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Feeding the Future: Food Recovery and Redistribution as Solutions to Food Insecurity and Sustainability

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Authors' contributions

This work was carried out in collaboration among all authors. Author OCU conceptualized the study. Authors OCU, AAC, STA, IPA and OAA wrote, reviewed and edited the manuscript. All authors read and approved the final manuscript for publication.

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ABSTRACT

Food recovery and redistribution initiatives offer a promising solution to the dual challenges of food insecurity and environmental sustainability. These initiatives have demonstrated success in reducing food waste, decreasing carbon emissions, and addressing hunger, particularly through models in regions like Africa and Europe. However, gaps remain in evaluating the long-term socio-economic impacts of these programs, including their scalability and sustainability. Successful

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expansion requires greater collaboration with communities, investment in infrastructure, and integration with broader sustainability practices such as the circular economy and climate change mitigation. To fully realize the potential of food recovery, policymakers, businesses, and communities must make substantial financial commitments and enact stronger policies. By doing so, food redistribution can contribute significantly to the development of a more sustainable, equitable, and resilient global food system.

Keywords: Food insecurity; food recovery; food waste; sustainability; climate change.

ABBREVIATIONS

FAO – *Food and Agriculture Organization*
SDGs – *Sustainable Development Goals*
SFS – *Sustainable Food Systems*
SNAP – *Supplemental Nutrition Assistance Program*
TEFAP – *The Emergency Food Assistance Program*

1. INTRODUCTION

According to the Food and Agriculture Organization (FAO), food insecurity is a state of affairs whereby an individual or group of people are unable to gain reliable access to adequate amounts of readily available foods that are safe for human consumption. This is considered a concern estimated to affect more than 820 million people globally and therefore is a major concern in society. Several factors contribute to aggravating the current situation, all of which are interconnected. These include pollution of the environment and the intensification of the negative impacts of climate change, which is likely to affect food production cycles and therefore lead to scarcity [1,2]. The awareness towards sustainability in food systems has recently gained urgency because of questions raised on the environmental footprints they make and the resources they use. These concerns call for the shift towards sustainable food systems (SFS) that align with and enhance the achievement of, the Sustainable Development Goals (SDGs). This will mean not only the provision of food for all but the preservation of the natural environment as well.

The consequences of food insecurity extend well beyond the mere experience of hunger. They also encompass significant social and economic consequences. There is a correlation between food insecurity and elevated healthcare expenses, largely due to its connection with adverse health consequences such as malnourishment, chronic illnesses, and mental health problems. Furthermore, the phenomenon of food insecurity is associated with a reduction in labour force participation and productivity. This, in turn, presents long-term challenges to the development of the economy and the wider community [3,4]. For instance, individuals experiencing food insecurity frequently encounter difficulties in fully engaging with the workforce due to poor physical health and mental well-being. This impedes economic mobility and community growth. It can reasonably be proposed that one of the principal contributors to both food insecurity and environmental degradation is food waste.

Globally, over ten percent of households experience food insecurity, with considerable variation across geographical regions [5]. In the United States, the estimated quantity of edible food waste amounts to approximately 30% of all available food, equating to a yearly figure in excess of 66.5 million tons [5]. This substantial quantity of discarded food products highlights the inefficiencies within the food system. Despite the existence of edible foodstuffs, a considerable number of individuals are unable to access sufficient nutrition, while vulnerable demographic groups, such as children and elderly people, are disproportionately affected by food insecurity, which in turn contributes to existing health disparities in society [4]. The disposal of edible food is also a source of greenhouse gas emissions, as the decomposition of food releases methane, a potent greenhouse gas. In addition, the resources utilized in the production of discarded foodstuffs, such as water, energy and land, are similarly squandered, thereby accelerating ecosystem deterioration and undermining biodiversity [2,5].

Some of the governmental measures aimed at addressing the problem of food insecurity include the Supplemental Nutrition Assistance Program (SNAP) and The Emergency Food Assistance Programme (TEFAP). Although such programmes provide significant support for the needy, it raises a concern to question the efficiency of such measures as a solution for this

challenge due to the high food insecurity rates [5]. Notably, there are critical inefficiencies within the food distribution channel, especially high levels of food waste. Enhancing food recovery and redistribution initiatives to address hunger could be highly advantageous. This review aims to determine if the utilization of food recovery and redistribution models can effectively solve the problems of food insecurity and sustainability.

2. IMPACT OF FOOD WASTE ON ENVIRONMENTAL SUSTAINABILITY

Food wastage is of critical importance in the world and has significant impacts on economic, environmental sustainability and social cohesion. Every year, global food waste amounts to 1.3 billion tonnes of food, this is equivalent to 3.3 gigatonnes of CO_2, which is the sixth portion of anthropogenic greenhouse gases [6]. The above statistics demonstrate that wastage occurs at all levels of the supply chain inclusive of producers, retailers and consumers in the food chain. In particular, very high losses are identified in developed countries where consumer waste a major portion of which remains inedible food, and food retailers have a high stock loss because of unsold products (Bagherzadeh et al. 2014). This has further shown that the quantity of waste generated in agricultural processes is fairly high. This consists of predetermined yield losses in the crop and animal farming sectors due to factors, such as overproduction, spoilage, and harvesting or handling damages. Majority of the foods that reach the retailers' stores are mostly either penned down as waste or destroyed since they rarely sell because they have probably developed some physical aspect of appearance that may be unattractive due to stock over accumulation. At the consumer level, it was estimated that avoidable food waste amounted to 344 million tonnes per annum and this excluded the energy and water used to produce the food [7]. Food waste is one of the biggest problems in terms of environmental impact since it has such a massive carbon footprint. Globally, water resource wastage is a significant problem, averaging 82 billion cubic metres of water lost annually in food that is produced but never consumed [7].

There are probable economic effects related to food wastage and current research indicates that the cost of food waste in the global market is $2.6 trillion annually [8]. Economou et al. [9] highlight that the financial effects stem from the shortcomings throughout the food supply chain, including the devaluation of labour, inputs and transport used in food production. In South Korean households, the average amount of lost economic value per day due to food waste is 3,855 won. This significant loss shows the consequence of wasted food on individual families and communities [10]. Although food waste has severe environmental and economic consequences, awareness and proper waste management implementation could be the solution. This shows that measures like food recovery programmes, composting and efficient supply chain management can effectively offset the negative impacts of food wastage.

3. FOOD RECOVERY AND REDISTRIBUTION: GLOBAL MODELS AND IMPACT

Recovery and redistribution of food serve as primary methods of tackling food insecurity and food waste. Food recovery refers to the process of gathering food that could have been discarded, whereas, food redistribution is the process of distributing such food items to those who need them. These initiatives are backed up by several frameworks such as food banks, gleaning programmes, and food rescue organizations. These frameworks enable the effective redistribution of surplus food from all levels in the supply chain including the producers, retailers, and restaurants to food-insecure populations [11,12]. Food banks prove to be a central form of food redistribution. They operate as collection, sorting and distribution points of excess food to all the affiliated groups, which may include shelter homes and soup kitchens. Gleaning programs, on the other hand, pick crops that are left behind in the fields after the process of harvesting, while, food rescue organizations actively approach retailers and restaurants to intercept unsold foods.

3.1 Utilizing Surplus Food: Models and Success Stories

Macro initiatives like *Feeding America* and *FoodForward SA* show that it is feasible to collect surplus and undamaged food from manufacturers, retailers and farms and redistribute to millions of people experiencing hunger (Table 1). Some of these involve extensive collaborations and infrastructure to get food products to very large geographic areas. The usage of Smart applications like *FoodCloud* helps in optimizing the actualization of food

sharing by bringing together efficient helpers such as the intended beneficiaries, people and businesses who have unused foodstuffs with respective needy groups in communities. Such organizations as *Food Not Bombs Malaysia* show that surplus food can be redistributed locally without passing through central storage channels. Bilateral cooperation and regional structures like *Food Rescue ASEAN* and targeted programs, such as the *Lagos Food Bank Initiative* and the *Lazarus Food Project*, prove the possibility of the utilization of surplus food as an instrument to ensure food security among the underserved and rural communities. These diverse initiatives draw attention to the great potential that surplus food has in addressing the problems of food waste and hunger.

Table 1. Selected food recovery initiatives

Food Recovery Program	Country	Key Focus	Outcomes	Unique Features
Feeding America	United States	National food bank network that rescues surplus food from manufacturers, retailers, and farms.	Distributes over 4 billion meals annually; partners with 200 food banks and 60,000 food pantries.	Large-scale operation utilizing logistics and partnerships to deliver food to underserved communities.
FoodCloud	Ireland, UK	Connects supermarkets and businesses with surplus food to charities through an online platform.	Saved 85 million meals from waste; partnered with major grocery chains like Tesco.	Centralized digital platform for businesses and charities to coordinate food donations.
Food Not Bombs Malaysia	Malaysia	Volunteer-run group redistributing leftover food from local markets and restaurants to homeless populations.	Provides hundreds of meals weekly to the homeless and low-income individuals.	Grassroots, community-led initiative emphasizing direct food distribution to vulnerable groups.
Food Rescue ASEAN	Southeast Asia (Thailand, Malaysia, Singapore)	Regional initiative to rescue food from retail, hotels, and food outlets, redistributing to charities and low-income communities.	Rescued over 500,000 meals in its first year, focusing on urban areas.	Focuses on collaboration with retail chains and hotels in Southeast Asia, providing tax incentives for participants.
FoodForward SA	South Africa	Large-scale food recovery network working with retailers, manufacturers, and farmers to redistribute food to over 1,000 organizations.	Redistributes over 30 million meals annually across South Africa.	Efficient, large-scale recovery system with an emphasis on connecting the entire supply chain for surplus food collection.
Lagos Food Bank Initiative	Nigeria	Recovers surplus food from food businesses and individuals to distribute to vulnerable groups, focusing on nutrition.	Reached over 1 million beneficiaries across Nigeria, particularly women and children.	Targets vulnerable populations with a focus on nutrition education and empowerment through food recovery efforts.
Lazarus Food Project	Kenya	Collects surplus food from farms, markets, and businesses, redistributing it to schools and orphanages.	Provides over 200,000 meals annually to underserved children in rural areas.	Focuses on rural food insecurity by distributing surplus food directly to schools and orphanages.

3.2 Key Stakeholders in Food Recovery

Food recovery and redistribution is reliant on multi-stakeholder support to achieve the desired outcomes. The involvement of the government in food recovery and redistribution is confined to offering legal requirements and subsidies. Non-profit organizations are accountable for the management of operational aspects of food recovery programs, while retailers and producers donate surplus food. In addition, volunteers assume significant responsibilities in the delivery of food items in regions that require assistance. Evidence originating from Europe has pointed out the importance of inter-sector collaboration whereby public, private and non-profit organizations have played a crucial role in identifying new and effective ways of implementing food waste recovery [12]. These collaborations are necessary to ensure the delivery of excess food items to needy households across the world, especially the food-insecure areas. For instance, selected governmental authorities and organizations involved in food recovery can engage in developing programs that are suitable for streamlining logistical processes and compliance with legal requirements.

4. IMPACT OF FOOD RECOVERY ON SUSTAINABILITY

This study has found that food recovery and redistribution have significant social relevance as they reduce food insecurity and hunger among the most vulnerable communities (Fig. 1). The schemes feed the hungry by intercepting food items that would have been decomposed, thereby enhancing social equity [12]. Food banks and charitable organizations benefit from food redistribution and contribute towards the eradication of poverty and narrowing down inequality. They also create advocacy mechanisms addressing social causes and encouraging people and companies to jointly solve hunger problems [13]. Furthermore, they drive means of civil unity among the affected communities by distributing surplus means of food, and establishing connections between food donors, volunteers, and recipients, which serves to enhance community resilience in times of crisis. By applying food recovery initiatives, social justice and solidarity are promoted alongside immediate hunger relief.

The benefits of food recovery and redistribution in an environmental context are numerous. They help minimize the level of wastage of food products which remain one of the biggest sources of pollution. It can also be a positive contribution to minimizing methane production, a dangerous greenhouse gas released from decomposing organic matter from landfills [14]. The reduction of food waste saves resources used in the food production process such as water, energy, and land, thus lowering the effects of the food supply chain on the environment [15]. Additionally, food recovery helps in mitigating the negative influences of waste management systems, by reducing the amount of waste that has to be processed into resources. These efforts serve sustainability purposes in addition to addressing food waste, which mitigates climate change and the preservation of natural resources.

To businesses that participate in food recovery, there may be cost savings since they would spend less on waste disposal and the potential receipt of tax incentives due to the donation of surplus food [16]. In addition, these programmes facilitate the efficient redirection of surplus food hence minimizing structural costs of overproduction and unsold stocks. From a broader perspective, the redirection of food that could otherwise go to waste fills other roles in easing the economic burden on social services, offering food support for low-income households. This in turn has the effect of decreased healthcare costs due to food insecurity [17]. As a result, food recovery and redistribution can be a value proposition solution that will solve both the problem of food waste and contribute to social welfare.

4.1 Barriers to Implementing Food Recovery

Food recovery programs are plagued by significant operational challenges in coordinating the pickup and transfer of recovered food products, as well as the storage and logistics of those surplus items (Table 2). Such programmes often face some fluctuations in food donations, with the perishable nature of fresh products making it more challenging. The geographical distances that exist between the donors for instance the rural farm producers and the recipients based in urban areas complicate the efficiency of the recovery of foodstuff [18, 19]. The lack of proper facilities especially as it relates to refrigeration and transport forms a major setback for organizations interested in the recovery and distribution of food [20].

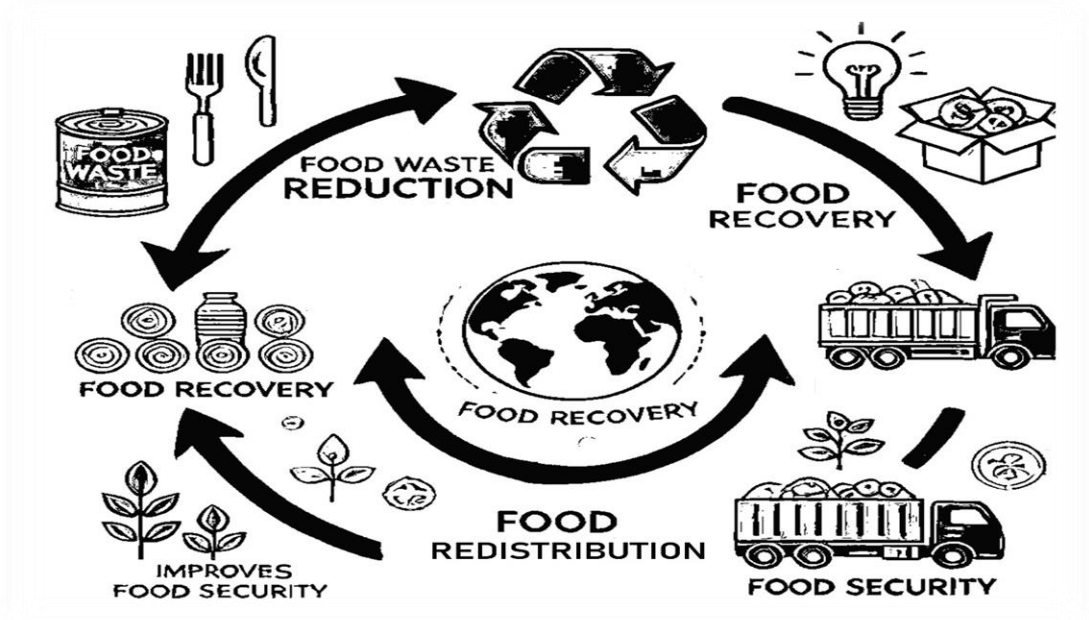

Fig. 1. Impact of food recovery and redistribution on food security and sustainability
Source: Okoye et al., 2024

Table 2. Barriers to implementing food recovery

Barriers to Food Recovery	Recommendations
Legal and Regulatory Hurdles	Simplifying food donation laws and offering tax incentives to encourage recovery efforts.
Logistical Challenges (Storage & Transport)	Implementing innovative solutions like digital platforms to streamline donation logistics and improve cold storage facilities
Food Safety Concerns	Developing clearer food safety protocols for handling and distributing surplus food, along with training for staff and volunteers
Public Perception & Stigma	Educating the public on the value of recovered food to reduce stigma, emphasizing its quality and safety
Funding and Resource Limitations	Engaging private companies in funding food recovery initiatives or contributing surplus resources
Inconsistent Food Donations	Implementing consistent food collection programs with retailers, restaurants, and manufacturers to ensure regularity of surplus food availability

Major challenges to engaging in food recovery activities involve the existing and strict regulatory measures on food safety especially in handling perishable and prepared foods. However, due to legal concerns including the far-reaching liability protections of the Bill Emerson Good Samaritan Act, small businesses continue to express concerns regarding potential liability. Compliance with the health code standard always requires a fairly significant investment in equipment and the laying of infrastructure, a financial burden which many recovery organizations cannot afford. This leads to hesitance among donors, which in extension, means reduced availability of surplus food for recovery [21].

Financial limitations represent a significant challenge for food recovery programmes. While surplus food is frequently donated free of charge, the costs associated with its collection, processing, and redistribution are considerable. A significant number of food recovery programmes are dependent on donations and grants, yet the lack of consistent funding hinders their capacity to expand their operations. Furthermore, excessive reliance on volunteers gives rise to challenges in management and sustainability, which in turn impede long-term planning and expansion efforts [19].

4.2 Future Directions and Opportunities

One major gap is the limited documentation of comprehensive evaluations of the socio-economic impacts of food redistribution programmes on local communities. As identified by Casson et al. [22], it is therefore necessary to assess the broader benefits of sustainability initiatives such as employment generation for community resilience and economic growth. Further studies are also needed to investigate the impact of sustainable food recovery on climate change and the effective use of resources [23]. The upscaling of food recovery programs is essential in extending the gains of the program to larger populations. Effective programs, as seen in figures from Africa and Europe, show that adequate partnerships, infrastructural provisions, and proper logistics networks are central to improving access to healthy foods in underserved regions. The minimization of waste facilitates a notable reduction in the environmental footprint of the food supply chain and helps to improve sustainability and food system resilience [24,25,26,27]. It becomes very clear that food recovery can only reach its maximum potential when it integrates the overall sustainability goals. Integrating the principles of the circular economy, which focuses on the recycling of resources and the utilization of materials, may help build an improved food system that operates within a closed loop. Linking food recovery measures with the climate change adaptation approach in reducing the emission of greenhouse gasses and conserving resources would improve the efficiency of attaining the created goals, and contribute to the United Nations' sustainable development goals including SDG 12 on Responsible Consumption and Production and SDG 13 on Climate Action [23,28].

5. CONCLUSION

The issues of food insecurity and the question of how food security can be sustained in the context of a future global environment that may be more resource-stable are closely linked. This study proposes that food recovery and redistribution represent a potential solution to this complex issue. These efficiency-oriented initiatives ensure the prevention of food waste by redirecting surplus food to those in need, thereby addressing the issue of hunger. Additionally, they have a beneficial impact on the mitigation of food waste-related consequences, including the reduction of greenhouse gas emissions and the conservation of natural resources. Despite the aforementioned successful models, several issues such as legal constraints, and a lack of unified information on residual effects remain unresolved. To enhance the viability and impact of the concept, food recovery should be extended to other communities and integrated with other related concepts, such as the circular economy and climate change. For food recovery to reach its optimal level of efficiency, support from governments, corporations and other communities is required in the form of the creation of supportive environments, investments in appropriate vehicles, and advancements in the utilization of technology. If undertaken on an integrated and larger scale, food recovery and redistribution have the potential to become strategic players in a sustainable global food system, significantly reducing food waste and hunger. The capacity for food systems to become sustainable and fair in the future may well be realized through the recovery of food.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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