

AN OVERVIEW OF LATEST TRENDS IN REDUCING FOOD LOSSES AND WASTE MANAGEMENT

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Abstract: *Since the adoption of the SDGs (Sustainable Development Goals) in 2015, the balance between economic development and social and environmental sustainability has become a global priority. According to FAO, approximately a third of all food produced for human consumption is lost or wasted. The food waste and losses are generated mainly by the households and the food supply chain. Because of the different origin of waste and losses, a variety of strategies and methods have been suggested by scientists and experts. Reducing the waste and losses requires legislative measures, innovations, and behavioral changes on an individual and corporate level. This review centers on articles with the keywords “food losses” and “food waste” that have become most prominent in the past five years, highlighting how these sources emphasize the critical priority of reducing these issues.*

Keywords: *food waste, food losses, food sustainability, environment, waste management.*

INTRODUCTION

One of the major challenges humanity will face in the coming decades is how to sustainably meet the food needs of a growing population with limited resources, while also safeguarding the environment. It has been reported that sustainable development is "a kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development served as the guiding principle to heal the gap between the North and the South (Siegel, K., M., Bastos Lima, M., G., 2020).

The SDGs are significant because they establish widely agreed-upon standards. On the surface, the 10 Goals promotes a strong standard for reducing inequality both within and among nations. However, this aim is weakened and skewed by the targets and indicators, which are limited in scope and set an agenda for inclusion rather than truly addressing inequalities (Fukuda-Parr S., 2019). According to some authors tracking the progress of SDG implementation should rely on a comprehensive qualitative analysis centered on the overarching goals, rather than solely on the indicator framework (Fukuda-Parr, S., McNeill, D., 2019).

According to FAO approximately a third of all food produced for human consumption is lost or wasted, and these losses have been valued at 1 trillion USD (FAO, 2015). According to FAO's Summary report in 2013 “Without accounting for GHG (greenhouse gas) emissions from land use change, the carbon footprint of food produced and not eaten is estimated to 3.3 Gtonnes of CO₂ equivalent: as such, food wastage ranks as the third top emitter after USA and China.” (FAO, 2013).

Food waste happens at every stage of the supply chain, from farming to distribution, retail, and finally to consumers, and it is classified differently depending on where occurs.

“Food loss refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. In addition, natural disasters play a role.”

“Food waste refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil. Often this is because food has spoiled but it can be for other reasons such as oversupply due to markets, or individual consumer shopping/eating habits.” (FAO, 2013, Gustavsson, J. et al., 2011).

A key obstacle to reducing food loss and waste is the lack of data at both national and international levels. To address this gap, the FAO created the Food Loss Index, which estimates the amount of food lost during production and the supply chain before reaching retail. However, there is still limited information on how much food is wasted by consumers, including households and retailers (Eurostat, 2024).

According to Eurostat from data for year 2022, households generate more than half of the total food waste, about 54% in the EU or 72 kg per inhabitant (Eurostat, 2024).

This overview aims to examine recent trends in research and publications with impact factor over the past five years, starting from 2020, highlighting the trend in current priorities and efforts aimed at reducing food waste and losses.

Information collected form database

Table1 Number of publications by key word from January '20 until 30th of September '24.

Year	2020		2021		2022		2023		2024 until 30/09		Total for the period	
Key word	Food waste	Food loss	Food waste	Food loss	Food waste	Food loss	Food waste	Food loss	Food waste	Food loss	Food waste	Food loss
Database												
Scopus	5569	6936	6715	8122	7502	8583	8447	8992	7269	7558	35502	40191
Elsevier	25174	62791	30981	72498	35077	76767	36226	81501	40783	88936	168241	382493
MDPI	506	441	880	703	1086	826	1089	815	693	538	4254	3323

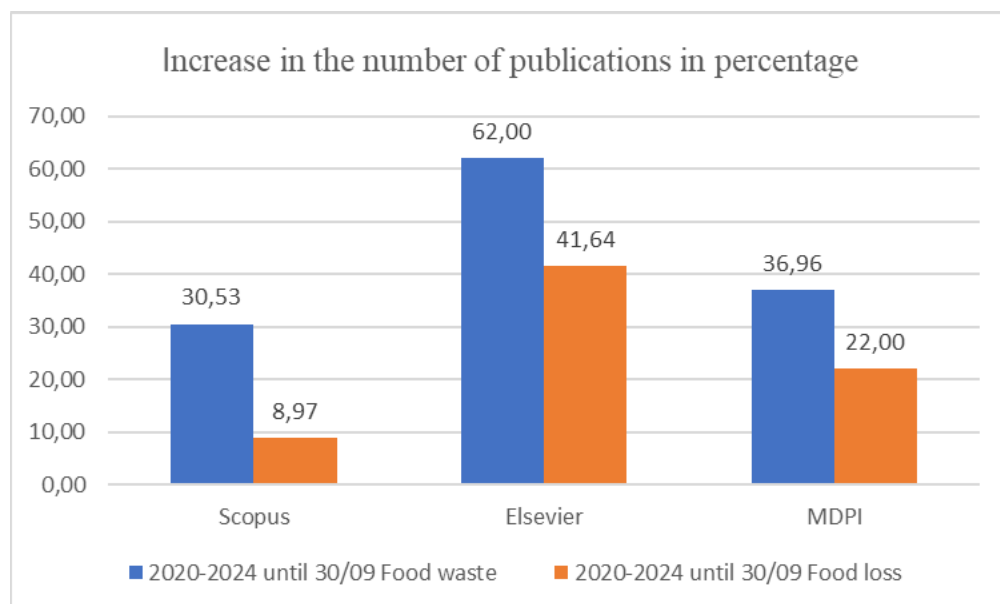


Fig. 1 Increase in the number of publications from January 2020 until 30th of September 2024 in percentage.

The summary data reveals a notable rise in publications on the topic, ranging from 9% to 62% since 2020. It's evident that “food waste” as a keyword shows greater growth compared to “food loss”. This surge in publication interest further highlights the importance of the issue, both in society and within the scientific community.

Publications with highest citation in scopus database

When examining citation data for statistics over the five-year period from the beginning of year 2020 to the end of September 2024, it's important to consider that older articles naturally tend to accumulate more citations. Therefore, articles from different years shouldn't be directly compared.

Instead, analyzing citation trends can reveal which topics have captured the most interest in the scientific field during this timeframe.

The publication on the subject with the highest citation for the period January 2020 until 30th September 2024 is published in the year 2020, found by key words “food waste” and has 2040 citations. It is a review article with open access with the title “Heavy metal pollution in the environment and their toxicological effects on humans”. This review examines how these pollutants enter the environment and their eventual impact. Some metals disrupt biological functions and growth, while others accumulate in various organs, leading to serious diseases such as cancer. Heavy metal pollution is an escalating issue of global concern due to its harmful effects on the environment. These inorganic pollutants are being released into our water, soil, and air as a result of the rapid expansion of agriculture, the metal industry, improper waste disposal, and the use of fertilizers and pesticides (Briffa, J. et al., 2020).

The second place by number of citations is with key words “food loss” with 1067 citations for the period. It is a review article with open access, published in 2021 with the title “Agriculture development, pesticide application, and its impact on the environment”. The review provides essential scientific information for future pesticide application and management. The significant growth in the global population during the 20th century would not have been possible without a corresponding increase in food production. Nearly one-third of agricultural output relies on the use of pesticides. Without them, there would be significant losses in the production of fruits, vegetables, and cereals. Pesticides are therefore crucial in controlling diseases and boosting crop yields worldwide. It is important to examine the agricultural development process, pesticide behavior, contamination, and negative environmental effects, as these chemicals can impact human health through environmental and food contamination (Tudi, M. et al., 2021).

In the year 2020, the article with the highest citations with key words “food loss” is an open-access article with 971 citations with the title “Remote sensing for agricultural applications: A meta-review”. The article is about how agriculture supplies essential resources such as food, fibers, fuel, and raw materials for human survival. Today, this role must be fulfilled within the constraints of environmental sustainability and climate change while also addressing the needs of a rapidly growing global population, all while ensuring the sustainability of agricultural activities for both subsistence and livelihoods. The authors outline the agronomic variables and plant traits that can be estimated through remote sensing, detailing both empirical and deterministic methods to retrieve this information. The second part of the review highlights recent research advancements that enhance the practical applications of remote sensing to meet the specific needs of different stakeholders. These agricultural applications include crop breeding, monitoring agricultural land use, forecasting crop yields, and supporting ecosystem services related to soil, water resources, and biodiversity conservation (Weiss, M. et al., 2020).

In 2021 the most significant article found by key words “food waste” is with 1230 citations for the period, published with the title “Food systems are responsible for a third of global anthropogenic GHG emissions”. This article, from the European Commission and the Statistics Division of the Food and Agriculture Organization of the United Nations, presents data from a newly developed global food emissions database (EDGAR-FOOD). This database estimates greenhouse gas (GHG) emissions, including CO₂, CH₄, N₂O, and fluorinated gases, for the period 1990–2015. It builds on the Emissions Database of Global Atmospheric Research (EDGAR) and incorporates land use and land-use change emissions from the FAOSTAT emissions database. EDGAR-FOOD provides comprehensive and consistent data over time and across regions on GHG emissions throughout the global food system, covering production, processing, transport, packaging, and consumption. It addresses the gap in detailed emissions data for many countries by offering sector-specific insights, crucial for developing effective mitigation strategies. In 2015, global food system emissions totaled 18 gigatons of CO₂ equivalent annually, accounting for 34% of total GHG emissions. The majority (71%) came from agriculture and land-use changes, with the remainder from supply chain activities like retail, transport, fuel production, waste management, and packaging. The article also discusses the temporal and regional trends of food system GHG emissions (Crippa, M. et al., 2021).

In 2022, the article found by key words “food loss” with the highest citations is an open access review article with 628 citations with the title “A review of the global climate change impacts, adaptation, and sustainable mitigation measures”. This study aims to conceptually analyze how climate variability is undermining the sustainability of various global sectors. The agricultural sector, in particular, faces heightened vulnerability as unpredictable weather patterns threaten food production and supply, posing a challenge to global food security, especially in countries where agriculture is central to the economy. Additionally, climate change endangers numerous species by altering optimal temperature ranges, accelerating biodiversity loss as ecosystems are transformed. This review evaluates climate change mitigation and adaptation strategies across sectors, as well as the associated economic costs. The findings emphasize the need for government involvement and strict accountability of resources to drive effective climate policies for long-term national development (Abbass, K. et al., 2022).

In the same year 2022, the article with key words “food waste” that shows the highest 1566 citations for the year is an open access article with the title “Discovery and quantification of plastic particle pollution in human blood”. The aim of this study was to develop a sensitive and reliable sampling and analytical method using double shot pyrolysis-gas chromatography/mass spectrometry and apply it to detect plastic particles ≥ 700 nm in the whole blood of 22 healthy volunteers. Four commonly used plastic polymers were identified and quantified in human blood for the first time. The most frequently detected were polyethylene terephthalate, polyethylene, and styrene-based polymers (including polystyrene, expanded polystyrene, and acrylonitrile butadiene styrene), followed by poly(methyl methacrylate). Although polypropylene was analyzed, its levels were below the quantification limits. Among this small group of donors, the average measurable concentration of plastic particles in blood was 1.6 $\mu\text{g/ml}$, marking the first assessment of plastic polymer mass concentration in human blood. This groundbreaking biomonitoring study confirmed that plastic particles are bioavailable and can enter the human bloodstream (Leslie, H.A. et al., 2022).

For the year 2023, the article with the highest citations found by key words “food loss” has 254 citations. It is an open access review article with the title “Climate change impacts on plant pathogens, food security, and paths forward”. This review explores how plant disease pressures are expected to shift under future climate conditions and how these changes might impact plant productivity in both natural and agricultural systems. It looks at the present and projected effects of climate change on pathogen distribution, disease occurrence, and severity, as well as their implications for ecosystems, agriculture, and food production. The authors suggest that revising the current conceptual framework and integrating eco-evolutionary theories into research could enhance our understanding and prediction of pathogen spread in future climates, helping to reduce the risk of future disease outbreaks. Additionally, they emphasize the importance of a strong science-policy partnership, working with relevant intergovernmental organizations to ensure effective monitoring and management of plant diseases under changing climate conditions, in order to secure long-term food security and ecosystem sustainability (Singh B.K. et al., 2023).

In the same year 2023, the highest cited article by key words “food waste” is with 216 citations. It is an open-access review article published with the title “Circular economy strategies for combating climate change and other environmental issues”. In this review, the authors examine circular economy strategies, particularly in relation to waste management, climate change, energy, air and water quality, land use, industry, food production, life cycle assessment, and cost-effective approaches. They found that expanding the use of bio-based materials presents challenges regarding land use and land cover. Overall, the authors offer a theoretical basis for building a sustainable future in industrial, agricultural, and commercial sectors by outlining cost-effective pathways toward a circular economy (Yang, M. et al., 2023).

For the last year 2024, the article with the highest citation until the 30th of September is found by key words “food loss” and has 84 citations. The title of the article is “Annealed peanut shell biochar as potential reinforcement for aloe vera fiber-epoxy biocomposite: mechanical, thermal conductivity, and dielectric properties” and the study examined the mechanical, thermal conductivity, and dielectric properties of epoxy resin composites reinforced with aloe vera fiber and toughened with peanut shell biochar. The primary objective is to investigate how incorporating graphitized biochar into the epoxy

resin, alongside aloe vera fiber, affects the load-bearing, thermal, and electrical conductivity characteristics (Balaji, N. et al., 2024).

For this year until the 30th of September the article with highest citations found by key words “food waste” is the same like the one found by key words “food loss” so the second one by significance has 80 citations and is titled “Advances in thermal energy storage: Fundamentals and applications”. Thermal energy storage (TES) is gaining importance due to the challenges posed by the fluctuating supply of renewable energy and the loss of waste heat to the environment. This paper covers the basic principles and innovative applications of TES materials, highlighting suitable materials for specific uses. It also provides a brief overview of current trends in TES applications across various sectors, including buildings, industry, power generation, food storage, smart textiles, thermal management, and desalination (Ali, H.M. et al., 2024).

Summery of trends reducing food losses and waste management

There has been growing interest in establishing food waste prevention and recovery programs throughout the world. The drive to target food waste and losses stems from increasing concerns about resource conservation, food security, food waste's environmental and economic costs, and a general trend in the waste management industry to transition to more sustainable practices. For better understanding of the drivers of food waste and their implications for sustainable policy development, the impacts of food system modernization on food waste generation have to be examined, including impacts related to food system industrialization, urbanization, globalization, and economic growth. Socio-demographic, cultural, political, and economic drivers of food waste have to be described with emphasis on how food waste perspectives may vary globally. Specific behaviors and attitudes which result from many of these waste drivers has to be discussed (Thyberg, K. L. et al., 2016).

When examining trends in food loss and waste, it's important to consider key factors that lead to differing views on the causes of food loss and waste, the strategies for addressing these issues, and the effectiveness of preventive and corrective actions.

Firstly, there is a lack of accurate data, despite having clear mechanisms for generating it at local, national, and global levels. Additionally, questions arise regarding the specific points along the globalization of the food market and the chain—from producer to processor, retailer or service provider, and consumer—where food loss or waste originates exactly by quntites.

And here is important to highlight one particularity: the foodservice industry is typically divided into two main sectors: the profit-driven or commercial sector and the cost-focused public or institutional sector. Both sectors are essential and expanding parts of most economies (Edwards, J. S., 2013).

It is also essential to consider the differing trends between highly economically developed countries and less developed ones. These variations are evident not only in the sources and types of food loss and waste but also in the effectiveness and relevance of prevention and control strategies, which are influenced by economic conditions.

A key reason for food waste at the consumer level in rich countries is that people can afford to discard food. In recent decades, the quantity of food available per person in retail stores and restaurants has risen in both the USA and the EU (Stuart, T., 2009).

On the same time in low-income countries, efforts should primarily focus on the producer perspective, such as enhancing harvesting techniques, farmer training, storage infrastructure, and cooling systems. In contrast, in industrialized nations, improvements at the producer and industrial levels would have limited impact if consumer food waste continues at its current rate (Gustavsson, J., et al. 2011).

Autors from Italy highlighted some of these particularities in their systematic review about strategies for reducing food losses and waste in 2021. According to them, the absence of a unified overview of food waste reduction strategies limits managers' ability to implement these strategies effectively and prevents researchers from pinpointing key obstacles. To address this, the authors reviewed 107 academic and grey literature sources, compiling a comprehensive list of strategies, with 180 strategies grouped into 30 distinct categories. They then mapped these strategies' impacts across all stages, uncovering a shortage of approaches targeting leftover and serving waste and noting that

83% are based solely on exploratory studies. Additionally, the review compared the popularity of these strategies in academic versus grey literature, revealing a misalignment, as only five of the top 10 recommendations overlap between the two sources (Vizzoto, F., Testa, F., Iraldo, F., 2021).

The summary of data collected by the ten articles represented in this review gives us the awareness that the most cited articles for each period are more review articles with open access. In terms of article content, it is evident that, despite the specified keywords, the articles do not directly address issues related to identifying food loss and waste or implementing strategies to mitigate these problems. Instead, the articles touch on topics indirectly related to this issue, such as various factors affecting agricultural production, the need for improved agricultural efficiency, and the environmental impact of pesticide use. Additionally, they discuss topics like greenhouse gas emissions from agriculture, the effects of soil and plastic pollutants, and their impact on human health.

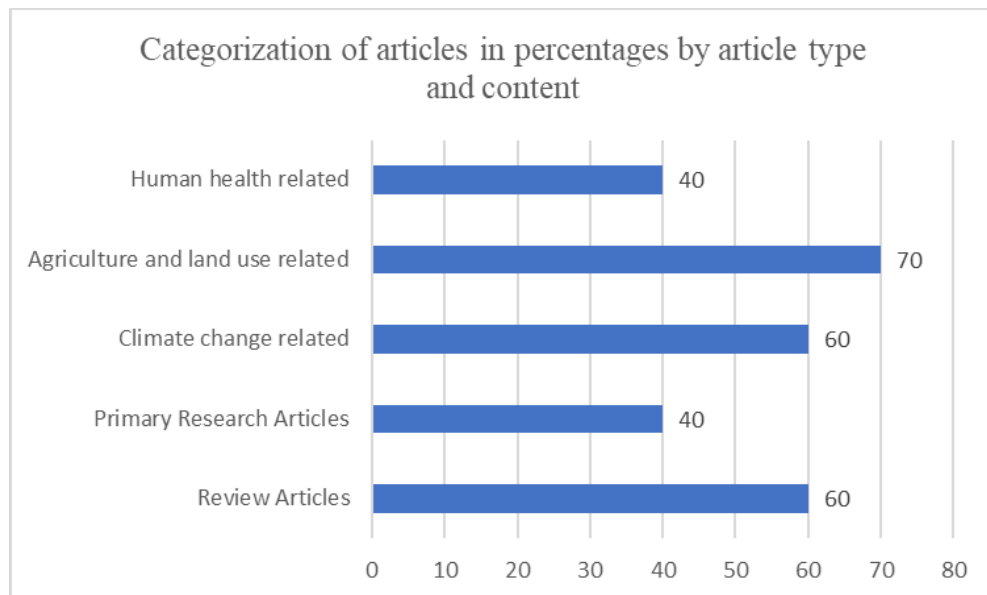


Fig. 2 Categorization of articles in percentages by article type and content

Figure 2 shows that review articles make up the majority at 60%. Articles focused on climate change and agriculture and land use also hold the largest portions, at 60% and 70% respectively, with the high percentages reflecting overlap in articles that cover both topics. Additionally, 40% of the articles discuss impacts on human health.

CONCLUSION

From the results of this analysis of trends in publications, we can conclude that addressing food loss and waste is increasingly viewed as crucial for achieving a balance between economic growth and environmental and social sustainability. Despite the emphasis on food waste reduction as a priority, the articles reviewed focus only indirectly on this issue. Instead, they largely address broader topics, including agricultural production efficiency, environmental impacts of pesticides, greenhouse gas emissions, and pollution, which are all relevant to sustainability in agriculture but not directly related to food waste reduction.

The growing interest in understanding the complex drivers of food waste globally—such as industrialization, urbanization, and economic growth—highlights the need for comprehensive approaches that account for cultural, socio-demographic, and economic differences. This suggests that effective food waste strategies will likely require tailored policies and programs that reflect these diverse influences. Overall, the analysis points to a need for more direct research into food waste and loss reduction strategies, alongside the more general sustainability topics currently emphasized.

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