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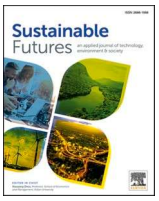

Non-thermal processing techniques for sustainable food supply chains

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ABSTRACT

This review examines the role of non-thermal food processing technologies in fostering sustainable food supply chains. Emphasizing energy conservation, carbon emission reduction, and circular economy principles, we investigate various non-thermal methods, their industrial applications, and societal impacts. Nonthermal technologies, including Pulsed Electric Fields, High Hydrostatic Pressure, Cold Atmospheric Plasma, and Light-Based Technologies, have been scrutinized for their potential to address conventional processing challenges. These techniques significantly enhance food safety and quality while minimizing environmental footprints. We explore recent progress and industrial applications indicating their effectiveness in extending shelf life, preserving nutritional values, and reducing resource consumption. The societal inferences, safety attention, regulatory issues, and consumer acceptance of these technologies are also discussed, highlighting the health rewards and the necessity for increased awareness and education. The review stresses nonthermal processing's pivotal role in promoting sustainable food systems by mitigating food waste, conserving resources, and lowering carbon emissions. It concludes with a call for current research and alliance to fully realize the potential of nonthermal technologies in securing a sustainable future for food production and consumption.

1. Introduction

Exploring innovative technologies is pivotal in the quest for sustainable food production and consumption. Among these, nonthermal food processing technologies have emerged as a beacon of hope, promising to revolutionize how we preserve and process food and contribute significantly to the sustainability of food supply chains. Nonthermal food processing technologies encompass a broad range of techniques designed to protect food by employing methods other than traditional heating. These include but are not limited to, high-pressure processing, pulsed electric fields, ultrasonic processing, and cold plasma. By avoiding or minimizing the use of heat, these technologies offer the dual advantage of reducing energy consumption and preserving the nutritional and sensory qualities of food products better than their thermal counterparts [1].

The significance of nonthermal technologies in fostering sustainable food supply chains cannot be overstated. The food industry is under increasing pressure to find energy-efficient, environmentally friendly solutions in a world grappling with climate change, population growth, and finite resources. Nonthermal processing technologies respond to this call by reducing energy consumption and, thus, carbon emissions, causal to reducing the food industry's environmental footprint [2]. Furthermore, these technologies align well with the principles of the circular economy by potentially reducing food waste through extended shelf life and offering prospects for valorizing by-products [3]. Interest in nonthermal food processing technologies is growing, driven by environmental benefits and consumer demand for high-quality, minimally processed foods. The market for such technologies is expanding as food producers seek to meet these demands while addressing the urgent need for sustainability [4]. Despite the promising potential, the adoption of nonthermal technologies faces challenges, including regulatory hurdles, high initial investment costs, and the need for further research to optimize their efficiency and ensure food safety [5].

This paper aims to introduce and discuss nonthermal food processing technologies, underlining their importance in achieving a sustainable food system and exploring the growing interest in these methodologies. Also, nonthermal food processing technologies hold significant promise for advancing sustainable food supply chains. Their ability to reduce

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