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A Narrative Review Aligning Food Security with Food Loss and Waste Reduction

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Abstract

This study explores the critical intersection between food security, sustainable development, and food loss and waste (FLW). Anchored in Sustainable Development Goals (SDG) 2 and 12, the research emphasizes the importance of aligning efforts to end hunger with strategies to reduce FLW. Food security requires consistent access to nutritious food, yet food insecurity persists, affecting millions worldwide, with significant consequences for health, economic stability, and environmental sustainability. The current review examines various policy approaches across different regions, highlighting how differing strategies impact the effectiveness of FLW reduction and food security enhancement. For instance, while some countries focus on legislative measures to prevent food loss, others prioritize innovative practices such as repurposing near-expiry food or investing in sustainable food systems. The study also highlights innovative practices, such as municipal restaurants in Türkiye, which provide affordable and nutritious meals while minimizing waste, and cooperative initiatives empowering women. Additionally, the role of artificial intelligence and circular economy models in reducing FLW is explored, emphasizing the need for systemic and structural reforms. Global initiatives like the Food & Agriculture Organization's "Save Food" campaign, along with policy-driven approaches such as food banks and food waste awareness campaigns, underscore the importance of a collaborative effort between governments, private sectors, and NGOs to tackle both the symptoms and root causes of food insecurity.

Keywords: Food loss and waste, food insecurity, nutrition policy, sustainable development

Gıda Güvencesi ile Besin Kaybı ve Atıklarının Azaltılmasının Değerlendirilmesi

Öz

Bu çalışma, gıda güvencesi, sürdürülebilir kalkınma ve besin kaybı ve atıkları arasındaki kritik kesişimi derlemektedir. Sürdürülebilir Kalkınma Amaçları (SKA) 2 ve 12'ye dayanan çalışma, açlığı sona erdirme çabalarının besin kaybı ve atıklarını azaltma stratejileriyle uyumlu hale getirilmesinin önemini vurgulamaktadır. Gıda güvencesi, sürdürülebilir olarak besleyici gıdaya erişim ile ilişkili olup; gıda güvencesizliği, dünya genelinde milyonlarca insanı etkileyerek sağlık, ekonomik istikrar ve çevresel sürdürülebilirlik üzerinde önemli sorunlar yaratmaktadır. Bu derlemede, farklı bölgelerdeki çeşitli politika yaklaşımları incelenmiş, farklı stratejilerin besin kaybı ve atıklarının azaltılması ve gıda güvencesinin iyileştirilmesi üzerindeki etkileri vurgulanmıştır. Örneğin, bazı ülkeler besin kaybını önlemeye yönelik mevzuata yönelik önlemlere odaklanırken, diğerleri son kullanma tarihi yaklaşmış gıdaların yeniden değerlendirilmesi veya sürdürülebilir gıda sistemlerine yatırım yapma gibi yenilikçi uygulamalara öncelik vermektedir. Çalışma ayrıca Türkiye'deki kent lokantaları gibi yenilikçi uygulamalara da dikkat çekmektedir; bu lokantalar uygun fiyatlı ve besleyici yemekler sunmanın yanı sıra israfı da azaltarak gıda güvencesine katkıda bulunmaktadır. Kadınları güçlendiren kooperatif girişimleri de bu bağlamda önem taşımaktadır. Ayrıca, besin kaybı ve atıklarının azaltılmasında yapay zekanın ve döngüsel ekonomi modellerinin rolü incelenerek, sistemik ve yapısal reformların gerekliliği vurgulanmıştır. Gıda ve Tarım Örgütü'nün "Gıdanı Koru" kampanyası gibi küresel girişimler, gıda bankaları ve gıda israfı hakkında farkındalık kampanyaları, politika odaklı yaklaşımlar arasında yer almaktadır. Bu tür girişimler, gıda güvencesizliğinin hem semptomlarını hem de kök nedenlerini ele almak için hükümetler, özel sektör ve sivil toplum kuruluşları arasındaki iş birliğinin önemini vurgulamaktadır.

Anahtar Kelimeler: Besin kaybı ve atıkları, gıda güvencesizliği, beslenme politikası, sürdürülebilir kalkınma

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Introduction

Sustainable Development Goal (SDG) 2 is related to ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture (Katoch, 2024; United Nations, n.d.). Food security requires that individuals not only have consistent access to sufficient food but also that this food is nutritious and adequate for a healthy life (Berry et al., 2015; FAO Food Security Programme, 2008). Food insecurity, on the other hand, occurs when there is uncertainty or insufficiency in access to food, leading to inadequate nutritional intake and potential long-term health consequences (Bedasa & Deksisa, 2024). United Nations (UN) estimates that more than 600 million people will struggle with hunger by 2030. Currently one in three people worldwide struggle with food insecurity (Chichaibelu et al., 2021; United Nations, n.d.). This widespread food insecurity has far-reaching consequences, including detrimental effects on children's cognitive development. Recent studies indicate a notable decline observed in IQ scores among children particularly after 2020. This phenomenon has been attributed to environmental factors, poor nutrition being one of the key determinants. Inadequate nutrition resulting from food insecurity not only affects immediate health outcomes but also has lasting impacts on cognitive development, potentially leading to generational disadvantages (Bratsberg & Rogeberg, 2018). Food insecurity was shown to exacerbate the cycle of poverty by hindering future economic growth.

In addition to immediate health consequences, food insecurity also directly intersects with sustainability, a key focus of SDG 12, which aims to ensure responsible consumption and production patterns. Food loss and waste (FLW), significant contributors to inefficiency in the food supply chain, exacerbate food insecurity by reducing the availability of food that could otherwise meet the needs of vulnerable populations. FLW occurs either quantitatively or qualitatively, with quantitative FLW referring to the decrease in food mass and volume, while qualitative FLW refers to the decrease in nutritional and sensory food quality (Boiteau & Pingali, 2022). While food loss is defined as the decrease in the quality and quantity of foods, food waste is defined as foods suitable for human consumption being left to spoil or expire by one's choice or as a result of negligence (Global Initiative on Food Loss and Waste Reduction, 2015). FLW were found to have negative impacts on food security in terms of food availability, accessibility, utilization and stability along with lost nutritional value. Reducing FLW not only crucial for improving food security but also for addressing broader environmental challenges, as it directly contributes to lowering greenhouse gas emissions (Principato et al., 2021). Consequently, the United Nations' Zero Hunger Challenge includes "zero loss or waste of food" (Global Initiative on Food Loss and Waste Reduction, 2015) as a critical intersection between SDG 2 and SDG 12 (See *Figure 1*).

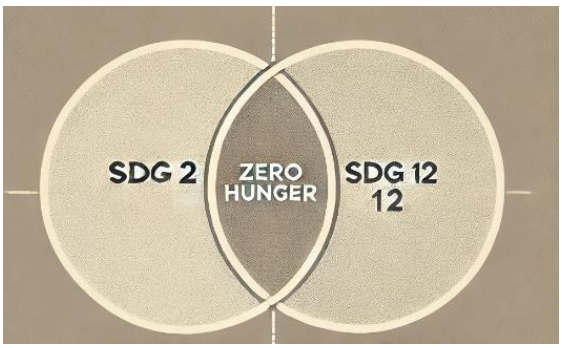

Figure 1. Zero hunger as the intersection of SDG 2 and SDG 12.

By aligning efforts to reduce food insecurity with initiatives to minimize FLW, it is possible to create a more resilient food system that supports both human health and environmental sustainability. This integrated approach is essential in addressing the global challenges of hunger malnutrition, and environmental degradation. A study by FAO highlighted that in 2007, approximately 1.3 billion tons of food were lost or wasted globally, equating to about one-third of the food produced for human consumption. This massive loss deprives undernourished populations in developing regions of scarce food resources while simultaneously depleting vital natural resources such as land, water, and fossil fuels along with contributing to greenhouse gas emissions associated with food production (Munesue et al., 2015).

Further studies demonstrated that a 25% reduction in food losses that become waste would prevent undernourishment among 821 million individuals (Principato et al., 2021; van Geffen et al., 2020). Therefore, integrating FLW should be an integral piece of lowering food insecurity in an equitable manner.

According to the FAO's 2023 State of Food Security and Nutrition in the World (SOFI) report, approximately 733 million people are globally struggling with hunger due to factors such as poverty and inadequate food systems. This highlights the persistent challenge of food insecurity, with the situation remaining particularly severe in Africa, where one in five people experienced hunger. The report also notes that 2.33 billion people worldwide experienced moderate or severe food insecurity that persisted since the significant rise observed in 2020 due to the COVID-19 pandemic (FAO et al., 2023). The management of food waste is seen as a means to provide gains in terms of both food security and environmental sustainability (Chen et al., 2020). The availability of food is one of the most fundamental human rights. Considering the global fight against hunger, it is considered that reducing FLW is an ethical and moral combat as well (Tsalis, 2020). *Figure 2* highlights the contrast between regions with high food waste and those suffering from food insecurity.

Figure 2. Images highlighting the contrast between regions with high food waste and those suffering from food insecurity.

Management of food waste necessitates comprehensive systems for storage, transportation and disposal. In developing countries, food waste primarily results from inadequate infrastructure for storage, transportation, preservation, and packaging. Conversely, in developed countries food waste is often driven by factors such as poor planning, the expiration of food products, and leftover disposal. Notably, waste occurs in developing countries during the production, transportation and storage stages, while in developed countries it is more prevalent at the consumption phase (O'Connor et al., 2021). Furthermore, food loss generally takes place during the early stages of the food supply chain, including harvesting and processing whereas food waste typically occurs at the final stages, such as retail and consumer consumption (J. Zhang et al., 2023a). The food supply chain itself is a complex system involving multiple stakeholders consisting of producers, processers, retailers and consumers who interact continuously, as illustrated in *Figure 3* (de Gorter et al., 2021).

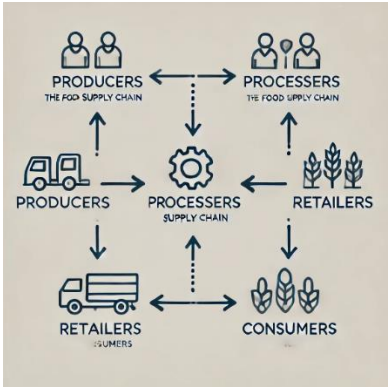

Figure 3. The stages of food supply chain.

Integrating Food Waste Reduction into Food Security Strategies

Reducing FLW is increasingly recognized as a critical component for improving food security and alleviating pressure on natural resources. Especially in the early stages of the food supply chain, reducing FLW is considered as an effective method to improve food security. By minimizing losses in the early stages of the supply chain, more food can reach markets and consumers, thereby, directly contributing to food security (Brian Lipinski et al., 2013; Food and Agriculture Organization of the United Nations, 2019). Moreover, reducing FLW can help stabilize food prices, making nutritious food more affordable for vulnerable populations (FAO et al., 2023). In addition to food security benefits, FLW reduction contribute to environmental sustainability by decreasing the demand for agricultural inputs such as water, land, and energy. This reduction in resource use translates into lower greenhouse gas emissions, aligning with global efforts to combat climate change (Kummu et al., 2012). The traditional linear model of FLW management, which primarily relies on incineration and landfilling creates a linear flow of nutrient utilization by ultimately depleting natural resources and worsening the environmental degradation. A transition to circular economy model is necessary wherein FLW is reduced, reused, and recycled in order to mitigate food insecurity as a key component of sustainable development (Wang et al., 2021).

Reducing Food Loss and Waste: Policy Models and Exemplary Practices

Effective strategies to reduce FLW involve multi-faceted approaches that include partnerships, sustainable food systems, and the integrity of the food supply chain. In this context, one of the initiatives launched by the FAO is "Save Food" campaign, which aims to provide collaboration and coordination on food loss and waste, to raise awareness, and to carry out research and projects (Global Initiative on Food Loss and Waste Reduction, 2015). In addition, ensuring food security requires a comprehensive approach that reviews eating habits, improving food production and minimizing food waste. Distributing surplus food to households affected by food insecurity not only prevents waste but also addresses the nutritional needs of vulnerable populations, creating a win-win situation (Papargyropoulou et al., 2022).

In Türkiye, urban municipalities have taken significant steps to address food insecurity through initiatives like municipal restaurants. For example, in cities such as Istanbul and Gaziantep, these restaurants provide affordable and nutritious meals to the public. The restaurants operate on a model where food is sold at low prices and remain open until the daily supply runs out, minimizing the waste. Portion control and bulk purchasing are integral to their operations, which helps in reducing costs and preventing food wastage (GAZİANTEP'İN İLK KENT LOKANTASI AÇILIYOR; Municipal Restaurants). Another important initiative in Türkiye is the establishment of cooperatives, many of which are predominantly run by women. These cooperatives are crucial not only for reducing food waste but also for empowering women, who

are often among the most affected by urban food insecurity ("The State of Food Security and Nutrition in the World 2020," 2020). By supporting these cooperatives, the government and civil society could contribute to systemic change that addresses the root cause of food insecurity rather than just treating its symptoms. Moving away from a culture of temporary aid and toward sustainable solutions through structural reforms should be part of policy models.

Achieving significant progress in reducing FLW and enhancing food security necessitates a merit-based collaboration between the governments, private sector. A merit-based approach ensures that the most qualified and effective actors are involved, leading to more impactful outcomes (Konefal, n.d.). When the government provides the necessary regulatory frameworks and financial support, the private sector could contribute through innovation and investment and NGOs could play a role in raising awareness, mobilizing resources, and help that the most vulnerable populations benefit from these initiatives. A collaborative effort of government, private sector, and NGOs could facilitate policies that are comprehensive and impactful, addressing both the symptoms and the root causes of food insecurity (Post et al., 2021).

Globally, food banks continue to play a crucial role in reducing FLW by collecting and distributing surplus food to people struggling with hunger (Penalver & Aldaya, 2022). In recent years, various countries have implemented laws and policies to address FLW more effectively. For example, the Republic of Moldova approved a law in May 2023 aimed at preventing FLW, recognizing the significant impact of post-harvest losses on food security. The FAO has organized webinars to support farmers and producers in improving post-harvest practices. On 29 September 2020, the first International Day of Awareness of Food Loss and Waste, FAO, UN Environment Programme (UNEP) and their partners highlighted the importance of reducing FLW and ensuring food security (Food and Agriculture Organization, n.d.).

In addition to initiatives like food banks and cooperatives, selling expired foods at a reduced price has emerged as a viable strategy to combat food waste and improve food security. For example, in Denmark, supermarkets such as WeFood have successfully implemented this model, where they sell products that past their expiration dates but are still safe for consumption. This approach not only reduced food waste but also makes nutritious food more accessible to low-income consumers (The Local DK, 2016). By offering these food products at significantly lower prices, these stores help mitigate the environmental impact of food waste while addressing food insecurity in a sustainable manner. Such initiatives demonstrate the potential of creative solutions in aligning economic incentives with social and economic benefits (Razouk et al., 2024).

Artificial Intelligence in Management of Food Loss and Waste with a Future Focus

Factors contributing to food insecurity include inadequate agricultural investment and infrastructure, climate change and environmental degradation, poverty and income inequality, food loss and waste, limited access to resources and technology, rising demand and rapid

urbanization, and political instability. The use of artificial intelligence (AI) in this context is seen as a promising method for improving global food security. AI can help optimize agricultural practices, stabilize product quality, reduce waste, and enhance traceability and quality control within the food supply chain (Pandey & Mishra, 2024). AI has the potential to enhance food security by boosting food production. Implementing AI-based methods across various stages of the agro-food system is considered beneficial for achieving SDG 2. AI can be used to detect and manage diseases in crops and animals, control pests and weeds, and monitor livestock and agricultural produce. It can also be applied to food production processes, packaging, and food waste management, among other areas. AI is seen as helpful in the transition to a sustainable and improved food system (Kutyauripo et al., 2023).

In a rapidly urbanizing world, food consumption patterns are also evolving. The traceability and transparency of the food supply chain are effective in ensuring food security. Smart food traceability systems are expected to enhance food safety, reduce foodborne outbreaks, and ensure food security (Yu et al., 2022). The complexity of the food supply chain makes it difficult to track the journey of food from farm to fork due to threats to food safety and food fraud scandals. Developing an effective food traceability system was shown to improve food quality and safety, reduce food recall costs, and decrease FLW. In this context, it is thought that approaches such as "Food Traceability 4.0", which use smart traceability systems (e.g. blockchain, internet of things, artificial intelligence, big data) could be effective in decreasing FLW (Hassoun et al., 2023).

Educational and Awareness Campaigns: Policy-Driven Approaches to Behavioral Change

Food waste generated at the consumption stage constitutes 35% of total food waste and 8-10% of global greenhouse gas emissions (Katajajuuri et al., 2014). One of the approaches to reduce food waste is "nudging", which refers to the individual's voluntary behavioral change without any economic incentive. Examples of “a nudge” are offering smaller portion sizes, modifying plate characteristics, and providing options for taking leftovers (J. Zhang et al., 2023b). In developed countries, food waste largely originates from the consumer, who operates in the final stage of the food supply chain. It is thought that wasteful behavior may be caused by psychological, social and socio-economic factors, and food waste generated in households may trigger this behavior. Investigating the causes and quantities of food waste generated in households is recommended. In addition, educational and awareness campaigns should be organized to encourage behaviors that contribute to reducing food waste. The policies and plans which have been implemented should be measured and monitored (Principato et al., 2021). Consumer-targeted food waste interventions should be easy to implement and favorable (van Geffen et al., 2020).

Policymakers have been known to create programs aimed at preventing FLW. Examples of such programs include Germany's "Waste Prevention" Program (Federal Ministry for the

Environment, 2013), Ireland's "Stop Food Waste" Program (Department of The Environment, n.d.), Italy's "National Plan for Food Waste Prevention," (Food and Agriculture Organization of the United Nations, n.d.) and Denmark's "Stop Wasting Food" Program (Stop Wasting Food Movement Denmark, n.d.). The programs developed aim to increase awareness of food wasting behaviors (Chinie et al., 2021). In the United States, the most prevalent approach to reducing food waste is to develop campaigns aimed at educating consumers and raising awareness. For instance, the United States Environmental Protection Agency's (US EPA) "Food: Too Good to Waste" Program (United States Environmental Protection Agency, 2016) encourages collaboration among local authorities, non-profit organizations, and industry. Such campaigns often include hosting public workshops to further raise awareness and educate the community (Soma et al., 2020). Awareness-raising campaigns are actively used as educational interventions in the combat against food waste in the UK as well. The "Love Food Hate Waste" Program (Waste and Resources Action Programme, 2024), launched and managed by the UK's Waste and Resources Action Program, focuses on evaluating leftovers, running consumer-focused campaigns, and offering tips to prevent food waste. This program is franchised globally (Soma et al., 2020).

Global and Regional Approaches to Food Waste and Food Security

The world is becoming more interconnected, and food systems are rapidly changing. This necessitates enhancing and expanding national and international collaborations, along with adopting a global approach to strengthening food systems. In this context, governments, food system stakeholders, and responsible authorities all have crucial roles to play (World Health Organization, 2022).

Approaches to food waste management can include developing measurement methods, offering discounts on products nearing their expiry dates, composting, and converting waste into bio-gas (Chirsanova & Calcatiniuc, 2021). It is suggested to measure and monitor food waste through food waste audits and waste analytics. One of the programs developed by The Waste and Resources Action Programme (WRAP) and The Institute of Grocery Distribution (IGD) in this context is the "Target, Measure, Act" Program (Waste and Resource Action Programme [WRAP], 2021). In this program, a target for food waste is set, the amount of waste is measured, and action is taken to reduce food waste (Cook et al., 2022b). Anticipating food scarcity leads consumers to buy, consume, and waste more than needed. Also, scales have been developed to measure the anticipated scarcity, and its use is considered potentially valuable for researching food waste and sustainability (Folwarczny et al., 2021). The need for monitoring food waste may vary based on institutional contexts. For instance, the healthcare industry is responsible for 5% of the global environmental footprint. Contributing factors include waste management practices, food spoilage, overproduction, food trimmings, meal quality, portion sizes, patients' lack of appetite, and medical interruptions (Cook et al., 2022a). Similarly, it is stated that food waste is higher in households with children than in households without children. This can be

attributed to children's changing food preferences and picky-eating behaviors. Additionally, parents' attempts to ensure their children have suitable meals can sometimes result in over-preparing food. Improving food waste management in households with children can be achieved through methods such as creating shopping lists, educating children in schools, and providing support to families. Policies designed to reduce food waste in households should be created and put into action (Tonini et al., 2023).

One contributing factor to household food waste is the confusion surrounding expiration date labels (Farr-Wharton et al., 2014). Expiration dates primarily indicate product quality and exceeding them does not necessarily pose a food safety risk. Consumers frequently throw away food that still looks edible once the expiration date has passed, mainly due to concerns about safety, freshness, and health. The waste generated by throwing away food as soon as its expiration date has passed needs to be investigated without compromising food safety rules (55). Food losses in the supply chain often occur due to non-compliance with quality standards. It is believed that implementing various pricing strategies to make these suboptimal foods more appealing to consumers could help reduce food waste. Suboptimal foods are deemed less desirable due to factors like appearance (e.g., shape, size), date labeling (e.g., nearing expiration), and packaging (e.g., dents) (15). It is proposed to update the legislation to encourage a more flexible consumer attitude toward food products that have exceeded their best-before dates. In this context, alternative labeling methods are being considered. For instance, implementing "Look-Smell-Taste" symbols on products and more actively involving consumers in assessing the nutritional quality of food are being considered such as illustrated in *Figure 4* (56). It is known that more than 50 million tons of food products in Europe become waste due to their inferior appearance (57). Providing information on how to avoid food waste has proven to be effective in preventing products near their expiration date from being discarded (58).

Figure 4. An illustration of the "Look-Smell-Taste" symbols on products for waste reduction

Conclusion

Food security ensures that all individuals have economic and physical access to nutritious, safe, and adequate amounts of food, enabling them to live a healthy and active life according to their

dietary requirements and preferences. Providing access to nutritious, safe, and adequate amounts of food involves the entire food system, including all factors affecting the system and the communities that benefit from it. In a globalized world, urbanization is on the rise, and the food system is rapidly evolving, affecting everything from farm to fork and altering individual eating behaviors. Understanding this change is crucial for developing solutions to the issues it presents and for keeping pace with the evolving dynamics of the food system.

Food insecurity goes beyond mere hunger. Even when individuals have access to food, poor dietary choices can result in malnutrition and contribute to food insecurity. On one side of the globe, people might make unhealthy food choices due to their habits and behaviors, while on the other side, individuals may face hunger and lack access to safe and nutritious food. Moreover, foods can be lost within food systems or end up as waste for various reasons. Advancing and standardizing food systems with technology, offering education on food waste management, raising awareness, and developing policies that support effective waste management are essential steps in reducing food loss and waste and improving food security. While efforts to drive change and raise awareness at the individual and household levels are crucial, actions must also be taken to foster change at the national and international levels. It is essential for governments and various authorities to actively engage in and support these initiatives. It is essential to create plans, policies and legislations, establish and sustain national and international alliances, and evaluate the effectiveness of these measures.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

All authors have made significant contributions to the conception and writing of the manuscript, and have reviewed and approved the final version.

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Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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