



Revolutionizing the supply chain: Cutting-edge strategies and technologies for food waste reduction

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ABSTRACT

Food waste has significant environmental, economic, and social impacts. Here we review the principal reasons and impacts of food waste while presenting what has been done to reduce it nowadays. We also suggest new strategies and technologies that should be prioritized for a better future tomorrow. The paper reviews innovative packaging concepts and active and intelligent systems to improve food preservation, such as modified atmosphere packaging, antimicrobial coatings for isolation of bio-pathogenic or exhaust gas treatment from perishable products storage areas, control of the diffusion mechanism in biopolymer stages critical principles embedding multiple antioxidative compounds with encapsulation technology and antioxidant. Case studies show results achieved by applying the techniques described so far. The review also confers fresh strategies innovators employ to prevent waste and developments in data analytics and AI-driven tracking and measurement technologies. It ends with assessing what working models are effective and explores the ground challenges and the potential for scaling these solutions in a circular economy. The broadness of this review has been purposely designed to provide a detailed resource that could pave the way to providing better sustainability and reducing food waste across different sectors.

1. Introduction

One of the most significant challenges facing mankind today is food waste, a global issue that adversely affects other aspects such as the environment, economy, and society (Dubey et al., 2023). From farm to fork, food waste is a massive problem and it occurs at every stage of the food supply chain: production, processing, distribution, and consumption. Various factors lead to this problem, like overproduction, improper cold chain management, lack of storage facilities, and rigid quality standards, which prompt rejection even when perfectly edible. In the US, for example, close to 40 % of food that is produced goes into bins instead of stomachs, resulting in millions and millions of tons wasted every year. This waste occurs in all stages of agricultural production, retail, and household consumption, magnifying the problem even more (Spyridakis et al., 2019). An estimated one-third of food produced at a global level is wasted, which equates to around 1.3 billion tonnes per year. Such wastage results in huge economic losses, especially for regions like the European Union, where food waste runs into billions of Euros annually. In South and Southeast Asia, the problem is equally grim

yet another proof that this issue plagues every corner of our planet (Hamik and Mohamed, 2022). The causes of food waste are multifaceted, ranging from inefficient production processes, overproduction, improper storage, and handling, to consumer behaviors such as over-purchasing and poor meal planning (Galanakis, 2018).

Food waste occurs from different sources, though a large percentage seems to derive from overproduction at the farm and processing plant level; poor storage practices lead to spoilage even before sale or consumption while consumers buy more than they consume also failing in effective meal planning (Elnakib, 2022). The implications of food waste are wide-reaching, with financial costs just the tip. On the environmental side, food waste is a major source of greenhouse gas emissions and forms a significant part of methane released from landfills. Food waste, on a social level, is an incredible shame since 1 in every 7 American households lack food security and are starving (Spyridakis et al., 2019). The social injustice is severe, as surplus food that could feed marginalized communities is instead discarded, impairing inequality and hunger globally (Tahmaz and Aksoy, 2024). In addition, wastage of food means the loss of potentially important technological

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