievable through HPP. This review demonstrated that HPP represents a safe and commercially viable pasteurization method capable of achieving a significant reduction (six logs) in major bacterial pathogens without the application of heat [1]. However, careful consideration should be given to the potential presence of resistant strains that may require higher pressures or alternative approaches for effective inactivation under standard HPP commercial operating conditions (i.e., 600 MPa).

Notable findings regarding the impact of HPP on the properties of pea and soy protein isolates were reported by Queirós et al. [4]. The researchers concluded that HPP treatment led to an increase in protein solubility and surface hydrophobicity for both isolates. However, they also observed a general decrease in the number of free sulfhydryl groups for both proteins when subjected to HPP, indicating a complex interplay between

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protein unfolding and subsequent aggregation under specific conditions. The effects of HPP on the emulsifying properties of the protein isolates were found to be influenced by several factors such as pH, pressure, holding time, and the utilization of either the soluble or total fraction of the protein isolates. These findings highlight the multifaceted nature of HPP-induced changes in protein characteristics, requiring a careful consideration of various parameters to achieve desired modifications in the emulsifying properties of pea and soy protein isolates.

Conde et al. explored the influence of high-hydrostatic-pressure (HHP) processing on the properties of starch in cassava flour [5]. The study revealed that the application of 600 MPa consistently induced a transformation from crystalline to amorphous starch structures. The gelatinization process triggered by HHP caused the starch granules to enlarge, resulting in the loss of birefringence and a decrease in the relative crystallinity percentage, while also introducing alterations in short-range order. These findings collectively suggest the potential of HHP as a means to modify the starch component in cassava flour, offering the possibility of producing flours with diverse levels of functionality. This study implies the prospects of utilizing HHP as a technique for tailored modifications of starch properties in cassava flour, allowing for the development of flours with desired functionalities for various applications.

Duque et al. delved into the underlying mechanism on how pulsed electric field (PEF) treatment influences the digestibility and characteristics of starch in oat flour [6]. The study revealed that applying PEF at energy levels surpassing 421 kJ/kg, along with electric field strength intensities ranging from 2.1 to 4.5 kV/cm, increased the proportion of rapidly digestible starch from 15% to around 19–20%. However, the rate of starch digestion remained unaffected. Further examination encompassing the structural, particle size, and thermal stability aspects of PEF-treated oat flour, achieved through fractionation into three distinct segments, unveiled substantial alterations caused by PEF treatment. These modifications included changes in particle size, damage and aggregation of starch granules, as well as disruption of both long- and short-range ordered structures of starch [6]. The findings from this study demonstrated that PEF treatment can serve as a strategy to modulate the in vitro starch digestibility of oat flour by either moderately slowing down the digestion rate or allowing a slightly higher amount of starch to be readily accessible to digestive enzymes, without compromising the digestion rate itself [6]. These insights highlight the potential of PEF treatment as a means to tailor the digestibility characteristics of oat flour, opening up avenues for the development of functional food products with desired nutritional properties.

In the comprehensive review on ultrasound pasteurization of foods, Bermudez-Aguirre and Niemira demonstrated that ultrasound, when combined with temperature, pressure, or antimicrobials, can effectively achieve a substantial five-log reduction in microbial load [2]. A significant focus of research in this field pertains to the impact of ultrasound on food bioactive compounds. Findings indicate that ultrasound treatment leads to an enhanced concentration of essential components such as phenolics, carotenoids, anthocyanins, and other vital nutrients [2]. These results highlight the potential of ultrasound as a promising technology for preserving and enhancing the levels of valuable bioactive compounds in food products.

Mesta-Vicuña et al. explored the processing of red prickly pear cactus juice using a continuous-flow UV-C system and assessed the quality of the juice during storage [7]. The UV-C treatment exhibited a process efficacy equivalent to thermal treatment in terms of inactivating coliform and mesophiles in the juice. Yeasts and moulds were effectively eliminated at a dose exceeding 15.13 mJ/cm^2. Interestingly, varying UV-C doses did not result in significant differences in the content of betalains, polyphenols, and antioxidant activity. However, a decline in these compounds was observed over the course of storage. The physical properties of the juice, including pH, acidity, and Brix, remained largely unaffected by the treatments, except for colour, which displayed changes [7]. These findings suggest that a UV-C dose of 15.13 mJ/cm^2, when applied using a continuous system, can serve as a viable alternative for processing red prickly pear juice at a pH of 3.6. This approach effectively extends the shelf life of the juice while preserving its key quality attributes [7].

Lastly, Zawawi et al. reached significant conclusions regarding the effective reduction of polyphenol oxidase or polyphenoloxidase (PPO) activity, an enzyme responsible for enzymatic browning, and the production of high-quality fruit products [3]. In their review entitled "Thermal, High Pressure, and Ultrasound Inactivation of Various Fruit Cultivars' Polyphenol Oxidase: Kinetic Inactivation Models and Estimation of Treatment Energy Requirement", they found that the resistance to different treatments varied across fruit types and cultivars. When compared to thermal treatment alone, the combined use of high pressure and ultrasound with heat proved more effective in PPO inactivation in fruits. Heat-assisted high-pressure processing predominantly followed a first-order kinetic behavior, although some fruit cultivars exhibited biphasic inactivation patterns [3]. Estimating the specific energy requirements for achieving over 80% PPO inactivation highlighted the dependence on equipment setup, process scale, and design. The thermal process alone indicated energy requirements ranging from 87 to 255 kJ/kg, while high-pressure processing indicated a range of 139 to 269 kJ/kg. Ultrasound processing, on the other hand, showed a wider energy range of 780 to 10,814 kJ/kg [3]. These findings emphasize the efficacy of combining high pressure and ultrasound with thermal treatment for reducing PPO activity and producing high-quality fruit products. However, it is crucial to consider the specific fruit cultivars and optimize the energy requirements based on the processing equipment, scale, and design.

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References

1. Silva, F.V.M.; Evelyn. Pasteurization of Food and Beverages by High Pressure Processing (HPP) at Room Temperature: Inactivation of *Staphylococcus aureus*, *Escherichia coli*, *Listeria monocytogenes*, *Salmonella*, and Other Microbial Pathogens. *Appl. Sci.* **2023**, *13*, 1193. [CrossRef]
2. Bermudez-Aguirre, D.; Niemira, B.A. Pasteurization of Foods with Ultrasound: The Present and the Future. *Appl. Sci.* **2022**, *12*, 10416. [CrossRef]
3. Zawawi, N.A.F.; Hazmi, N.A.M.; How, M.S.; Kantono, K.; Silva, F.V.M.; Sulaiman, A. Thermal, High Pressure, and Ultrasound Inactivation of Various Fruit Cultivars' Polyphenol Oxidase: Kinetic Inactivation Models and Estimation of Treatment Energy Requirement. *Appl. Sci.* **2022**, *12*, 1864. [CrossRef]
4. Queirós, R.; Ferreira, R.; Saraiva, J.A.; Lopes-da-Silva, J.A. High-Pressure Effects on Selected Properties of Pea and Soy Protein Isolates. *Appl. Sci.* **2023**, *13*, 2359. [CrossRef]
5. Conde, L.A.; Kebede, B.; Leong, S.Y.; Oey, I. Effect of High Hydrostatic Pressure Processing on Starch Properties of Cassava Flour. *Appl. Sci.* **2022**, *12*, 10043. [CrossRef]
6. Duque, S.M.M.; Leong, S.Y.; Agyei, D.; Singh, J.; Larsen, N.; Sutton, K.; Oey, I. Understanding the Mechanism of How Pulsed Electric Fields Treatment Affects the Digestibility and Characteristics of Starch in Oat Flour. *Appl. Sci.* **2022**, *12*, 10293. [CrossRef]
7. Mesta-Vicuña, G.; Quintero-Ramos, A.; Meléndez-Pizarro, C.O.; Galicia-García, T.; Sánchez-Madrigal, M.Á.; Delgado, E.; Ruiz-Gutiérrez, M.G. Physical, Chemical and Microbiological Properties during Storage of Red Prickly Pear Juice Processed by a Continuous Flow UV-C System. *Appl. Sci.* **2022**, *12*, 3488. [CrossRef]