

ALL SCIENCES ACADEMY



Proceeding Book of 3rd International Conference on Recent Academic Studies ICRAS 2024

December 03 - 04, 2024: Konya, Turkey



PROCEEDING BOOK OF
3RD INTERNATIONAL
CONFERENCE ON
RECENT ACADEMIC
STUDIES ICRAS 2024

PROCEEDING BOOK OF 3RD ICRAS 2024:

03-04 December 2024

Konya, Turkey

Publication date: 11.12.2024

Publisher: All Sciences Academy

Proceeding Book of 3rd International Conference on Recent Academic Studies ICRAS 2024

<https://as-proceeding.com/index.php/icras/home>

3rd International Conference on Recent Academic Studies ICRAS 2024: edited by All Sciences
Academy.

ISBN: 978-625-6314-79-5

As this is a serial book published, it has ISBN. All full papers were peer reviewed.

ISBN 978-625-6314-79-5

Printed in the Turkey with ISBN 978-625-6314-79-5

International Conference Website

<https://as-proceeding.com/index.php/icras/home>

INTRODUCTION

We had the great honor of organizing 3rd International Conference on Recent Academic Studies ICRAS 2024. It was truly a great pleasure for us to greet a lot of participants from many different countries attending ICRAS 2024! We firmly believe that the conference will become an important international event in the field of cross-industry discussion about innovations in Academic Studies.

Three cooperating organizations supported the two-day conference. There were 483 papers accepted for presentation at ICRAS 2024, contributed from different countries. We had plenary speeches and several well-known scientists and experts, to give invited talks at different sessions.

The purpose of ICRAS 2024 was to provide a forum for the participants to report and review innovative ideas, with up-to-date progress and developments, and discuss novel approaches to the application in the field of their own research areas and discuss challenges of doing science.

We sincerely hope that the exchange of ideas on doing research, science and improving education will help the participants, and international cooperation sharing the common interest will be enhanced.

On behalf the Organization Committee of ICRAS 2024, we would like to heartily thank our cooperating organizations for all they have done for the conference. We would also like to thank the authors for their contribution to the proceedings; the participants and friends of ICRAS 2024, for their interest and efforts in helping us to make the conference possible; and the Editorial boards for their effective work and valuable advice, especially the ICRAS 2024 secretariat and the ICRAS 2024 staff, for their tireless efforts and outstanding services in preparing the conference and publishing the Proceedings.

Publisher: All Sciences Academy

Food Waste as a Barrier to Achieving Sustainability

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Abstract – The mounting concern about food waste has become a pivotal topic in the global sustainability discourse. This exhaustive review commences with a straightforward elucidation of the term 'food waste,' subsequently transitioning into an analysis of its interdependence with sustainable practices and the detrimental repercussions it begets. Drawing from a thorough examination of global and regional datasets, the review exposes the prodigious extent of food wastage, establishing its roots in production, distribution, and consumption stages. Ecologically, the implications of food waste are profound, significantly contributing to increased greenhouse gas emissions, accentuating water and energy resource depletion, and posing impending threats to biodiversity. Socioeconomically, the consequences are diverse and extend beyond mere financial implications. Global food insecurity challenges are amplified, compounded by prevailing consumer misconceptions. Emphasis is placed on proactive waste management's discernible ecological and economic dividends. The review underscores a triad of resolutions in its concluding sections: technological advancements, holistic educational campaigns, and a pressing call for legislative overhauls. In its entirety, this review advocates for holistic strategies, asserting that the redressal of food waste transcends ethical considerations, solidifying its stance as an indispensable facet of sustainable global progress.

Keywords – Food Waste, Sustainable Development Goals (SDGs), Waste Reduction.

I. INTRODUCTION

In today's global landscape, food waste emerges not merely as an inefficiency within our food systems but as a profound challenge to sustainability [1]. Defined as the discarding of consumable food at any stage of the food supply chain, from production to household consumption, food waste is distinct from food loss, which pertains to food items rendered unsuitable for consumption due to harvesting, storage, or transportation issues [2]. The ramifications of such waste extend beyond the ethical concerns of squandered opportunities to address hunger [3]. The resources—be it water, land, energy, labor, or capital—deployed in producing wasted food are expended without return, representing both an economic inefficiency and an environmental strain [4]. Moreover, the methane produced from decomposing food in landfills, a potent greenhouse gas, underscores the ecological urgency of this issue [5]. Worldwide, food waste is on the rise. Fig 1 shows the scale of global food waste [6]. Thus, addressing food waste is integral to sustainability, emphasizing the need to judiciously utilize resources to fulfill the present needs without jeopardizing future generations. Food waste has emerged as a critical challenge within the global sustainability agenda, contributing significantly to environmental degradation and resource depletion. Approximately one-third of the food produced globally is wasted each year, and human environmental impact results in substantial carbon emissions and the depletion of water, energy, and biodiversity [7]–[12]. This pervasive issue not only heightens environmental pressures but also exacerbates socio-economic inequalities, particularly in the context of global food insecurity. The scale of food waste

highlights its profound impact on sustainability, positioning it as an urgent priority for international environmental and economic policies. The environmental implications of food waste are multifaceted and severe. Methane emissions from landfills, a byproduct of food decomposition, contribute significantly to climate change [13]. Additionally, inefficiencies across food production and supply chains accelerate greenhouse gas emissions, intensifying the carbon footprint associated with agriculture and distribution. Unsustainable effects linked to overproduction threaten ecosystems and biodiversity, undermining ecological balance and resilience [14,15]. The dual burden of resource depletion and environmental harm underscores the necessity of integrated solutions to address food waste effectively. Emerging technologies have demonstrated considerable potential in mitigating food waste and advancing sustainability goals. Microalgal cultivation, for instance, offers innovative pathways for repurposing food waste into biofuels and other valuable biomass products [16]. These technological advancements exemplify the role of innovation in bridging gaps between environmental, economic, and social priorities. The socio-economic dimensions of food waste are equally compelling. Inefficient food systems perpetuate disparities in resource distribution, amplifying food insecurity in vulnerable populations. Using bio-based structures in food storage can provide a sustainable solution for building applications [17]. Addressing these challenges requires a holistic framework that integrates sustainable technologies with educational campaigns to shift consumer behavior and legislative reforms to enforce waste reduction practices, and it is necessary to keep the stress of urbanization down [18,19]. When scaled appropriately, these localized efforts can inform broader initiatives to reduce food waste while conserving biodiversity. Furthermore, inspiration can be drawn from the principles of terraforming, which emphasize the transformative potential of algae and other ecological innovations in restoring environmental balance [20]. Such perspectives highlight the interconnectedness of terrestrial and extraterrestrial strategies in achieving sustainability. In conclusion, addressing food waste necessitates an integrative approach that combines technological innovation, educational initiatives, and robust policy frameworks. The multifaceted nature of food waste requires solutions that extend beyond immediate environmental concerns, encompassing socio-economic and cultural dimensions to ensure long-term sustainability. By leveraging advancements in environmental technologies and fostering regional and global cooperation, it is possible to mitigate the ecological footprint of food waste and contribute to a more sustainable future.



Fig 1. Scale of global food waste [6]

II. DIMENSIONS OF FOOD WASTE

The scale and implications of food waste are staggering, transcending geographical boundaries and permeating all facets of the food supply chain. To holistically grasp its magnitude and root causes, one must dissect its prevalence from global and local perspectives and understand the principal stages at which waste predominantly occurs.

Globally, approximately one-third of all food produced for human consumption, roughly 1.3 billion tons annually, is either lost or wasted [21]. This figure stands as a testament to the severity of the issue on an international scale. However, delving deeper into local contexts reveals a nuanced picture. Developed

countries typically experience significant waste at the retail and consumer levels, primarily due to a culture of abundance and strict aesthetic standards for produce [22]. Fig 2 shows food waste composition in some countries [23]. In contrast, developing nations grapple with food losses predominantly during post-harvest and processing phases, often attributed to infrastructural and technological constraints [24].

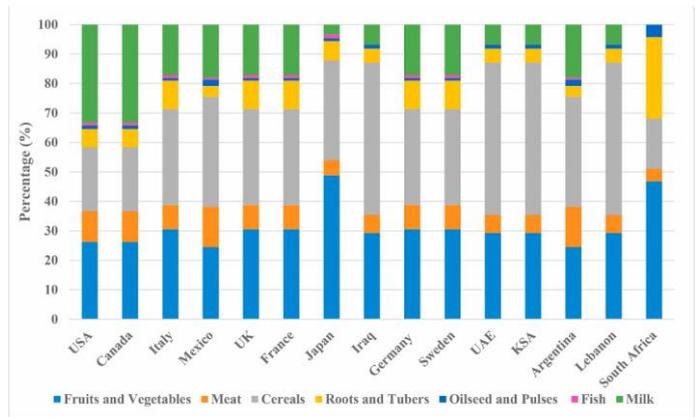


Fig 2. Food waste composition in some countries [23]

The production phase, the genesis of the food chain, witnesses waste due to factors like pest infestations, diseases, and unpredictable weather events [25]. The absence of efficient logistical networks and proper storage facilities during transportation can lead to spoilage [26]. Lastly, at the consumption stage, especially in urbanized societies, over-purchasing, lack of awareness, and the misconception of expiry dates contribute to substantial food discard [27]. The confluence of these factors across the food supply chain paints a comprehensive picture of the diverse dimensions of food waste.

III. ECOLOGICAL IMPACTS

Beyond its evident economic and social implications, food waste has profound ecological consequences that ripple through our environment. The wastage of food, often overlooked in broader environmental discourses, plays a pivotal role in exacerbating several pressing ecological crises [28]. These include significant contributions to greenhouse gas emissions, undue strain on freshwater and energy resources, and detrimental impacts on biodiversity [29]. Fig 3 indicates that food loss and waste have ramifications for the interconnected food-energy-water (FEW) nexus during food production and waste management [30].

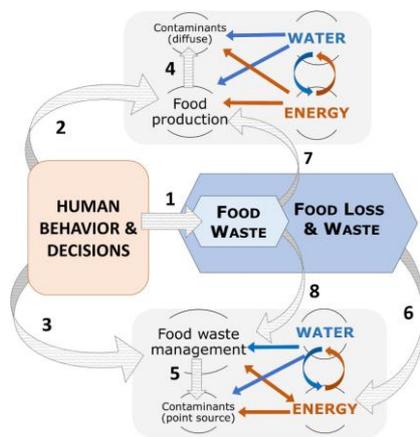


Fig 3. FEW nexus [30]

Furthermore, the connection between food waste and climate change is intricate and alarming. Wasted food contributes to methane emissions, a potent greenhouse gas, and signifies the misuse of resources that went into its production, such as energy and water [31]. This mismanagement amplifies the ecological footprint of food systems and indirectly fuels the cycle of climate change. Moreover, the cascading effects

of climate change can result in altered agricultural patterns and decreased yields, potentially amplifying food waste due to supply chain disruptions [32].

Human migrations occur due to climate change; migration patterns also intersect with food waste and its ecological consequences. As changing climates influence agricultural productivity and food availability, vulnerable communities might experience increased food scarcity and livelihood challenges [16,17]. This, in turn, can spur human migration as communities seek more stable environments. Thus, food waste contributes to a complex interplay of ecological factors that impact the environment and human societies.

Addressing food waste takes on renewed urgency in the face of these challenges. Effectively tackling this issue requires a multifaceted approach encompassing efficient resource management, responsible consumer behaviors, and broader shifts toward sustainable production and consumption.

The lifecycle of food, from its production to disposal, is associated with considerable carbon emissions [26]. For instance, decomposing organic matter in landfills produces methane, a greenhouse gas with a global warming potential many times greater than carbon dioxide [35]. Moreover, the energy expended in producing, processing, and transporting wasted food translates to avoidable carbon emissions [36]. When aggregated, the greenhouse gas emissions from global food waste are so substantial that if it were a country, it would rank third after China and the USA in total emissions [37].

A significant proportion of the world's freshwater resources is utilized in food production [38]. When food is wasted, the embedded water within it, which was used for irrigation, processing, and transportation, is also squandered [39]. This is especially concerning in regions grappling with water scarcity. Concurrently, energy consumption in food production, storage, and vehicles is substantial. Wasted food signifies lost caloric intake and vast wasted energy[40].

The agricultural expansion, driven partly by the need to compensate for food losses and waste, results in habitat destruction, deforestation, and land degradation. This, in turn, jeopardizes various species, leading to reduced biodiversity. Overfishing, a consequence of inefficient seafood supply chains, further threatens marine ecosystems. Consequently, food waste indirectly accentuates the loss of biodiversity, underscoring the interconnectedness of our food systems with the broader ecological balance [41].

IV. SOCIOECONOMIC IMPACTS

Food waste doesn't merely cast a shadow on ecological considerations; it's intrinsically linked with complex socioeconomic repercussions. These range from tangible economic burdens to subtle yet profound implications on hunger and food security, as well as shifts in social awareness and consumer behaviors.

The direct economic costs of food waste are staggering. Globally, the monetary value of food wastage stands at approximately \$1 trillion annually [42]. These costs encompass the face value of the wasted food and the cumulative expenses involved in production, processing, distribution, and disposal. Every uneaten morsel represents a cascade of wasted financial resources throughout the supply chain. Moreover, the burden only partially lies with producers or retailers; consumers also bear considerable costs in purchasing food that eventually remains uneaten.

While vast amounts of food are wasted, nearly 9% of the global population, or about 690 million people, need more nourishment [43]. This stark contrast highlights the misallocation and inefficiency within global food distribution systems. Reducing food waste could significantly alleviate hunger and malnutrition, especially in regions where food insecurity is rampant. The irony that food surpluses in some areas exist concurrently with needs in others underscores the urgency to re-evaluate and restructure our food distribution systems.

Social perceptions play a pivotal role in exacerbating or mitigating food waste. In many affluent societies, a culture of abundance and stringent aesthetic standards for produce contribute to substantial wastage. Misunderstandings about 'best before' and 'use by' dates also lead to premature discarding of food [44]. However, as awareness grows, there's a palpable shift in consumer behaviors. Grassroots movements,

educational campaigns, and sustainable consumption trends are emerging as powerful counter-forces, nudging consumers towards more informed, waste-conscious decisions.

V. SUSTAINABILITY AND FOOD WASTE

The concept of sustainability is inextricably linked to food waste. Addressing the latter is paramount to achieving broader sustainability objectives, particularly as food systems impact numerous environmental, economic, and social dimensions. This connection pivots to establishing sustainable food supply chains, understanding food waste within the context of global sustainable development goals, and recognizing the multifaceted benefits of waste reduction.

A sustainable food supply chain aims to optimize resource use and reduce waste while ensuring economic viability and social equity. This encompasses the entire lifecycle of food, from agricultural practices that prioritize soil health and water conservation to processing methods that maximize yield and minimize by-products to distribution systems that ensure food reaches those who need it, minimizing wastage. Implementing technologies such as cold storage in transport, utilizing circular economy principles, and promoting local food systems can enhance the sustainability of the food supply chain [45].

The United Nations Sustainable Development Goals (SDGs), particularly Goal 2 (Zero Hunger) and Goal 12 (Responsible Consumption and Production), are directly influenced by food waste. Fig 4 exhibits the United Nations sustainable development goals [46]. Inefficient food systems hinder progress toward ending hunger and promoting sustainable agriculture. Moreover, the unnecessary resource use and environmental degradation resulting from food waste counteract the objectives of other SDGs, including clean water and sanitation, affordable and clean energy, and climate action. Thus, mitigating food waste is not just a stand-alone objective but crucial for the broader vision of global sustainable development.



Fig 4. United Nations sustainable development goals [46]

Reducing food waste offers tangible and far-reaching benefits. Ecologically, this means reduced greenhouse gas emissions, conserved freshwater resources, and less strain on land and biodiversity. Economically, it implies savings for producers, retailers, and consumers and the potential redirection of resources to areas of need. Socially, waste reduction can alleviate food insecurity, create job opportunities in waste management and food redistribution, and foster a culture of value and respect for food and the labor behind it [47].

VI. RECOMMENDATIONS AND STRATEGIES

The multifaceted challenge of food waste, with its ecological and socioeconomic ramifications, necessitates an equally comprehensive response. Experiencing food waste and its implications reveal a significant global challenge with vast ecological and socioeconomic repercussions. The volume of food wasted at every stage, from production to consumption, signifies lost food and denotes broader environmental impacts—these range from increased greenhouse gas emissions to excessive water and energy consumption and potential threats to biodiversity. Furthermore, on the economic front, the effect of food waste is felt both in tangible costs and systemic inefficiencies, leading to disparities like increased hunger levels and skewed societal perceptions. The intertwined relationship between food waste and sustainability underscores inefficiencies in the global food system. These inefficiencies hinder progress

towards the Sustainable Development Goals but also present opportunities. Strategic interventions in the form of technological innovations can enhance the food supply chain, while educational initiatives can reshape societal understanding and actions. On the policy front, well-informed and collaborative frameworks can catalyze systemic change. In summary, addressing the challenge of food waste transcends mere resource conservation. It's a clarion call for understanding the complex interdependencies within our global food systems, valuing every resource, and collaboratively working towards a sustainable and equitable future. In an age of rapid technological evolution, leveraging these advancements can significantly reduce food waste. Innovations like innovative packaging, which can indicate the freshness of food, or apps that connect consumers with surplus food from restaurants have the potential to bridge the gap between excess and need. On the supply chain side, advancements in cold storage technology, real-time monitoring of food shipments, and precision agriculture can prevent spoilage and optimize production. Decentralized platforms, empowered by blockchain, can enhance transparency and efficiency in food distribution, ensuring that products reach their intended destinations in optimal conditions.

Awareness is a potent catalyst for change. Comprehensive educational campaigns targeting different societal segments can reshape food value and wastage perceptions. School curricula can integrate modules on sustainable food practices, fostering a future generation conscious of its consumption habits. Media campaigns, workshops, and collaborations with influencers can amplify the message for the broader public. Grassroots movements and community-driven initiatives can also play a pivotal role in transforming societal norms from the ground up. Government interventions and policy shifts are indispensable in the fight against food waste. Implementing policies that incentivize sustainable farming practices, discourage food wastage in the retail sector through tax breaks or subsidies, and promote the donation of surplus food can drive systemic change. Regulatory reforms also include more accurate and standardized food labeling, reducing confusion around expiration dates. Additionally, supporting research into food preservation, waste management, and sustainable agricultural practices can further underpin the transition to a waste-reduced food system.

VII. CONCLUSION

Our deep dive into food waste and its multifaceted implications makes it evident that the issue extends beyond mere food loss. It represents a complex interplay of environmental, economic, and social challenges. The consequences of wasted food touch upon pressing concerns like climate change, resource depletion, economic inefficiencies, and global hunger. This paints a picture of a global food system that, while abundant, struggles with sustainability and equitable distribution. Yet, within these challenges lie vast opportunities. Technological innovations, reimagined educational paradigms, and responsive policies can collectively steer us toward a more sustainable and just food system. To harness this potential, a collaborative and holistic approach is paramount. The urgency to act is apparent, and the benefits of doing so are manifold. As societies, industries, and policymakers, we hold the collective responsibility and power to transform food waste from a global challenge into a testament to human ingenuity and cooperation.

ACKNOWLEDGMENT

Authors thank Gaziantep University, Environmental Research Center (GÜÇAMER)

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