# Closing the loop: sustainable approaches for managing and recovering food industry residues

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**Abstract:**
Food waste management is a growing global concern, driven by the imperative to address environmental sustainability, resource conservation, and global hunger. This article aims to provide a theoretical analysis of the historical evolution of food waste management, delving into the definition of the term and its international relevance. Additionally, it critically examines the need for sustainable approaches. The methodology comprises a comprehensive literature review from 2013 to 2023, utilizing keywords related to food waste, sustainability, and the circular economy. The databases used include Science Direct and MDPI. Findings reveal a shift from individual to institutional food waste sources, underscoring the necessity for alternative approaches. Environmental analysis highlights the adverse impacts of conventional practices, while strategies such as food rescue, fermentation, and anaerobic digestion emerge as promising solutions. Understanding consumer behavior is crucial, and smart labels are introduced as potential tools to reduce food waste. The article identifies the challenges and limitations of current food waste management practices, emphasizing the need for sustainable treatments. Sustainable approaches in managing food industry residues, including food rescue, fermentation, and anaerobic digestion, are discussed as alternatives to conventional methods. The article concludes by proposing future research directions, emphasizing the importance of understanding consumer behavior, exploring the potential of smart labels, and addressing gaps in current knowledge to achieve a more sustainable and responsible approach to food consumption and waste management.
**Keywords:** Challenges and limitations; Circular economy; Food waste; Sustainability; Waste in food industry.

## *Fechando o ciclo: abordagens sustentáveis para gestão e recuperação de resíduos gerados pela indústria de alimentos*

***Resumo:***
*A gestão do desperdício alimentar é uma preocupação global crescente, impulsionada pela necessidade de abordar a sustentabilidade ambiental, a conservação de recursos e a fome global. Este artigo tem como objetivo fornecer uma análise teórica da evolução histórica da gestão de resíduos alimentares, aprofundando-se na definição do termo e na sua relevância global. Além disso, examina criticamente a necessidade de abordagens sustentáveis. A metodologia compreende uma revisão abrangente da literatura de 2013 a 2023, utilizando palavras-chave relacionadas ao desperdício de alimentos, sustentabilidade e economia circular. As bases de dados utilizadas incluem Science Direct e MDPI. Os resultados revelam uma mudança das fontes de desperdício alimentar individuais para as institucionais, sublinhando a necessidade de abordagens alternativas. A análise ambiental destaca os impactos adversos das práticas convencionais, enquanto estratégias como o resgate de alimentos, a fermentação e a digestão anaeróbica surgem como soluções promissoras. Compreender o comportamento do consumidor é crucial, e os rótulos inteligentes são introduzidos como ferramentas potenciais para reduzir o desperdício alimentar. O artigo identifica os desafios e limitações das atuais práticas de gestão de resíduos alimentares, enfatizando a necessidade de tratamentos sustentáveis. Abordagens sustentáveis na gestão de resíduos da indústria alimentar, incluindo resgate de alimentos, fermentação e digestão anaeróbica, são discutidas como alternativas aos métodos convencionais. O*

*artigo conclui propondo direções futuras de investigação, enfatizando a importância de compreender o comportamento do consumidor, explorar o potencial dos rótulos inteligentes e abordar as lacunas no conhecimento atual para alcançar uma abordagem mais sustentável e responsável ao consumo alimentar e à gestão de resíduos.*
***Palavras- chave:*** *Desafios e limitações; Economia circular; Desperdício de alimentos; Sustentabilidade; Resíduos na indústria de alimentos.*

## 1 Introduction

Food waste management has become increasingly critical in recent years, driven by concerns over environmental sustainability, resource conservation, and global hunger. While food waste management is a global challenge, individual and industrial efforts are essential to creating a solution. In 2019, 931 tons of food were sent to landfills worldwide (UNEP, 2021), yet almost 1 billion people were experiencing hunger (WHO, 2019). Efficient management of agro-industrial waste is crucial for the industry to become increasingly sustainable (Serpa-Fajardo *et al*., 2022).

Food loss and waste (FLW) have yet to be universally defined (Boiteau; Pingali, 2023). Some researchers and scholars in the food science and nutrition fields argue that food is only considered wasted when it is still edible, while others argue that food is considered wasted when it crosses the threshold from edible to non-edible and is therefore not consumed.

As defined by the Food and Agriculture Organization (FAO), food loss (FL) is the decrease in weight (dry matter) or quality (nutritional value) of food that was originally produced for human consumption. On the other hand, food waste (FW) is defined by the FAO as food appropriate for human consumption being discarded, whether it is left to spoil or kept beyond its expiry date. According to the FAO, FL occurs during the first three stages of the food supply chain (FSC), and FW refers to wastage that occurs at the final stage of the FSC (FAO, 2013). According to this definition, FW is related to retailer and consumer behavior (Ishangulyyev; Kim; Lee, 2019).

To avoid inconsistency and misinterpretation of data, the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security recommends that all stakeholders in global food security systems (states, international organizations, private sector, and civil society) agree on a shared understanding, definition, and scope for FLW (HLPE, 2014), thus emphasizing the importance of this global issue.

The first food waste-focused report by the American Public Health Association was in 1891 when they found that the city of Chicago burned 19.9 pounds of garbage per capita that year, while Washington D.C. collected 207 pounds of garbage per capita (Bovay; Zhang, 2020).

From an environmental standpoint, food waste emitted throughout the food processing chain is harmful in multiple ways. In addition to the greenhouse gases generated and released throughout the food chain, gases are also produced by the decomposition of food (FAO, 2019). When food is sent to the landfill to decompose, it releases methane gas. As a result, FLW would be the third largest greenhouse gas emitter if it were a country, with the production of 3.3 Gt of $CO_2$ equivalent per year (Lévesque; Perreault; Mikhaylin, 2023).

Additionally, the aggregation of resources utilized in the food production process is squandered when food is wasted. For example, the water, land, and plants used in food production are also wasted when a particular food item is discarded. The subsequent loss of biodiversity due to agricultural expansion is another subset of the negative environmental impact that excess food waste causes. To meet the growing demand for food, more resources are expended by corporations, governments, and consumers alike.

Therefore, this article aims to conduct a bibliographical review, highlighting important aspects that cover the consequences of waste in the food industry, the circular economy, sustainable approaches, societal habits, and government measures that can mitigate this damage.

Sustainable approaches address the environmental issues caused by improper waste management in the food industry and suggest alternatives with a lower environmental impact, such as fermentation and anaerobic digestion. The challenges and limitations highlight the significant amounts of industrial waste, especially from dairies and slaughterhouses, and underscore the potential for reusing these by-products due to their added value. The circular economy advocates methods that contribute to sustainable development goals, aiming to close the food chain loop. Furthermore, future

directions should include raising awareness and promoting campaigns for continuous improvement in reducing waste.

## 2 Methods

The search strategy employed to identify relevant literature involved the use of keywords and terms crucial for addressing the topic at hand, including food waste, waste management in the food industry, sustainability, waste, recycling of food waste, recovery of waste in the food industry, and circular economy. Selection criteria for articles included examination of abstracts, English language proficiency, and publication type, focusing on peer-reviewed scientific articles of significant relevance to the study. Additionally, Boolean operators "AND" and "OR" were utilized in conjunction with keywords as part of the search strategy. Literature beyond the timeframe of 2013 to 2023 and keywords unrelated to the study subject were excluded from the review search. Science Direct and MDPI databases were chosen due to their esteemed reputation, availability of relevant articles, and comprehensive coverage of related topics. Official documents providing worldwide data on food rescue were also selected for analysis.

## 3 Sustainable approaches for managing food industry residues

Over the last century, the focus of food waste management has shifted from individual households to institutions, commercial enterprises, and systemic approaches. As concerns for the environment and sustainability have deepened, institutions have increasingly considered the environmental impact of food waste. In lower-income countries, a significant portion of food waste occurs at the beginning of the food chain due to insufficient financial and technological resources for harvesting, storage, and refrigeration (Chen; Chaudhary; Mathys, 2020). Conversely, in more affluent countries, food waste is predominantly generated by consumers (UNEP, 2021).

Countries with high gross domestic product (GDP) typically produce the largest quantities of food waste. In the United States of America, the Economic Research Service of the United States Department of Agriculture (USDA) estimated that 31% of food is lost or wasted at the retail and consumer levels, resulting in approximately 133 billion pounds of discarded food worth $161 billion annually (FSIS, 2016).

China, on the other hand, sees over 70% of its food waste originating from households and food service establishments such as restaurants and cafeterias (Wang; Yang; Wang, 2022). Despite having only 7% of the world's arable land, China feeds 19% of the global population and contributes significantly to food waste, with an estimated 5.5 million tons of grain wasted annually at the household level and 10% originating from cafeterias (Wang; Yang; Wang, 2022). This results in substantial costs in land, water, labor, and other resources used for production, exacerbating environmental pollution (FAO, 2013). Consequently, China has initiated campaigns like "Clean Your Plate" and "Anti-food Waste Law" to address urgent environmental, economic, and social issues and to raise awareness of food waste (Asefi *et al*., 2024; Wang; Yang; Wang, 2022).

Leftovers are food produced during a meal that becomes surplus or remains unused, often comprising previously prepared meals or ingredients not fully utilized (Aloysius et al., 2023). When food waste is disposed of in landfills, not only is the physical mass discarded, but also its entire molecular composition. Fruits and vegetables discarded often represent a significant amount of wasted potential, as many contain bioactive compounds (Ray *et al*., 2023). For instance, discarded fruits may contain polyphenols, vitamins, pigments, and fatty acids, with these components exhibiting bioactivities such as anti-diabetic, antioxidant, anti-inflammatory, antimicrobial, anticancer, cardioprotective, and neuroprotective properties (Ray *et al*., 2023).

Conventional food waste management, such as landfills and incineration, causes environmental, social, and economic problems (Xiong *et al*., 2019). Discarded food waste in landfills can emit harmful gasses into the air, while Incineration is energy-intensive and could produce highly toxic gasses such as dioxins (Palansooriya *et al*., 2023). While millions of people around the world go hungry, leftover food, and all its potential, is cast away for disposal. Many scientists are looking critically at the different ways food waste can be redistributed and reallocated to people in need, starting with food rescue.

Food rescue, also known as food recovery or food redistribution, involves collecting and redirecting surplus food that would otherwise be wasted to individuals or organizations in need. Food rescue initiatives aim to prevent edible food from being discarded and ensure it is safely and efficiently redistributed to address food insecurity and reduce food waste. The term "rescue" refers to food typically destined for the landfill due to blemishes, expiration dates, packaging malfunctions, etc. One organization, in particular, focuses its food rescue efforts on fresh produce, including items that are blemished or nearing the end of their salability (Sewald; Kuo; Dansky, 2018).

Foods with imperfections or nearing the end of their shelf life are often overlooked and excluded from human consumption. This has resulted in the loss of over U$40 billion worth of food in the United States because it is aesthetically deviant and lacks prototypical product category standards in terms of shape, size, color, and texture (Mookerjee; Cornil; Hoegg, 2021). This represents a massive loss of money and investment, as well as edible food that could still be consumed. This is known as rescue-based food (RBF), or food that is fully or partly made from ingredients that are perfectly safe for human consumption and within expiration dates, yet destined to become garbage due to aesthetic issues or oversupply (De Visser-Amundson; Peloza; Kleijnen, 2021). The RBF allows this food to be transformed in such a way that it can re-enter the human food chain as a valuable product rather than being discarded (De Visser-Amundson; Peloza; Kleijnen, 2021).

Fermentation is an excellent waste management alternative to landfills and incineration. Of the hundreds of millions of tons of food waste generated each year, 40-50% is contributed by fruits and vegetables (Sirohi *et al*., 2021). Compared to vegetable residues, fruit residues usually contain higher saccharides and are suitable for developing many value-added products (Zhao *et al*., 2023). The major waste produced by the fruit processing industry includes peels, pulp, seeds, and bagasse (Zhao *et al*., 2023). In some cases, the peels, seeds, pulp, and other residues discarded after fruit consumption can be higher in nutrients than the part of the fruit that was consumed. This is the case with pineapple peels, as they are richer in antioxidants (like gallic and caffeic acid) than pulp or juice (Tanamool; Chantarangsee; Soemphol, 2020).

Another emerging method for alternative waste management is anaerobic digestion (AD), which aims to reuse food waste for renewable energy production, contributing to sustainability and avoiding landfill disposal (Neri *et al*., 2023). This process is considered one of the most efficient technologies for transforming waste into fertilizers and biogas to obtain electrical energy or biofuel within the concept of a circular economy (Tena; Perez; Solera, 2021a). Anaerobic digestion is a biochemical process carried out by various microorganisms that do not require oxygen to live. It consists of four successive stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Currently, there are three types of anaerobic developments on a commercial scale: single-stage, where waste bioconversion takes place in a single reactor; two-stage processes, where the acidogenic and methanogenic stages are separated into two reactors; and, finally, temperature-phase sequential (TPAD), which combines a thermophilic pretreatment unit before mesophilic anaerobic digestion (Tena; Perez; Solera, 2021b).

In the Basque Country, some by-products from the food industry have been identified, such as those derived from potatoes, apples, grapes, bread waste, and coffee husks. As an alternative, a study proposed the use of these residues as raw materials for animal nutrition, considering their ability to meet the hygienic and sanitary conditions required for consumption (San Martin; Ramos; Zufía, 2016).

According to Beretta *et al*. (2013), some food waste can be avoided, such as overproduction of food, expired expiration dates, and processing losses. It is recommended to adopt practices that minimize this waste, such as redistributing/donating excess food before it deteriorates; monitoring storage; and improving technological conditions for food processing. Some losses are inevitable, such as food contamination, transport condition failures, and climate changes that affect post-harvest.

Aiming at the utilization of industrial food waste, Cerón-Martínez *et al*. (2023) proposed the use of pear guava (*Psidium guajava*) and Tommy Atkins mango (*Mangifera indica* L.) seeds located in Colombia, to create an oily extract with bioactive properties. For the procedure, the supercritical extraction method with carbon dioxide was used. The oily extract showed antioxidant, and anti-inflammatory activity, and the potential to reduce cholesterol levels in the human body. According to Gaharwar *et al*. (2023), another example of waste reuse is the use of apple peel to produce extracts, which not only contributes to the circular economy but also brings benefits due to its antioxidant activity, thanks to the presence of polyphenols.

Kiwi is an example of a fruit that generates a large amount of waste, both for producers and in industrial processing. These residues, when discarded, cause environmental impacts and result in the loss of kiwi bioactive compounds, which have antioxidant, anti-inflammatory, anti-tumor, and anti-microbial activities. These compounds can be applied in various innovative applications across different areas (Chamorro *et al*., 2022). According to Weber, Trierweiler, and Trierweiler (2020), sweet potato waste is useful for biorefineries, aiming to produce bioethanol and distilled beverages, significantly contributing to sustainable development and the circular economy. Furthermore, biorefinery is a field that adds greater economic viability to processes.

Food waste can be reduced if consumers also collaborate. An example of this would be the acceptance of purchasing foods that do not meet aesthetic standards but are still healthy for consumption. To reduce waste, everyone must contribute to this issue. While actions such as donating food help a lot, they have their limitations, and more measures are needed to promote this cause (Beretta *et al*., 2013).

The food sector must adopt more sustainable practices. It is essential that companies generate less waste, support environmental sustainability, and consequently increase available resources. Environmental improvements require economic commitment and time and are considered a future investment (López-Cabarcos *et al*., 2024).

## 4 Challenges and limitations

The rapid change in lifestyle over the past few decades and accelerated urbanization have led to an increase in the production of various residues from the food industry, including fruits and vegetables, cereals, meat products, dairy products, poultry remains, eggs, seafood, kitchen waste, and agricultural waste (Arya *et al*., 2022; Sharma *et al*., 2020). Food waste is concerning for multiple reasons: it results in the loss of rich resources and causes environmental damage, as landfills generate toxic gases harmful to humans. This occurs due to poor management during the food lifecycle stages, leading to environmental, social, and economic consequences. An alternative to this problem would be sustainable treatment for food waste (Sharma *et al*., 2020).

The food processing industry is one of the sources of food waste generation (Sharma *et al*., 2020). Globally, between 4 to 11 million tons of dairy products are wasted each year (Usmani et al., 2022). Dairy residues are examples of nutrient-rich organic matter, such as proteins, lipids, and carbohydrates. This nutritious medium makes them susceptible to deterioration, increasing their perishability (Sharma *et al*., 2020). Lactose and proteins present in milk add value to dairy waste (Lappa *et al*., 2019), and can be reused, returning to the food chain.

Another source of waste is animal slaughterhouses, comprising 49% of bovine remains, 47% of sheep and lambs, 44% of pigs, and 37% of chickens, in addition to another 37% of inedible remains. This generates a large amount of waste from slaughterhouses, which significantly harms the environment (Adhikari; Chae; Bressler, 2018). A cow that weighs 350 kg generates around 210 kg of waste, a pig that weighs 70 kg generates approximately 31.5 kg, and a goat that weighs 30 kg generates 18 kg of waste (Chowdhury *et al*., 2022). The most commonly wasted parts in slaughterhouses are feathers, hair, skin, horns, hooves, bones, and deboning residues. Water from the slaughterhouse can become contaminated by blood, proteins, lard, and tallow, in addition to organic matter, requiring proper disposal to avoid environmental harm. Some industries reuse these residues to make flour (Yaakob et al., 2019).

Waste management is essential and requires the cooperation of all members involved in waste collection, such as citizens and the bodies responsible for collection (Castiglione *et al*., 2023). Among some waste, those produced in kitchens and back offices can be highlighted, such as peelings, shells, eggs, packaging, or waste from front offices, like those found on customer dishes. Restaurants have greater control over the waste generated, but in the front office, this control is also carried out by customers. Waste management is fundamental, as some can be avoided, such as a failure in the cold chain (Martin-Rios *et al*., 2018).

According to UNEP (2020), improperly disposed food waste deeply affects the environment, with landfill decomposition contributing to the generation of about 1.5 tons of carbon dioxide released into the air. Innovation, technology, and behavior change are some of the solutions to reduce food loss and waste (UNEP, 2020). Sharma *et al*. (2020) assert that food waste can be useful in converting

molecules to produce biodiesel, ethanol, biohydrogen, methane, butanol, biosurfactants, bioplastics, organic fertilizers, and electricity.

To mitigate food loss and waste, it can be identified several areas that can assist in minimizing food waste, such as innovation platforms; government incentives to address food loss and foster collaboration in supply chains; technology and innovation training for smaller-scale producers; modifying rules to be less strict and rigid for food packaging standardization; and making the norms for aesthetic requirements of fruits and vegetables more flexible. Better redistribution of leftover food to specific banks for this activity, as long as it is suitable for consumption, is also crucial. Additionally, investing in infrastructure and logistics, especially in sustainable cold chains, is vital for preserving food (UNEP, 2020).

In this context, it is necessary to join efforts to combat food waste worldwide, especially in the food industries, as they are among the largest contributors (Sharma *et al*., 2020). Food is a rich source of nutrients, and food waste discarded by industries could be reused for other functions, utilizing the circular economy (Borrello *et al*., 2017). Treating all stages of the food life cycle responsibly and sustainably can minimize unnecessary waste. It is essential for universities, as centers of research and technology, to interact with industries to support this mission (UNEP, 2020). Given the above, scientific developments and innovations are based on quality university research, making it an important pillar for waste analysis.

The general public's lack of awareness and certain cultural habits contribute to food waste worldwide. To address this problem, the government must create public policies that promote waste reuse. One approach would be investing in research focused on this area and implementing measures to raise public awareness (Champions, 2020). According to Champions (2020), governments and companies must set goals aimed at reducing waste, as well as measure their losses and waste to identify critical points and develop strategies to address this situation.

## 5 Circular economy and waste in the food industry

The circular economy can be defined as a model of production and consumption that shares, recovers, and reuses materials over a long period. Waste is reused and transformed into new resources for future activities (Acerbi *et al*., 2021), contributing to reduced food waste in the industry. The three essential challenges involved in adopting circular economy principles in the agri-food supply chain are institutional, financial, and technological barriers (Mehmood *et al*., 2021). Most urban waste is treated improperly, potentially harming the environment. This situation can cause air pollution, spread diseases, and consequently affect the health of living beings (Castiglione *et al*., 2023).

Short food supply chains can be conceptualized as marketing channels involving few connections, typically at most one intermediary between the farmer and the consumer (Unay-Gailhard; Bojnec, 2021). They foster interaction between the countryside and the city, aiming to achieve sustainability and food governance objectives (Reina-Usuga; De-Haro; Parra-Lopez, 2018). The sustainable objectives of the food supply chain are described in three dimensions: environmental, economic, and social (Kamble; Gunasekaran; Gawankar, 2020). Short food supply chains can help prevent food waste and pursue circular economy goals by reducing the perishability rate of food, thus wasting less and avoiding the disposal of non-standard foods (Kiss; Ruszkai; Takács-Gyorgy, 2019). In this chain, producers use little or almost no packaging material due to the specificity of their economic and commercial activities. The quantity of products sold is reduced, and the purchasing process is shorter than in large chains (Kiss; Ruszkai; Takács-Gyorgy, 2019).

Aiming to implement a circular economy, regardless of the industry, two fundamental strategies can be applied: minimizing the amount of waste; and sustainably managing this small portion. Waste recovery is based on transforming it into more useful products. Landfills, incineration, and composting are known practices for treating waste, but they are not completely satisfactory due to strong odors, methane gas emissions, and slow reactions (Arancon *et al*., 2013).

The United Nations 2030 agenda is an example that drives sustainable actions worldwide, aiming to reduce food waste by half, with the help of governments and companies to accelerate progress in lagging countries, setting a target for sustainable development goals (SDGs). It is important to remember that achieving these goals is possible; the United Kingdom reduced waste per

capita by 27%, and several companies have managed to reduce their waste by 25% (Champions, 2020).

The sustainable development goals were defined in 2015 by the United Nations, and at least 11 of the 17 SDGs are linked to food, addressing the first goals, "no poverty" and "zero hunger" (Hassoun *et al*., 2022). For this sustainable development, waste management would significantly contribute to reducing poverty and achieving zero hunger.

Technology is a very useful area to help minimize waste globally. Blockchain technology can be used in the circular economy to manage waste through traceability and allow customers to verify stored information such as the amount of waste and its reward. Blockchain brings advantages by helping to monitor the collection process and improving waste management control in cities. Citizens send data on the waste discarded in the dump to the garbage collection operator, who then monitors the filling of the dumps, preparing for better collection and transport of this waste (Castiglione et al., 2023).

## 6 Future research directions

There has been significant global progress in food waste management in recent years. Governments, NGOs, businesses, and individuals have been working together to seek and implement effective solutions. This progress has notably improved due to increased awareness and education about food waste and its impact on global systems. For example, the *Think, Eat, Save* campaign from the United Nations emphasizes that changing attitudes and behaviors towards food purchase and consumption is the first step in successfully reducing and managing food waste more sustainably (UNEP, 2021).

Understanding consumer behavior is critical for preventing food waste (Quested et al., 2013). The behaviors that lead consumers to contribute to household food waste are influenced by psychological, socio-cultural, and economic factors, including awareness, attitudes, cognitions, emotions, and context-related aspects such as available technologies (Vittuari *et al*., 2023). To catalyze significant changes in food waste management, it is essential to start with societal perceptions of food and resources.

Bretter *et al*. (2023) found that individuals who believe food waste is morally wrong are less likely to waste food. Additionally, each food category has attributes that influence people's decisions when sorting, preparing, storing, and discarding that food (Ananda; Karunasena; Pearson, 2022). Therefore, solutions like smart labels could be a promising tool for reducing the generation of food waste.

Smart labels are app-based food labels that provide up-to-date information about a specific product. In addition to basic nutritional value information, smart labels can provide customers with information about the product's origin, quickly identify products involved in a food safety concern or recall, notify consumers, and provide up-to-date shelf life information. Providing consumers with consistently updated product information, smart labels, and intelligent food packaging can also increase consumers' likelihood of purchasing these products, thereby helping to reduce food waste (Skinner, 2015).

Many US consumers dispose of edible food due to package date labels, which they often misconstrue as an indication that food is unsafe after that date (Wilson *et al*., 2017). Conversely, when shoppers choose products nearing spoilage that they consume right away, they effectively prevent waste at the retail level (Qi; Roe, 2016). The largest amount of food waste in the United States comes from households (37.2%), followed by consumer-facing businesses (13.1% in retailers and 15.8% in food service outlets), which significantly affects the environment, as food production requires large amounts of energy and water (EPA, 2020). Therefore, programs that incentivize consumers to purchase foods closer to their expiry dates and food rescue programs are both productive ways to mitigate food waste from households and retail levels.

Another important factor in the food industry is packaging. It is known that the function of packaging is to preserve and protect food, ensuring its quality. Currently, this objective is also focused on incorporating materials that benefit the environment. The use of biodegradable packaging is an alternative to conventional packaging because it uses polymers that degrade naturally, such as agricultural residues (Nath *et al*., 2023). Cassava peels and bagasse are examples of agricultural

residues that can be used as alternative sources of starch for the development of biodegradable packaging (Thuppahige *et al*., 2023).

## 7 Conclusions

Food waste is a significant global problem, particularly in the industry, where large amounts of waste are discarded. During food processing, numerous challenges arise that make it difficult to reduce this waste, but some methods can be implemented to aid in this minimization. Waste management aims to close the cycle by adopting measures that promote the circular economy and prevent the wastage of nutrient-rich food suitable for consumption. Furthermore, the use of biodegradable packaging and the conversion of waste into renewable energy are practices that enhance sustainability. In this context, future research must be conducted to significantly contribute to sustainable approaches in waste management and promote social awareness, as closing the loop is everyone's responsibility.


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The authors declare no conflict of interest.

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