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The Role of Packaging in Food Loss and Waste Reduction: A Mini Review from Indonesia

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Abstract
This brief review highlights findings from research conducted in Indonesia, examining how packaging can play a crucial role in reducing food loss and waste within the supply chain. While the broader economic, social, and environmental ramifications of food waste are extensively covered in existing literature, this study specifically focuses on how innovative packaging solutions can mitigate food loss. In the realm of fresh produce, effective packaging not only preserves quality but also optimizes product protection, ventilation, and temperature regulation. The study explores several avenues for packaging improvements, including enhanced designs for distribution that reduce damage during transportation and handling, and consumer packaging innovations that help reduce household food waste by facilitating correct portion control and clarifying expiration date labeling. Furthermore, the adoption of pre-packaged goods is shown to streamline handling processes and improve inventory turnover in retail settings. A key insight from this research is that optimal waste reduction sometimes necessitates increased packaging use, highlighting the need for a holistic approach where packaging design is integrated thoughtfully with product needs to foster sustainability in the supply chain.
Keywords: *indonesia, packaging, food loss, food waste*

Abstrak
Tinjauan singkat ini menyoroti temuan dari penelitian yang dilakukan di Indonesia, yang meneliti bagaimana pengemasan dapat memainkan peran penting dalam mengurangi kehilangan dan pemborosan makanan dalam rantai pasokan. Meskipun dampak ekonomi, sosial, dan lingkungan yang lebih luas dari pemborosan makanan dibahas secara luas dalam literatur yang ada, studi ini secara khusus berfokus pada bagaimana solusi pengemasan yang inovatif dapat mengurangi kehilangan makanan. Dalam bidang produk segar, pengemasan yang efektif tidak hanya menjaga kualitas tetapi juga mengoptimalkan perlindungan produk, ventilasi, dan pengaturan suhu. Studi ini mengeksplorasi beberapa cara untuk perbaikan pengemasan, termasuk desain yang disempurnakan untuk distribusi yang mengurangi kerusakan selama transportasi dan penanganan, dan inovasi pengemasan konsumen yang membantu mengurangi pemborosan makanan rumah tangga dengan memfasilitasi kontrol porsi yang benar dan memperjelas pelabelan tanggal kedaluwarsa. Lebih jauh, adopsi barang pra-kemasan terbukti dapat memperlancar proses penanganan dan meningkatkan perputaran inventaris dalam pengaturan ritel. Wawasan utama dari penelitian ini adalah bahwa pengurangan pemborosan yang optimal terkadang memerlukan peningkatan penggunaan kemasan, yang menyoroti perlunya pendekatan holistik di mana desain kemasan terintegrasi secara cermat dengan kebutuhan produk untuk mendorong keberlanjutan dalam rantai pasokan.
Kata Kunci: *indonesia, pengemasan, food loss, food waste*

1. Introduction

Global food supply chains face significant pressures from a rapidly growing population and environmental stressors. According to studies by the FAO [1], Gustavsson et al. [2], and additional researchers [3,4], the global population is projected to rise to 9 billion by 2050, necessitating a 77% increase in food production. This challenge is compounded by the shrinking availability of productive land and clean water resources, exacerbated by environmental factors such as salinity, droughts, flooding, climate shifts, and competition for land use [5,6]. Remarkably, up to 40% of all the food that is produced for human consumption in industrialized nations is lost [1]. Food waste and loss in Indonesia make up sufficient quantity to sustain 47% of its population annually [7]. The distinction between food 'loss,' which occurs during production, post-harvesting, and processing, and food 'waste,' which occurs closer to the consumer

end of the supply chain, highlights the need for strategic intervention at all parts of the food supply chain [8].

Solutions to these issues include streamlining supply chain operations [9,10], stimulating consumer behavior and awareness [11], and improving packaging technology [12]. Optimizing packaging, surprisingly, is not just about reducing waste but also about optimizing product protection, and in certain instances, this involves utilizing greater amounts of materials, not less, in order to avert foodborne disease and spoilage [13,14]. Packaging plays an important role in the provision of food integrity throughout the farm-to-consumer chain. Packaging protects food from mechanical damage, biological spoilage, and contamination and has promotional roles in terms of accentuating product benefits and brand name [14]. Furthermore, packaging has to incorporate key information on handling, preparation, and product disposal, hence enhancing distribution ease as well as the consumer experience. Good packaging is also responsible for extending the shelf life of a product, significantly minimizing waste [15].

Over time, the function of packaging has expanded to embrace convenience, safety features, and interactive technologies that inform stakeholders about the condition of the food and its environment [13]. The primary aim of food packaging is to deliver the right product to the right consumer in a manner that is safe, cost-effective, and user-friendly [16]. To meet the year-round demand for fresh and processed foods, a diverse array of packaging materials and designs are employed. These range from primary packaging that directly encases the product—for example, plastic bags, glass jars, and metal cans—to secondary and tertiary layers that protect these primary containers during transit, such as corrugated boxes, pallets, and stretch wraps [17].

While packaging constitutes only a minor portion of the total energy input in an average person's weekly food consumption, its strategic design is crucial for minimizing food waste and, by extension, its broader environmental impacts [12,16,18]. The trade-offs between packaging volume and waste reduction are complex, particularly as market trends shift towards single-serve formats, which, while increasing packaging use per serving, potentially reduce food waste by better matching consumer needs [19,20].

Selecting the most appropriate packaging solution involves analyzing demand throughout the supply chain and understanding the specific market requirements for the product [21]. Insights from a comprehensive literature review have deepened our understanding of food waste dynamics within the Indonesian context, enabling targeted strategies to improve packaging and reduce food waste effectively.

2. Material and Methods

The importance of packaging in preserving both fresh and processed foods throughout all stages of the supply chain is often overlooked in discussions on food security and waste reduction. For example, the Minister of Environment and Forestry Regulation No. P.75/MENLHK/SETJEN/KUM.1/10/2019 aims to cut down on packaging but fails to recognize the potential of packaging innovations to decrease food wastage. This oversight was initially addressed in Indonesia Law No. 18 of 2012, which mandates that food packaging must adhere to safety standards and pose no threat to human health or the environment. The research encapsulated in this document leverages a thorough review of both national and international literature concerning Indonesia's food and packaging sectors. This comprehensive approach allows us to examine food waste throughout the supply chain, particularly focusing on pre-consumption stages, including agricultural production, post-harvest handling, and the storage of raw materials as well as commercial and industrial sectors like food manufacturing and distribution.

Despite the extensive research on food waste, there has been less focus on the waste attributed directly to packaging within the supply chain. Our literature review spans numerous databases and includes analyses of scientific journal abstracts and unpublished reports that detail the extent of food waste and the effectiveness of current packaging methods. The review began in October 2024 and utilized resources from databases such as Garuda, Google Scholar, Science Direct, Scopus, and Web of Science

3. Results and Discussion

In the recent years, a systematic attempt has been seen from the stakeholders like government bodies, agricultural producers, food producers, retail sectors, and consumers to analyze and achieve the causes of food wastage. According to the Food and Agriculture Organization of the United Nations, annually 1.3 billion tonnes of food intended for human consumption is lost or wasted globally [2]. Even though Indonesian food wastage levels are not known, the loss is estimated to range from 115 to 184 kg per capita annually. The figure is expected to rise to 344 kg per capita in 2045, and it is an increasing problem [7]. One of the challenges encountered in quantifying Indonesian food loss and waste is the diversity of causative factors and sporadic data collection across various industries and regions.

Significant losses are observed in various industries, characterized by the specified supply chain and national consumption practices. The Agricultural Sector, including activities from harvesting to post-harvesting, undergoes widespread loss, particularly in highly perishable products like fruits, vegetables, and fish, prone to breakage and deterioration. This sector contributes to 43.88% of the nation's total food loss and waste. Similarly, the Transportation and Logistics sector faces challenges due to inadequate infrastructure and lack of proper storage facilities, contributing to 18.56% of the loss. The most significant losses, however, occur in the Retail and Household sectors, driven by consumer purchasing habits, ineffective stock management, and poor food handling awareness. This sector accounts for 37.55% of food waste, with households alone contributing 80% of this figure. Notably, 44% of the food waste consists of edible leftovers [7].

A 2023 study by the Indonesian Ministry of Environment and Forestry indicates that food waste constitutes 40.7% of the total waste produced nationwide, yet only a small fraction (2-5%) of this waste is effectively recycled or processed. The challenges of food loss and waste are prevalent in both developed and developing contexts. In Indonesia, inefficiencies in harvesting, storage, transportation, and processing are predominant causes of food loss, while waste typically accumulates at the retail and consumer stages in more developed settings [22,23]. The factors contributing to food loss and waste are diverse, ranging from pest and disease damage, variable weather conditions, failure to meet quality standards, and issues in storage and handling, to spillage and degradation [19,24,25].

In the distribution phase, several factors contribute to food loss and waste. These include packaging failures, spoilage during transportation or storage, non-compliance with produce specifications, or insufficient shelf life due to inadequate stock rotation or poor sales [25]. In the realm of food services, issues such as inefficient inventory management, incorrect food handling practices, misunderstandings about expiration labels, and surplus food contribute significantly to waste [26]. Similarly, at the household level, waste typically arises from spoilage, over-preparation of meals, and the delayed consumption of leftovers [27]. Tackling these issues is crucial for reducing food waste across the supply chain.

This paper's findings highlight impactful ways in which packaging technology can be leveraged to minimize waste. **Figure 1** outlines the primary causes of food loss and waste across four key stages of the food supply chain and presents viable packaging strategies for stakeholders in Indonesia, including government agencies, manufacturers, retailers, and community support organizations. Drawing from global research, several innovative approaches are recommended [19,28–30]:

a. Enhance the protection and shelf life of fresh produce with custom packaging solutions from farm to retail.
b. Implement recovery systems for excess and unsalable produce at farms using specialized distribution packaging geared towards food rescue operations.
c. Employ secondary packaging designed specifically for its protective roles throughout the supply chain.
d. Design packaging processes to extend food shelf life and reduce wastage from distribution points to consumption areas, with an emphasis on recyclability and reuse.
e. Develop and incorporate new packaging materials and technologies, such as those enabling atmospheric modification and the use of oxygen scavengers, to prolong shelf life.
f. Educate all stakeholders, including manufacturers, retailers, and consumers, on the correct interpretation and application of 'use by' and 'best before' labels to prevent the premature disposal of still-edible food.
g. Tailor packaging designs to suit changing consumption trends and the needs of smaller households, focusing on single-serve and smaller-portion options.
h. Foster collaboration within the industry to deepen the understanding of food waste sources and solutions, thus optimizing the supply chain and minimizing environmental and economic impacts.
i. Introduce innovative packaging and effective data sharing systems to harmonize the supply chain, thereby reducing instances of overstocking or expired goods.
j. Promote the use of ready-to-use packaging in retail settings to minimize handling and damage, enhance stock management, and ensure that packaging is fit for purpose and recyclable at the end of its lifecycle.

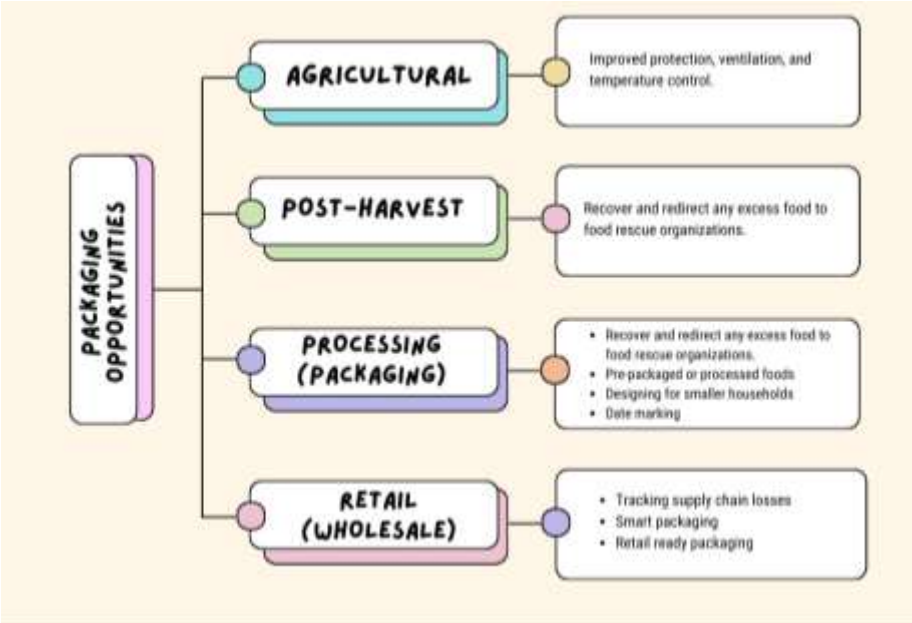

Fig. 1: Opportunities for packaging exist throughout the entire food supply chain

By adopting these strategies, stakeholders can significantly reduce the volume of food lost or wasted, while also ensuring sustainability and efficiency within the food supply chain. The adoption of initiatives aimed at minimizing packaging consumption, enhancing product protection, and curbing food waste is crucial and can be supported through expanded research efforts. Such studies can elucidate both the advantages and potential drawbacks linked to these initiatives. Suggested areas for future research include [9,19,20,24]:

a. Empirical Observations and Waste Analysis: Conducting direct observations and sampling at crucial points in the supply chain, such as during post-harvest assessments, sorting, and packaging processes. This approach aims to identify areas where waste reduction is feasible by examining waste patterns within the broader context of supply chain trends.
b. Targeted Supply Chain Studies: Undertaking detailed studies on the efficacy of packaging systems in reducing waste within the food supply chain. These studies would benefit from the collaboration of industry associations, private companies, governmental bodies, academic institutions, and research organizations. Selection of food types for these studies should be based on factors such as economic importance, sales figures, environmental impact, or the quantity of waste generated.
c. Causality Research in Food Service: Investigating the causes of waste in food service environments to pinpoint opportunities for introducing innovative packaging solutions and waste management systems. This could include developing enhanced methods for capturing and processing waste at its end-of-life, for instance, through composting.
d. Life Cycle Assessments: Performing life cycle assessments of various packaging formats, including those designed to extend product shelf life. These assessments would help clarify the balance between packaging usage and food waste reduction, as well as the interactions among primary, secondary, and tertiary packaging systems.
e. Comprehensive Lifecycle Impact Studies: Conducting comprehensive assessments of different packaging formats—such as single-serve versus bulk—and their effects on different types of products, including ambient, chilled, and frozen items. These studies aim to provide a holistic view of the impacts of packaging choices on product protection and waste across the product lifecycle.

The goal of these research endeavors is to empower the industry and consumers to adopt practices that not only reduce food waste but also mitigate associated environmental impacts. By deepening our understanding of these dynamics, we can develop more effective strategies for sustainability in the food supply chain.

4. Conclusion

Packaging innovations and technologies are of immense value to mitigate food wastage in the supply chain. There are numerous sources for food loss and wastage, including damage to foods at farm activities and food in surplus left over from home meal preparation. Although some wastage is inevitable, the

majority is caused by supply chain inefficiencies and issues in transport and handling phases. To address such waste, it is important to inform stakeholders in food and packaging supply chains about improvements that can be made available. Government-led educational programs, industries, and professional associations play a central role in highlighting the importance of good packaging and minimization practices. The upcoming 2045 food waste and loss management program has the objective of introducing educational content regarding the key role that packaging has in a product's shelf life and effective use. The program will heavily incorporate industry best practices demonstrating effective deployment of packaging technologies and supply chain optimization resulting in food waste avoidance. Besides, addressing consumer-led food wastage, fueled by tendencies of having smaller household sizes, wanting higher quality food, and confusion regarding product dating and packaging use, is essential.

This review is the beginning of an attempt to comprehend and minimize wastage of food along Indonesia's food supply chain. It has pinpointed several methods which would be capable of effectively addressing the dynamic interplay between use of packaging and food wastage to improve environmental and economic outcomes. These are not only applicable locally but can potentially be utilized in order to modify food supply chain management globally. Indonesia's circular economy and sustainable development vision is outlined in its national development plans that seek the double challenge and opportunity of fulfilling the increasing Asian markets' demand and sustaining agricultural and manufacturing processes. One of the key objectives of such plans is to minimize the per capita food wastage, which is more critical in a world with a scarcity challenge. Developing food packaging systems that are designed to achieve maximum efficiency while minimizing waste at every step of the supply chain becomes increasingly important.

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