# THE EFFECTS OF FOOD WASTE ON FOOD SECURE

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**Abstract**

Food waste is a growing global concern with far-reaching implications for food security, public health, and environmental sustainability. It is estimated that nearly one-third of all food produced worldwide is lost or wasted, amounting to approximately 1.3 billion tons annually. This loss not only exacerbates food insecurity but also contributes to significant environmental damage through the emission of greenhouse gases, resource depletion, and the strain on waste management systems. The European Union (EU) has taken active steps to address this issue by setting ambitious goals to reduce food waste by 50% by 2030, in alignment with the United Nations' Sustainable Development Goals (SDGs). Policies such as the EU Waste Framework Directive and the Farm to Fork Strategy are designed to integrate sustainability into the entire food supply chain, from production to consumption. This paper reviews these initiatives, along with the broader implications of food waste reduction on food safety, greenhouse gas emissions, and biodiversity conservation. Furthermore, it explores the role of technological innovation, legislative measures, and consumer education in driving meaningful reductions in food waste across the EU. By adopting a circular economy approach, the EU seeks to create a more resilient and sustainable food system for future generations.

**Keywords:** Food waste, food security, food safety, sustainability, European Union, circular economy, greenhouse gas emissions

## 1. Introduction

Food waste represents one of the most critical challenges facing global food systems today. It has far-reaching consequences that impact food security, environmental sustainability, and economic stability. According to the Food and Agriculture Organization (FAO), approximately 1.3 billion tons of food—equivalent to one-third of all food produced globally—is either lost or wasted each year [7]. These losses occur at various stages along the food supply chain, from production and transportation to processing and consumption [8]. Such extensive waste not only increases food insecurity but also aggravates global hunger, a pressing issue considering that 828 million people worldwide suffer from hunger and malnutrition [8].

In the European Union (EU), the scale of food waste is equally alarming. Each year, about 59

million tons of food are wasted within EU borders, amounting to 131 kg of waste per person [6]. This widespread wastage poses a significant threat to achieving food security and resource sustainability across Europe. The environmental impact is profound, with food waste contributing to an estimated 8-10% of global greenhouse gas emissions [9]. Food waste exacerbates resource depletion, as significant amounts of water, energy, and labor are consumed to produce food that ultimately goes uneaten [9]. This creates additional pressure on agricultural systems already struggling with challenges like climate change, soil degradation, and biodiversity loss [9].

From an economic perspective, food waste translates into substantial financial losses. The FAO estimates that the global economic cost of food waste exceeds $1 trillion per year [7], which includes losses in farm revenue, the cost of waste disposal, and the depletion of natural resources. In the EU, food waste has become a growing area of concern, particularly within the context of the European Green Deal and the push for a circular economy that seeks to minimize waste and make efficient use of resources [3].

The European Union has taken a leadership role in addressing the issue of food waste through legislative measures and policy frameworks aimed at curbing losses across the food supply chain. One of the cornerstone initiatives is the Farm to Fork Strategy, which is part of the broader European Green Deal [4].

This strategy aims to make Europe's food system more sustainable, ensuring that food production, distribution, and consumption contribute to a healthier planet. The strategy also aligns with the United Nations Sustainable Development Goal (SDG) 12.3, which calls for a 50% reduction in food waste at retail and consumer levels by 2030 [4]. In addition to the Farm to Fork Strategy, the EU Waste Framework Directive [5] plays a crucial role in driving Member States to implement prevention measures, promote food donations, and enhance the monitoring of food waste data across the continent.

The introduction of national regulations, such as Romania's Law no. 217/2016 on food waste reduction [1], further exemplifies the increasing emphasis placed on minimizing losses within the food sector.

However, despite significant legislative efforts, disparities remain in the effectiveness and enforcement of food waste policies across EU Member States. Consequently, the need for technological innovation, improved consumer education, and better coordination among countries is becoming increasingly evident.

In this context, addressing food waste is not just an environmental necessity but a socio-economic imperative. By reducing food waste, the EU can alleviate pressures on natural resources, improve food security for vulnerable populations, and contribute to the broader fight against climate change (9).

## 2. Methods

This study employs a multi-faceted approach to analyze the causes, implications, and solutions related to food waste within the European Union (EU). A combination of qualitative and quantitative methods was used, drawing upon a range of primary and secondary data sources, including policy documents, statistical reports, case studies, and academic literature. The research is structured around the following key components:

### *1. Data collection and sources*

Primary data was collected from EU institutions such as the European Commission (EC), Eurostat, and relevant governmental agencies within EU Member States. Legislative documents like the EU Waste Framework Directive [5], the Farm to Fork Strategy [4], and individual national policies such as Romania's Law no. 217/2016 on food waste reduction [1] were analyzed to understand the regulatory landscape across the EU. Furthermore, data on food waste levels across various stages of the supply chain—production, retail, and consumption—were gathered from sources like Eurostat [6] and FAO [7]. This included food waste data from 2010 to 2023, focusing on waste generated at household, retail, and production levels across different EU countries.

Secondary sources include research papers, academic journals, and reports from international organizations such as the Food and Agriculture Organization (FAO) (7) and the Intergovernmental Panel on Climate Change (IPCC) [9]. These sources provided insights into the environmental and economic impacts of food waste, as well as best practices for mitigation. In addition, literature on consumer behavior, food labeling, and technological innovations in waste reduction was reviewed to support the analysis.

### *2. Legislative and policy analysis*

A critical component of the methodology involved analyzing the legal frameworks and policy initiatives designed to combat food waste across the EU. The study reviewed EU-level directives and regulations such as:

- ✓ **EU Waste Framework Directive (2008/98/EC):** This directive sets out waste prevention measures, including the promotion of recycling and reuse, and requires Member States to implement national strategies to reduce food waste [5].
- ✓ **Farm to Fork Strategy (2020):** This comprehensive strategy aims to make food systems more sustainable by reducing food waste and enhancing food security across the EU [4]. It includes specific targets for reducing waste at the retail and consumer levels by 50% by 2030.
- ✓ **Circular Economy Action Plan (2020):** A key part of the European Green Deal, this plan addresses food waste reduction by promoting resource efficiency and sustainability in food production and consumption [3].

In addition to EU-wide initiatives, national policies from Member States were also evaluated. For example, the study examined France's Law Against Food Waste (2016), which mandates supermarkets to donate unsold food, and Italy's Law 166/2016, which encourages food donation and penalizes food waste in retail sectors.

### *3. Case Studies and Comparative Analysis*

To assess the effectiveness of food waste reduction policies, case studies from various EU countries were conducted. These case studies focused on:

- ✓ **France:** Known for its comprehensive approach to food waste reduction, France's policies were examined to determine the impact of its legislation on supermarkets and consumers. The country's success in cutting food waste by 30% in some sectors serves as a benchmark for other EU states.
- ✓ **Italy:** Italy's laws promoting food donation and tax incentives for businesses that donate surplus food were analyzed. Italy's approach was compared with countries where food waste policies are less developed.
- ✓ **Germany and Sweden:** These countries were selected for their advanced consumer education programs and the use of technology to reduce food waste at the household level. Germany's use of digital tools to monitor expiration dates and Sweden's public campaigns on the importance of food labeling served as key examples.

### *4. Technological Innovations*

Technological advancements play a crucial role in reducing food waste across the supply chain. The study reviewed the following technologies:

- ✓ **Supply chain management tools:** Digital solutions, such as the "First In, First Out" (FIFO) systems, have been implemented by retailers to ensure that older food products are sold first, reducing the risk of waste. The study evaluated the effectiveness of these systems in major supermarket chains across the EU.
- ✓ **Food Monitoring and Forecasting Software:** Retailers and food manufacturers increasingly use AI-driven platforms to predict consumer demand and adjust inventory levels accordingly. The study assessed how these tools help minimize food overproduction and excess stock.
- ✓ **Mobile Apps for Food Redistribution:** The study examined platforms such as "Too Good To Go" and "Olio," which connect consumers with businesses offering discounted or surplus food nearing its expiration date. The adoption and effectiveness of these apps in reducing consumer-level food waste in the EU were analyzed.

### *5. Quantitative Data Analysis*

Quantitative analysis was used to examine food waste data, both at the EU level and across individual Member States. Statistical tools were employed to evaluate trends in food waste generation between 2010 and 2023, with a particular focus on waste reduction rates post-implementation of key policies such as the EU Waste Framework Directive [5] and the Farm to Fork Strategy [4].

The study also assessed the correlation between national legislation and food waste reduction outcomes. For instance, countries with strict food donation laws were compared to those with less stringent policies, with data showing variations in food waste reduction percentages.

### *6. Economic and environmental impact assessment*

A key objective of this study was to assess the broader economic and environmental impacts of food waste reduction measures. The analysis focused on:

- ✓ **Economic Costs:** Using FAO’s estimates [7], the study quantified the economic losses from food waste across the EU, including costs related to wasted food production, distribution, and disposal. The study also evaluated the potential economic benefits of

reducing food waste, such as lower waste management costs and savings for households.

- ✓ **Environmental Impact:** The environmental impact of food waste was evaluated based on greenhouse gas emissions, water usage, and resource depletion. Data from the IPCC [9] and Eurostat [6] were used to estimate the reductions in CO2 emissions that could be achieved through successful implementation of food waste policies across the EU.

## 3. Results and discussion

The BRC standard is one of the most complex because it covers a large part of the food safety field, starting from production and ending with the final product that reaches the market and finally the final consumer [2].

This standard, in addition to the legislative part, emphasizes the HACCP part and good hygiene practices. Implementing these standards aims to provide clients and consumers with confidence in food products. Before being applied, each standard is developed by the commission and the members of the BRC and periodically reviewed at three-year intervals to be consistent with the changes that occur periodically at the legislative level.

The IFS standard is recognized by GFIS and focuses specifically on the safety and quality of food, taking into account first of all the technological process of obtaining and the type of products offered by food operators or manufacturers. This standard is applied in food processing units and in units where processed goods are packaged.

The European Union (EU) aims to ensure the hygiene of food products at all stages of the production process, from farms to processing plants, to retailers, and to the final consumer. Article 4 of Regulation (EC) no. 852/2004 requires food sector operators (OSA) to comply with the general sanitary requirements set out in detail in Annex I in the case of primary production and related activities, as well as in Annex II in the case of other stages of the food production chain [5].

They are supplemented by specific hygiene rules that apply to food of animal origin, provided for in Regulation (EC) no. 853/2004 [5], Article 5 of Regulation (EC) no. 852/2004 requires operators in the food sector to develop, apply, and permanently use one or more procedures based on HACCP principles [5].

The principles of HACCP are generally considered and internationally recognized as a useful self-control system used by food business operators to control risks that may arise with respect to food.

Stakeholders pointed out that in practice there is often a gap between BPI and CCP in addressing intermediate risks and certain significant risks and concepts such as attention points, control points, etc. were introduced. Codex and ISO 22000 have taken two different approaches to managing these risks:

- ✓ The "General Principles of Food Hygiene" stipulated in Codex Alimentarius, CXC 1-1969, refer to "BPI requiring increased attention" to address identified significant risks. Thus, for some BPIs, based on food safety concerns, providing safe food may require "extra care". Increased attention may include greater frequency of enforcement, monitoring, and verification.
- ✓ ISO 22000 was introduced into pre-operational programs (PRPOs) in 2005 to fill this gap. They are control measures that are put in place to prevent a significant risk to food safety or to reduce it to an acceptable level. Measures are identified during the risk analysis as important to control certain significant risks.

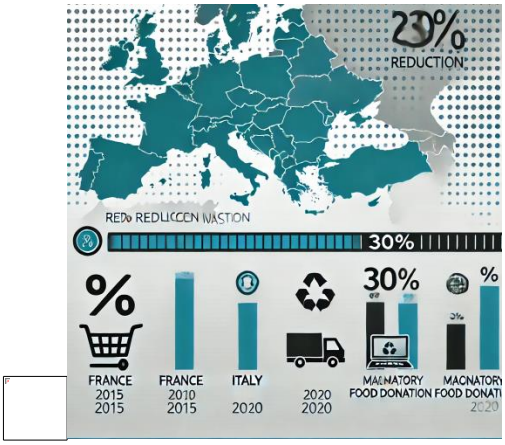
Typical examples of BPI and/or PRPO include:

- ✓ Cleaning of equipment and surfaces that come into contact with ready-to-eat food – these should be given more attention than other surfaces, such as cleaning walls and ceilings because if food contact surfaces are not properly cleaned, this could lead to direct contamination of food with *Listeria monocytogenes*.
- ✓ More intensive cleaning and disinfection and more rigorous personal hygiene (e.g., mouth protection masks and additional staff protection) in high-risk areas, for example in ready-to-eat packaging areas.
- ✓ Checking the packaging of food cans from the point of view of cleanliness and defects.
- ✓ A more rigorous check on arrival when receiving raw materials, if the supplier does not guarantee the desired quality/safety level (for example, mycotoxins in spices).
- ✓ Effective intermediate cleaning to control cross-contamination between production batches containing various allergens (nuts, soy, milk, etc.). The severity of the health effect is high and the risk of deviation (presence through cross-contamination) could be substantial, but real-time monitoring is impossible.
- ✓ Considering the bacteriological quality of irrigation water as control points might be appropriate, especially for ready-to-eat crops.

- ✓ Control of the vegetable washing process (for example, the frequency of washing water renewal to avoid microbial cross-contamination, mechanical action in the water to remove physical hazards such as stones or pieces of wood).
- ✓ Control of the bleaching process for quick-frozen products (time/temperature); washing and bleaching processes may generally not be considered CCP because neither complete elimination nor reduction to an acceptable level of significant microbiological risks can be achieved or aimed at; however, they will influence the microbial load of processed products and, when associated with other control measures, will help to eliminate significant risks or reduce them to an acceptable level [10].

In the EU, risk analysis plays a fundamental role, being considered essential to identify different levels of risks, for example, whether BPIs are sufficient or whether intermediate risks and/or risks of significant hazards need to be addressed through PRPOs and/or respectively the PCC. As BPI requiring increased attention are not necessarily identified by the risk analysis in the Codex General Principles of Food Hygiene, but PRPO is listed in ISO 22000, reference is made to PRPO in this document (Figure 1).

**Figure 1. Food waste reduction across european countries (2015-2020): impact of policy and innovation**




Due to the lack of coordination between Codex and ISO 22000, it was necessary, in the context of the guidance provided in this document, to make this choice to avoid confusion on the part of operators between the two different approaches or due to unnecessary separation of two types of similar risks. However, the guidelines set out in this document are considered by both international

standards, which can additionally be used as source material for the implementation of the SMSA. Codex Alimentarius is recognized as the official reference in the context of world trade [8].

Before applying HACCP-based procedures to any establishment, the food business operator must have implemented PRP, including BPI and the other measures provided for in Regulation (EC) no. 178/2002 [5]. These are the prevention and preparedness pillars of each SMSA and are necessary to develop HACCP-based procedures, representing a systematic control by the OSA of significant, specific risks that are not sufficiently controlled by the PRP alone.

A two-step approach (PRP/CCP) is the minimum legal requirement, but it may be recommended to use the three-step approach to identify PRP, PRPO, and CCP. Many businesses could apply a two-step approach, while the three-step approach may be more suitable for larger and more complex enterprises.

National and EU guidelines provide useful advice on how to implement GMP and HACCP-based procedures. They can be integrated but do not replace OSA-specific risk analysis.

Several European sector-level stakeholder organizations have developed EU guidelines for good hygiene practices.

The list of these guidelines can be consulted at: EU Food Hygiene Guidance Platform. In some cases, the European Commission itself has provided sector-specific guidance, particularly where OSAs are often small businesses:

- ✓ Commission Communication establishing guidelines on food safety management systems for food retailing activities, including food donation ("Commission Communication on Retailing Activities").
- ✓ Communication from the Commission regarding the orientation document regarding the approach at the level of primary production to the microbiological risks presented by fresh fruits and vegetables through the application of hygiene rules.

On the other hand, Hazard Analysis and Critical Control Points (HACCP), which underpins food safety programs, presents a systematic approach to identifying, evaluating, and controlling food safety hazards based on the following seven principles:

- ✓ A risk analysis should be carried out.
- ✓ Critical control points should be identified.
- ✓ Critical limits should be established.
- ✓ Monitoring procedures should be established.

- ✓ Corrective actions should be established.
- ✓ Verification procedures should be prepared.
- ✓ Record-keeping and documentation procedures should be established.

These basic principles of food safety apply to all stages of the food industry, from cultivation, harvesting, processing, production, distribution, and sale to consumption.

Thus, the Codex Alimentarius Commission developed a series of standards for the food industry, trying to cover the entire sector. The list of Codex Alimentarius standards is too extensive to be presented in this article. It can be accessed on the web page www.codexalimentarius.com. Codex Alimentarius standards on hygiene include the following:

- Any sector of the food industry must operate and implement the Codex Alimentarius General Principles of Food Hygiene before developing and implementing the HACCP system.
- Management commitment is essential for the implementation of a HACCP system.
- There may be situations in which it is necessary to redesign an operation or a process if a hazard that requires control but is not considered a CCP has been identified.
- Any stage must be included in the HACCP plan and revised, if necessary.
- The implementation of the HACCP system requires flexibility, if all circumstances are taken into account.

In the EU, risk analysis plays a fundamental role, being considered essential to identify different levels of risks, for example, whether BPIs are sufficient or whether intermediate risks and/or risks of significant hazards need to be addressed through PRPOs and/or CCP (IPCC, 2019) [9], (Table 1).

**Table 1 Food waste reduction in Europe (2015-2020)**

| Country | Food Waste Reduction Percentage (%) | Key Measures Implemented |
|---|---|---|
| France | 30% | Mandatory food donation laws (2) |
| Germany | 25% | Consumer education programs, expiration monitoring technology (5) |

| Country | Food Waste Reduction Percentage (%) | Key Measures Implemented |
|---|---|---|
| Italy | 30% | Promotion of donations and fiscal incentives (3) |
| Romania | 15% | Law 217/2016 for reducing food waste (10) |
| Sweden | 20% | Public campaigns on food labeling (5) |

## 4. Conclusions

1. Food waste poses a significant challenge to the European Union, with wide-reaching impacts on food security, environmental sustainability, and economic efficiency. While the EU has set ambitious targets, such as reducing food waste by 50% by 2030, achieving these goals requires stronger and more consistent efforts across all Member States.
2. Legislative frameworks like the EU Waste Framework Directive and the Farm to Fork Strategy have driven progress, with countries like France and Italy demonstrating success through mandatory food donation laws. Technological innovations, such as supply chain management systems and food-sharing apps, have also proven effective in reducing waste at various points along the supply chain.
3. Consumer education is key, as awareness campaigns and better food labeling in countries like Sweden and Germany have led to significant reductions in household food waste. Expanding these efforts across the EU can drive further improvements.
4. Reducing food waste offers clear economic benefits, including cost savings and resource conservation, while also helping to lower greenhouse gas emissions and protect biodiversity. By strengthening policy implementation, leveraging technology, and increasing consumer awareness, the EU can move closer to achieving its food waste reduction goals, contributing to both environmental sustainability and improved food security.

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