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Unlocking value: circular economy in ngos' food waste reduction efforts in Brazil and Togo

Omar Ouro-Salim[1] · **Patrícia Guarnieri**[1] · **Ayawovi Djidjogbe Fanho**[2]

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Abstract
This article delves into the intriguing realm of food waste valorization conducted by nongovernmental organizations (NGOs) in two distinct locales—Brasilia, Brazil, and Lomé, Togo. The primary focus of this exploration is the lens of the Circular Economy (CE), a concept that emphasizes the sustainable utilization of resources within closed loops. The discourse is further enriched by introducing the notion of upcycling, a complementary force to the Circular Economy, particularly within the intricate web of food supply chains. The ReSOLVE framework, a strategic approach for managing food waste, is a guiding light in this research. Upon dissecting the outcomes, noteworthy limitations come to the forefront, shedding light on the challenges of aligning NGOs from both countries with the principles of the Circular Economy in their food waste management endeavors. These challenges assume heightened significance against the backdrop of the intricate global food security landscape, effectively underlining the intricacies of harmonizing the Circular Economy's ambitions with the pragmatic goal of diminishing food waste. The overarching objective of this study is to galvanize circular-oriented initiatives that can effectively curtail and prevent food wastage on a global scale, with a particular emphasis on developing nations. This pursuit is underscored by the triad of benefits such initiatives confer: economic advancement, social amelioration, and a positive ecological footprint. In an era where sustainability stands as a paramount concern, this research advocates for concerted efforts to harmonize the noble ideals of the Circular Economy with the pressing need for food waste reduction, especially within regions striving for holistic growth and development.

Keywords Sub-Saharan Africa · Latin America · Circular economy · Food waste · Nongovernmental organizations (NGOs) · Sustainability · Upcycling

1 Introduction

There has been a significant upsurge in global concern over food waste in recent years, attracting attention from policymakers, nongovernmental organizations (NGOs), and researchers. This heightened focus is primarily driven by apprehensions about food security and environmental impacts [95]. As the world anticipates a surge in food demand due to population growth and rising incomes, especially in developing regions such as sub-Saharan Africa and Latin America, concerns about the availability of arable land have become more pronounced [40].

Food waste encompasses all stages of the food life cycle where wastage can occur, from production and processing to distribution, retail, food service activities, and household food waste before, during, or after meal preparation. This

✉ Omar Ouro-Salim, ouromar@yahoo.fr; Patrícia Guarnieri, patriciaguarnieris@gmail.com; Ayawovi Djidjogbe Fanho, fanhoparfait@gmail.com | [1]Brasília University, Brasilia, Brazil. [2]Department of Economy at the Federal University of Rio Grande do Sul University, Porto Alegre, Brazil.

comprehensive definition underscores the squandering of raw and cooked food materials, emphasizing the loss of valuable resources with significant economic, social, and environmental implications [1]. Food waste is a global threat to sustainability and requires urgent action outlined in the United Nations' Sustainable Development Goals for 2030 [55].

Various strategies, such as composting, reverse logistics, and anaerobic digestion utilizing Circular Economy (CE) technologies, provide avenues for reusing food waste [100]. Policymakers increasingly focus on waste prevention and reduction programs aligned with the SDGs, offering economic advantages and enhancing food security [23].

The global significance of the circular economy approach is particularly evident in developing nations such as Brazil and Togo [29, 87]. This approach has effectively reduced pollution and greenhouse gas emissions by transforming waste into higher-value products [10, 47].

Operating on the principle of eliminating waste and promoting the continual use of resources, the circular economy in the food sector involves reducing food waste, reusing food byproducts, and recycling materials to create a more sustainable and efficient food production system [93]. Despite these advancements, there are considerable gaps in circular economy research in African and Brazilian contexts [50, 81, 85]. Notably, studies have yet to address the recovery and transformation of food waste by NGOs in developing countries, considering the circular economy and exploring the concept of upcycling. Upcycling involves repurposing waste or unwanted products into new materials or products of higher quality or environmental value without significant degradation [5].

NGOs play a pivotal role in sustainable development and food waste mitigation through various channels such as advocacy, policy influence, awareness and education, food recovery and redistribution, support for sustainable agriculture and food systems, collaboration and partnerships, and research and innovation [96]. In Brazil, NGOs like Favela Orgânica, Gastronomia Responsável, Bancos de Alimentos, and others actively contribute to reducing waste and promoting Sustainable Development Goals 12.3 [22]. Similarly, in Togo, NGOs are crucial in addressing environmental education, sanitation, malnutrition, and hunger [69].

Against this backdrop, the research question emerges: What circular economy initiatives have NGOs in Brazil and Togo undertaken to reduce the volume of food waste? These questions are essential in framing the study, delineating its focus and purpose, and guiding the practitioner/researcher on its objectives. They underscore the research's significance by pinpointing specific knowledge gaps and areas of interest to explore while also setting the stage for the methodology and data analysis, informing the practitioner/researcher about the study's approach to addressing these questions and serving as a roadmap.

This study delves into the practical application of circular economy principles by NGOs, specifically Ecozinha in Brazil and ENPRO in Togo, as a strategic approach to addressing food waste. Firstly, the study aims to contribute to food waste management by aligning with circular economy principles. The research methodology involves case studies in Brazil and Togo, allowing for a comparative analysis of how these NGOs manage food waste and implement circular economy practices within different socio-economic and cultural contexts. The chosen countries enable the examination of strategies, challenges, and opportunities for reducing and valorizing food waste in distinct national settings.

The study employs a comparative, qualitative, and multi-method approach to gain comprehensive insights into food waste management by exploring diverse socio-economic contexts, cultural influences, and institutional pressures. The goal is to provide valuable knowledge that contributes to a more thorough understanding of sustainable food management practices. The framework presented in the study illustrates the symbiotic relationship between NGOs and their external environments to inspire future research in the same domain. This approach ultimately contributes to the broader field of food waste management aligned with circular economy principles.

The paper unfolds in four sections. Initially, the theoretical background introduces the concept and principles of circular economy, establishing its connection with food waste and upcycling. Subsequently, the methodology section outlines the documents analyzed and questionnaires addressed to NGO managers for the research. The section dedicated to presenting and discussing the results sheds light on the specific actions undertaken by each analyzed NGO, delving into their theoretical and practical implications and ending with the conclusion section.

2 Theoretical background

2.1 Circular economy concept

Through its principles, the circular economy will inspire other aspects necessary for its functioning and circular processes in the economy. Thus, four pillars establish the practices that fall within the objective of circularizing the economy to create value [33]. These are (see Fig. 1):

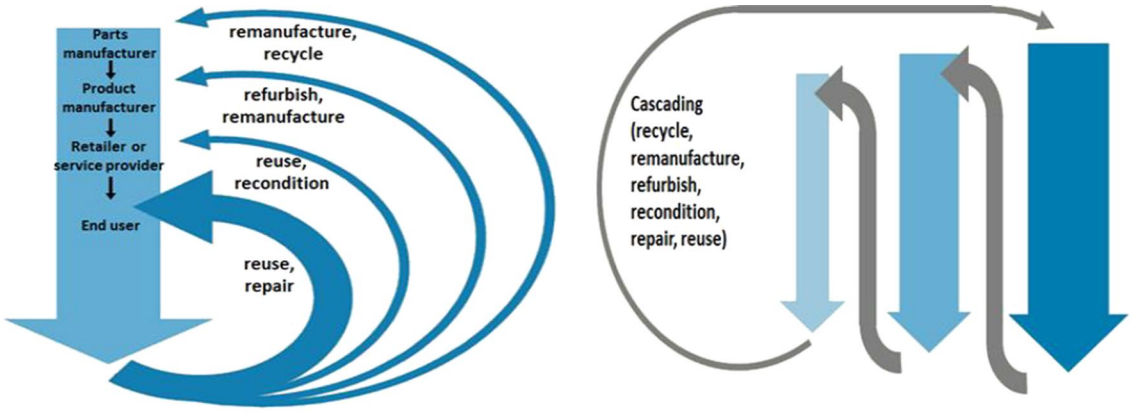

Fig. 1 The pillars for creating economic value. [33] Source: EMF

The implementation of sustainable strategies within a circular economy is delineated through various approaches, each contributing to resource conservation and extended product life cycles. Short circuits prioritize the maintenance and repair of products, aiming to preserve their integrity, minimize costs, and reduce embodied energy, thereby avoiding unnecessary expenditures on creating new items. On the contrary, long circuits emphasize maximizing usage cycles and prolonging the duration of each cycle, effectively extending the overall lifespan of resources and products. This approach incorporates biological and technological processes to minimize waste and diminish the need for new raw materials [33]. Cascading loops involve diversifying the reuse of materials and components, facilitating their adaptation for different purposes over time. This strategy incorporates biological recycling and transformations of the original product, contributing to a more versatile and sustainable product lifecycle. Finally, the Pure Assets strategy focuses on maintaining the quality of materials, enhancing collection efficiency, and reintegrating them into the economic cycle. While this approach contributes to prolonged product life and increased productivity, achieving a fully circular economy, as envisioned by Andersen [4], remains complex. Nonetheless, these diverse strategies collectively provide a framework for fostering sustainability and circularity within resource management [4, 31, 33].

When materials are extracted to be reused, the quality usually decreases, and other input materials must be improvised. Although the circular economy cannot be realized completely, this does not mean the linear economy will remain forever. However, circular practices can change this mentality [31]. For example, promoting recycling will reduce the extraction of virgin raw materials and increase the efficiency of the circular economy [32].

It is essential to understand that the shorter the cycle, the less value the product loses. Therefore, there is a sequence of priorities for forms of recirculation, which are maintenance, reuse, remanufacturing, and recycling, as the possibilities for recirculating matter and energy are numerous [34].

2.1.1 Circular economy business models

In Ref. [73] present five circular business models: circular supply chain, recycling, product life extension, and product and service sharing platform. Circular models offer competitive advantages through cost reduction, revenue generation, and risk mitigation [73]. In Ref. [84] highlight how circular economy business models can generate new commercial opportunities, growth, and sustainability and transform customer relationships.

In Ref. [84] discuss nine elements of a circular business model: customer segments, value propositions, relationship channels, revenues, resources, activities, partnerships, and costs. In Ref. [53] explore circular model innovation with leasing contracts and performance-based services.

In Ref. [8] address the lack of knowledge about eco-innovative resources in circular models and their role in supply chains in developed countries. In Ref. [73] point out that circular models operate symbiotically.

[108] propose a circular model for Italian multinational companies, integrating several dimensions, including information and communication technology (ICT). In Ref. [46] define circular business models as those that cycle, extend, intensify, and dematerialize resources, innovating through conceptualizing and implementing circular models.

The circular economy requires new business models to reduce and create positive environmental impacts. Practical implementation begins with developing products, processes, and models that have a positive effect [11]. In Ref. [64] note that the circular business model is central to a circular economy.

In the sphere of developing nations, the application of the ReSOLVE framework provides essential support for the enactment of circular economy practices. This comprehensive framework encompasses a spectrum of actions, encapsulated in the acronym ReSOLVE: Regenerate, Share, Optimize, Loop, Virtualize, and Exchange. Regeneration entails adopting reusable and renewable materials and energy, encompassing endeavors like recovering, retaining, and restoring ecosystem health and reintroducing recuperated biological materials into the biosphere. Share involves the communal utilization of assets, such as cars, spaces, and lighting, emphasizing the reuse of materials already employed by others and the extension of product life through maintenance, durability, and upgrades. Optimize focuses on enhancing product performance and efficiency while minimizing waste in the production chain, leveraging tools like big data, automation, and remote production control. Loops comprise integrating remanufactured products and components into the system, emphasizing recycling, anaerobic digestion, and the extraction of biochemicals from organic waste. Virtualizing involves the direct dematerialization of goods, exemplified by products like books and CDs, and the indirect dematerialization of services. Finally, Exchange revolves around substituting old materials for new, nonrenewable ones, involving the application of new technologies and the conscious selection of innovative products or services. This multifaceted ReSOLVE framework provides a structured approach for developing countries to embrace sustainable and circular economic practices [12, 33].

Adopting circular economy principles is increasingly recognized as a pivotal strategy for attaining sustainable development goals. To facilitate this, the creation of novel circular models becomes imperative, aiding professionals, decision-makers, and policymakers in embracing and evaluating the impacts of this approach [94]. The essence of the circular economy lies in diminishing the exploitation of natural resources, promoting the reuse of discarded products, and mitigating environmental pollution [31, 66].

In the context of Brazil, despite existing policies and programs aimed at sustainable development and circular practices, there is a pressing need for more comprehensive national guidelines regarding the application of circular models. While the National Solid Waste Policy-(PNRS) [14] incorporates circular economy concepts, challenges persist in waste management [52]. Noteworthy studies by [6, 21, 51] underscore the need for more research on the circular economy in Brazil, mainly focusing on conceptual frameworks, practical applications, and the intricate relationship with the National Solid Waste Policy.

The implementation of reverse logistics encounters formidable challenges in Brazil, and the National Solid Waste Policy has yet to fulfill its objectives, notably in eliminating landfills [42, 52]. Brazil's embrace of the circular economy is hindered by myriad financial, operational, structural, attitudinal, and technological obstacles [17, 92].

Specific sectors, such as electronics, materials recovery, construction, and those employing closed plastic circuits, appear more amenable to integration into the circular economy. However, the complexities of waste management vary based on individual municipalities' financial and technical capacities [3].

Comprehending the circular economy in Brazil necessitates a thorough examination of regulatory approaches, an assessment of the efficacy of instruments, and the formulation of guidelines for their practical application [6, 51]. Circular economy research in Brazil should delve deeper into social and economic considerations [51]. In Ref. [42] underscore the circular economy's potential to modernize waste policies and underscore its economic significance.

Brazil's National Circular Economy Policy (PNEC) promotes the circular economy by fostering resource efficiency, recycling, innovation, technological development, and reducing carbon emissions and environmental impacts [15]. The vision of the circular economy entails innovations across multiple facets [72].

In sub-Saharan Africa, particularly in Togo, the circular economy is pivotal in addressing social, economic, and environmental crises stemming from challenges such as poverty, hunger, and limited access to services [12, 74]. The circular economy can enhance resource efficiency, agricultural productivity, and economic benefits, rooted in traditional circular practices like reuse and tontines within African communities [104].

Despite enduring challenges in waste management and the relative neglect of environmental sustainability in underdeveloped countries, initiatives in nations like Rwanda and South Africa are at the forefront of promoting the circular economy. Institutes and organizations like the African Circular Economy Network (ACEN) actively seek solutions and raise awareness [24, 36]. The circular economy is perceived as a crucial avenue to tackle the sustainable development challenges in the region, notwithstanding the barriers that require overcoming, including a lack of education and political will in waste management [27].

In countries such as South Africa, university students wield the potential to drive transformative change through recycling projects and environmental education [83]. Despite the inherent difficulties, the circular economy is deemed indispensable for fostering sustainability and well-being in sub-Saharan Africa [12, 82].

2.2 Circular economy of food waste

Businesses employ various strategies to minimize food waste in their production processes. These strategies encompass adopting cleaner production practices, establishing eco-industrial parks, enhancing supply chain management, utilizing real-time food waste monitoring technology, donating excess food, and repurposing food waste into innovative products. These approaches reduce the environmental impact, yield cost savings, and enhance the reputation of businesses among sustainability-conscious consumers [29, 30, 79].

The circular economy model proves particularly pertinent in addressing food waste within the food sector. This model emphasizes the reduction, reuse, and recycling of food and its byproducts to eliminate waste and prolong the utilization of resources [67]. By embracing circular economy principles, businesses can mitigate the environmental impact of food production and consumption. Strategies involve reducing overproduction, repurposing food waste into new products, and optimizing supply chain management for efficient and sustainable use of food resources. Implementing these principles contributes to a more sustainable and resource-efficient food system, maximizing the value of food resources [5, 75, 86].

Numerous case studies highlight the successful implementation of sustainable production practices in the food industry. Companies have creatively repurposed surplus food, optimized supply chain management to minimize overproduction, and employed technology to monitor and track food waste. Collaborations with other organizations for food donations and adopting cleaner production practices to reduce water and energy usage are evident. These examples demonstrate how businesses in the food industry can effectively integrate sustainable practices into their production processes, contributing to a more environmentally responsible food system while simultaneously reducing waste and conserving resources [79, 86, 96].

Circular processes can transform food waste into higher-value products [20, 21, 85]. In developed nations, adopting circular models has led to collaborative consumption initiatives such as public refrigerators, food-sharing apps, industrial symbiosis, and food exchange programs [38, 41]. In the production sphere, alternative approaches include using innovative packaging to extend the shelf life of food [44, 45].

For developing countries, comprehensive strategies to reduce food waste should encompass efficient supply chain management, packaging improvements, capacity building, communication/education, logistics optimization, and enhanced handling practices [29].

The increasing focus on food waste and adopting circular models also pave the way for new business opportunities and solutions. Table 1 below highlights some examples of circular models applied to mitigate food waste at different stages of the food supply chain.

Food waste's inedible and unavoidable components can undergo anaerobic processing, yielding green resources like compost, biogas, or green electricity, thereby maintaining a circular life cycle and enhancing value [98]. However, as highlighted by [33] and [76], it is crucial to reevaluate our connection with natural resources and adopt approaches that minimize extraction and excessive disposal. Upcycling, a process that transforms food waste into more valuable products, aligns with the core principles of the circular economy, maximizing the utility of resources [5, 107].

Moreover, [101] stresses the necessity for a systemic and collaborative approach to environmental and economic challenges. The synergy between upcycling and the circular economy fosters partnerships across different sectors, driving innovation in production and consumption while creating markets and commercial opportunities [13].

The "donut" model balances human needs with the planet's limits. The integration of upcycling and the circular economy aligns with this paradigm, reducing waste and addressing social inequalities by generating employment opportunities and facilitating access to quality food for vulnerable populations [91].

Within the studied NGOs, a sensible approach would involve collaboration among all actors in the food chain. Establishments like restaurants, supermarkets, retailers, wholesalers, producers, farmers, and other sectors can form a symbiotic chain with NGOs specializing in transforming and valorizing food waste, providing multifaceted benefits throughout the supply chain and society, as illustrated in Fig. 2. Integrating IoT sensors at all levels is necessary to enhance information dissemination and communication [75, 85, 86].

Table 1 Business models and circular initiatives

Agriculture	**Post-harvest**	**Processing**	**Distribution**	**Consumption**
Horticultural waste	**Transport and storage of waste**	**Food manufacturing waste**	**Logistics**	**Food waste**
- Unwanted harvests - Losses during harvest - Crop damage, natural disasters	- Spillage, deterioration, contamination	-Wineries, breweries -Canning factories, food processing -Out of specification (e.g., confectionery) -Slaughterhouses, slaughter waste	- Losses during packaging/transportation -Supermarkets, wholesalers	- Families -Retailers -Restaurants - Large facilities and services (e.g., airports, hospitals)
Waste of animal origin				
- Large animals, pigs, poultry for products - Bycatch - Pasture losses				
Different treatments for food waste				
Mechanic	**Chemical**	**Thermal**	**Biology**	
Mechanical conversions	**Chemical conversions**	**Thermal conversions**	**Conversions biological**	
- Dehydration - Filtration (e.g., micro and ultrafiltration) - Centrifugation	- Composition analysis - Standard solvent extraction - Other solventless extraction	- Gasification - Pyrolysis - Incineration - Hydrothermal liquefaction	- Anaerobic digestion - Fermentation - Composting - Vermiculture - Insect processing	
New features with added value				
Harvesting inputs	**Industrial products**	**High-value products**	**Animal feed**	**Human nutrition**
Putty materials	**Energy**	**Food system products**	**Animal food**	**Food for humans**
- Compost -Fertilizer -Carbon	- Gas -Diesel and ethanol - Hydrogen - Electricity Materials - Fibers - Biocomposites	- Nutraceuticals - Starch and fibers - Other additives (colorants) **Nonfood products** - Pharmacological agents - Polymers -Fibers	- Reprocessed waste - Waste redirected	- Fresh food **Reprocessed food** - Broths - Fermented foods

Source: This research

The collaboration between upcycling and circular economy principles in the fight against food waste promotes more sustainable and resilient food systems [19, 26]. This synergy reduces environmental impacts, improves food security and social equity, and stimulates innovation in various sectors [30, 86]. By applying lessons from the literature, there is a chance to turn challenges into solutions, contributing to a more prosperous and balanced future [109].

3 Methods

The studies were conducted in two developing countries, particularly in the capitals of Brazil (Brasília) and Togo (Lomé), as shown in the map below (Figs. 3, 4).

We employed a mixed-methods approach, utilizing structured and semi-structured questionnaires to gather comprehensive data from NGO managers. This methodological choice aimed to provide a nuanced understanding of how these professionals perceive and interpret the issues under study, enriching our research with valuable insights. To enhance the robustness of our theoretical and empirical contributions, we incorporated triangulation [48], leveraging multiple sources of evidence to analyze the research topic from diverse perspectives. Additionally, content analysis [7], a systematic method for objectively describing the content of communications, was employed to validate the research question.

The synergistic application of these methodologies guaranteed a comprehensive examination of NGO managers' perspectives, reinforced by a meticulous data analysis process. Nevertheless, it is imperative to recognize potential areas for enhancement, including the time and resource intensiveness inherent in employing multiple data collection methods and the requirement for expertise in conducting content analysis and triangulation [16]. Furthermore, it is crucial to acknowledge that, for the scope of this study, food loss and waste are regarded as synonymous in both countries, aligning with the [9] definition. Interpreting data from diverse sources may introduce complexities in the analysis and synthesis of findings.

Applying the Ellen MacArthur Foundation's ReSOLVE framework [33], we scrutinized a model of organic food waste management within NGOs in Brazil and Togo. Our analysis focused on identifying points where circular economy principles align. Data collection involved thoroughly examining documents from two NGOs in both countries, readily accessible on their websites. These documents encompassed external standards, such as government regulations and internal standards outlined in NGO documents. Importantly, these documents were publicly accessible and did not require prior authorization. The collected information covered various aspects, including the NGOs' mission, vision, objectives, aims, and activities, as detailed in Table 2.

Document analysis serves as a transformative process, enhancing the accessibility and reliability of document content, thereby contributing to the development of documentation services or databases. Subsequently, data collection involved the administration of questionnaires to NGO managers. The voluntary participation of these managers not only ensured accessibility but also aligned with the exploratory nature of the research. The questionnaires, comprising six questions

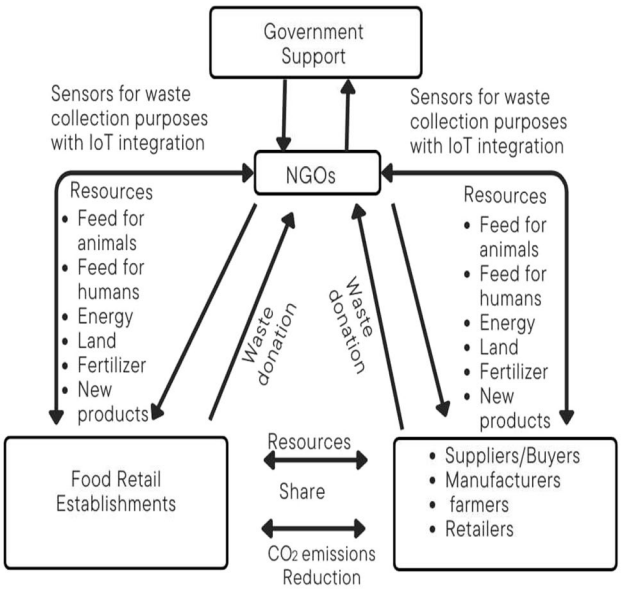

Fig. 2 Framework illustrating the symbiotic chain between NGOs and the external environment. Source: This research

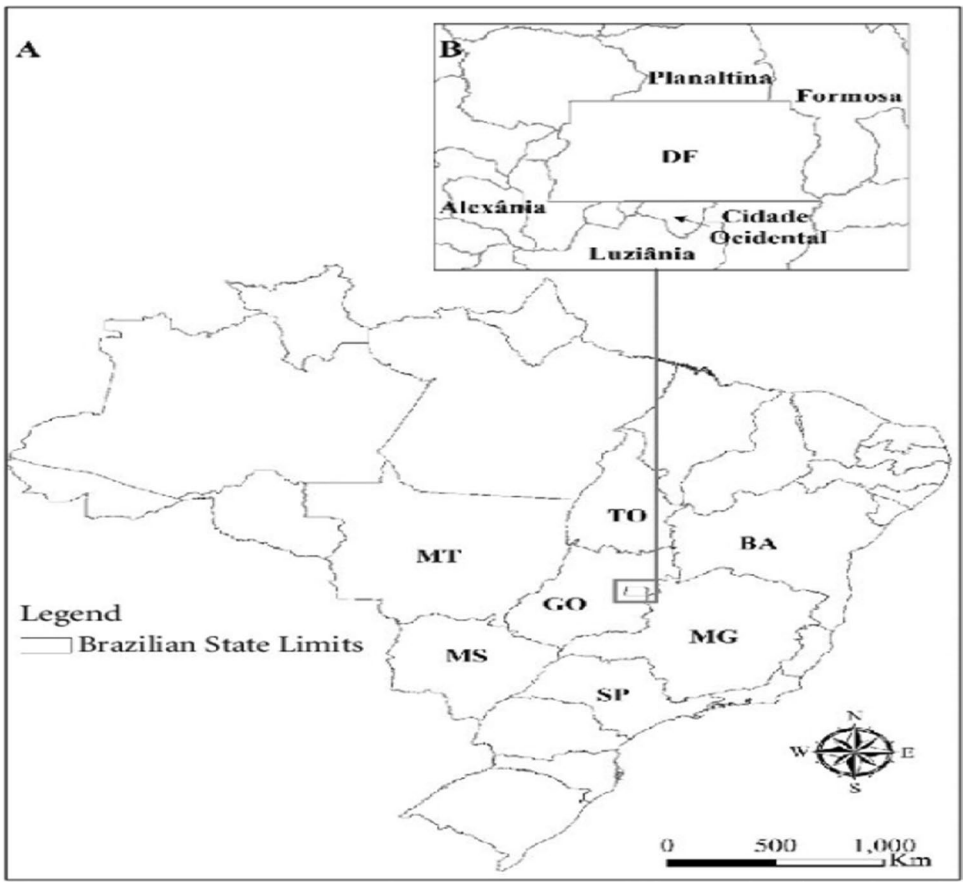

Fig. 3 Location of Brasília, Federal District (DF), in the Brazil map. Source: Gallassi et al. [49]

encompassing both objective and subjective elements, were designed using Google Forms to gather insights on food waste management from the circular economy perspective.

The data collection spanned from August 2022 to January 2023 in both Brazil and Togo, with full questionnaire completion by four managers from each NGO. The methodology adhered to the framework proposed by [7], involving stages of pre-analysis, exploration, and data treatment. Content categorization of the respondents' answers was based on thematic similarity, facilitating subsequent comparisons between the practices implemented in Brazil and Togo.

4 Results and discussion

4.1 Ecozinha institute

The Ecozinha Institute is a nonprofit NGO in the Federal District, Brazil, founded in 2017 by hotel, bar, and restaurant companies. Its mission is to promote a more sustainable community through responsible waste management. The organization manages organic waste, recyclables, and waste from associates through reverse logistics. It faces challenges related to waste reduction, separation, and disposal. Members contribute monthly fees to support these activities. Approximately 60% of the waste members generate organic, including food waste, prunings, and cork stoppers. These materials are separated and sent to composting yards with the collaboration of partners such as *Projeto Compostar* and *Engaia Compostagem*. The Ecozinha Institute also uses logistics technology provided by the company "*Sólidos*" to track and audit waste, ensuring recycling or composting by accredited recyclers. Its environmental impact includes reducing more than 20,000 tons of greenhouse gases through composting [60].

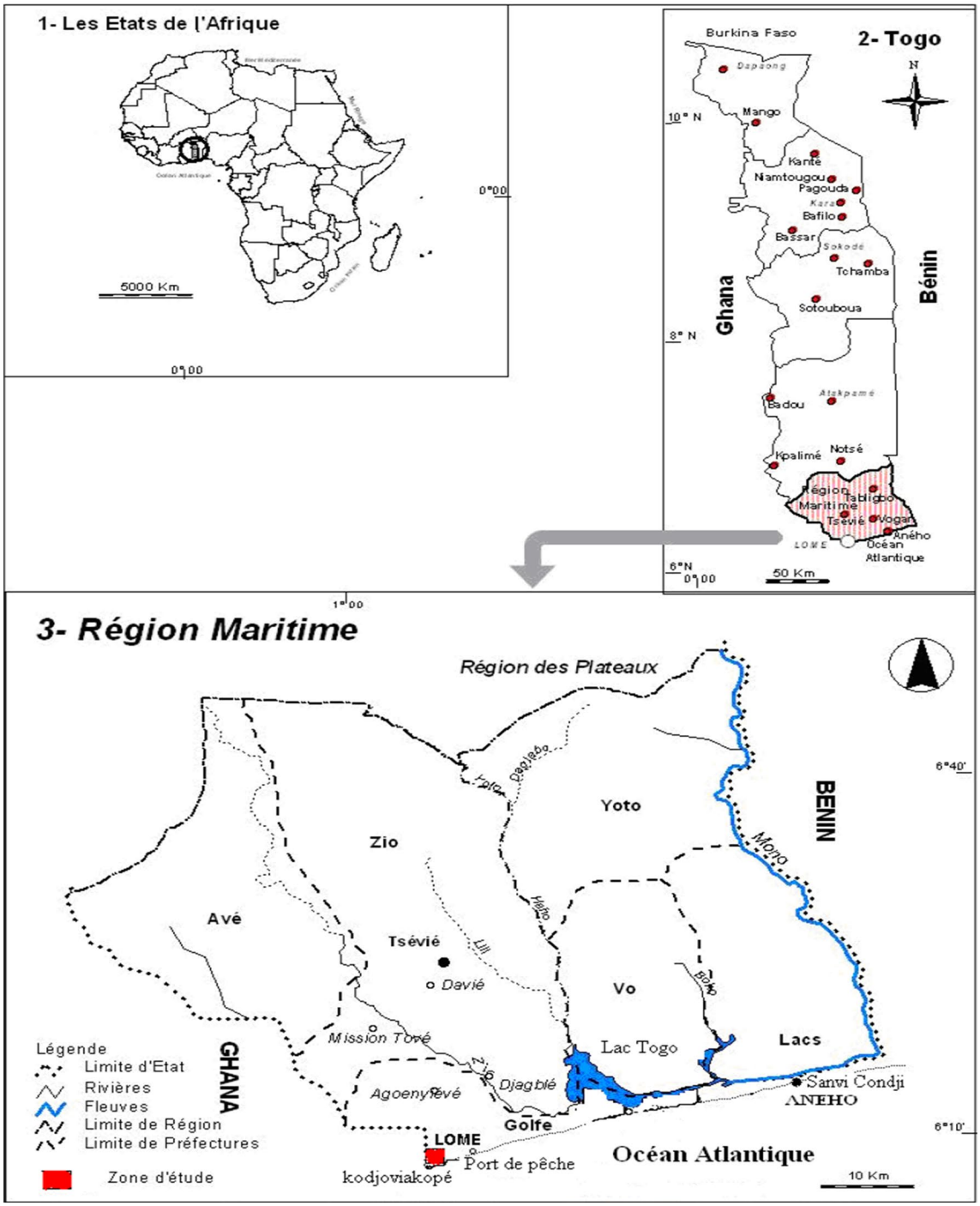

Fig. 4 Location of Lomé, Capital city, in the Togo map. Source: Koledzi [50]

4.2 ENPRO

ENPRO is an NGO established in 1999 in Togo after the closure of the SOTOEMA company, which was responsible for waste management in Lomé. Its mission covers environmental, social, technical, and economic aspects. The organization collects food waste and other municipal solid waste, processing it mainly through composting, resulting in more than 300 tons of compost annually. ENPRO also seeks new activities that benefit the environment and society while

Table 2 Documents explored

NGOS	Documents	SITES
ECOZINHA	Site presentation	https://www.institutoecozinha.org.br/recursos/pdf
	Handouts	https://www.institutoecozinha.org.br/_files/ugd/985f74_0cfd73c80ebd434f97bf1caded4808a8.pdf
ENPRO	Composting project	https://www.reseauprojection.org/wiki/images/0/0e/Ludington_Gevalor_Projection_240114.pdf
	Making the most of organic waste	https://www.nitidae.org/actions/africompost-valorization-des-dechets-organiques-municipaux-en-compost-pour-ameliorer-la-gestion-des-dechets-et-developper-l-agriculture-locale-peri-urbaine-dans-5-villes-d-afrique.pdf
	Presentation of the site and activities	https://documents.plateforme-resources.org/wp-content/uploads/2017/03/A158-Presentatipon-de-lONG-ENPRO.pdf

Source: This research

seeking financial sustainability through diversification strategies and the sale of recyclable waste. Since its inception, the organization has evolved, becoming recognized by local authorities in waste management and establishing international partnerships, such as the *Africompost* project in collaboration with the French association *Gevalor* [35].

4.3 Circular economy practices used in the organizations studied

The CE strategies used by NGOs in both countries were analyzed in light of the ReSOLVE framework. The questionnaire sent to the managers of Ecozinha and ENPRO provided primary data for comparing their organic food waste management practices (see Table 3).

Table 3 provides a comprehensive comparison between the ReSOLVE framework—Regeneration, Share, Optimize, Loop, Virtualize, and Exchange—and the actions undertaken by NGOs.

Regenerate, focusing on eco-friendly agricultural materials and animals to promote soil regeneration, is embraced by both NGOs. They adopt regenerative approaches, converting waste into compost to enhance soil health and food production. Share emphasizes sharing organic waste to reduce the use of virgin materials and emissions. Ecozinha facilitates proper waste disposal, while ENPRO collects and transforms organic waste into aggregate products. Optimize targets economic efficiency through waste management optimization. Ecozinha aids establishments in waste management, promoting circular economy principles and economic development. ENPRO valorizes waste, contributing to improved basic sanitation and promoting healthy eating. Loop emphasizes the reuse of existing materials, with both NGOs adopting composting to close the loop on materials and share compost with farmers. Virtualization is achieved digitally, promoting transparency and information exchange. Both NGOs utilize social networks to publicize practices and impacts. Exchange encourages innovation, with Ecozinha exchanging information and ENPRO raising awareness and creating jobs. This analysis illuminates how these NGOs effectively integrate circular economy principles into their operations, advancing sustainability and environmental responsibility in the agrifood supply chain.

Table 3 demonstrates the alignment of each ReSOLVE aspect with specific activities carried out by environmental NGOs. By illustrating this alignment, the comparison accentuates how NGOs can effectively incorporate the ReSOLVE framework's principles into their operations, emphasizing the significance of sustainable and responsible environmental management.

The importance of this comparison lies in its ability to showcase how the ReSOLVE framework's principles, designed to promote sustainable and responsible environmental management, are practically applied by environmental NGOs. The comparison highlights how NGOs can implement the ReSOLVE framework to foster more sustainable and environmentally responsible practices by highlighting this synergy. This insight is invaluable for guiding the development of environmental programs and initiatives and promoting greater awareness and understanding of sustainable environmental management practices within the NGO sector. Ultimately, this alignment has the potential to enhance the effectiveness and impact of environmental conservation and sustainability efforts.

Furthermore, the ReSOLVE approach advocates for circularity in agrifood supply chains, a critical consideration in addressing climate change challenges, particularly in emerging economies adopting circular practices [106]. In this context, we analyzed the food waste management practices of Ecozinha and ENPRO within the framework.

4.4 Barriers for ecozinha and ENPRO

The challenges the Ecozinha and ENPRO confront align with the existing literature on the circular economy's economic, social, and environmental aspects [51, 58, 71]. However, it is noteworthy that the literature often emphasizes theoretical aspects, necessitating more direct linkages between theory and practice, particularly in developing countries [28]. A recognized gap in the literature is the need for frameworks that seamlessly integrate the micro, *meso*, and macro levels of circular economy implementation [62].

Literature also underscores the importance of collaboration between various stakeholders to promote the circular economy [55, 81]. The Ecozinha and ENPRO encounter funding challenges for their expansion; a barrier echoed in other studies [79]. The complexity of circular economy practices amplifies with scale, presenting a challenge for developing countries [43].

Both organizations encounter difficulties gaining recognition from society and policymakers, akin to barriers identified in prior studies [2, 25]. The absence of financial support from local authorities poses a significant challenge, potentially

Table 3 Relationship between ReSOLVE and management methods practiced by NGOs

	ECOZINHA	ENPRO
Regenerate	Soil regeneration	Soil regeneration
	Compost/fertilizer production	Compost/fertilizer production
Share	Compost project	Farmers
	Romero Melo Gardens	Workers
	Restaurants, bars, and hotels	Restaurants, homes
	CH4 Bio	Gardeners
	Pura Vida	Waste recycling companies
	Farmers	
	Vital Environmental Solution	
Optimize	Compost sales	Waste management and recovery
	Composting	Urban sanitation and environmental protection
	Recovery of organic waste	Organic waste recovery
	Taking waste out of the waste cycle and into the food cycle	Compost sales
Loops	Turning waste into an environmental liability	Composting practices
	Promoting the circular economy through food	Processing and recovery of organic waste
	Obtaining quality organic fertilizer	Obtaining 100% organic products
	Sequestering GHGs in the atmosphere	Reduction
	Composting	Reuse
	Reuse	Recycling
	Recycling	Recovery
	Rethinking	
Virtualize	Use of social networks such as Instagram, Facebook, and websites to publicize the need for restaurants, hotels, and bars to join and their social, economic, and environmental impacts	Use of the website and LinkedIn to disseminate information about initiatives and their social, economic, and environmental impacts
Exchange	Environmental education to preserve the environment	Knowledge shared with other waste recovery companies
	Promoting low carbon through food	Source of jobs
	Participation in restaurants, hotels, and bars	Sustainable development
	Exchange of knowledge with other waste recovery companies	Awareness campaign
		Healthy food consumption
		Community well-being
	Marketing products	Reducing pollution
		Protecting the environment
		Fight against poverty

Source: This research

hindering the future development of the initiatives in both countries [70]. The necessity for appropriate technology for collecting and recovering food waste is a shared obstacle in developing countries [61].

In summary, the hurdles the Ecozinha and ENPRO face align with challenges documented in the circular economy literature, including the need for theoretical-practical integration, financial barriers, lack of recognition, and technological difficulties in developing countries [29].

4.5 Theoretical and practical implications

NGOs and startups play a crucial role in exemplifying the circular economy concept through tangible actions. A notable example involves collecting surplus food from restaurants for distribution to those in need. These organizations collaborate with restaurants, transforming excess food into meals donated to charities [70, 79, 80].

The application of lean and sustainable operations within NGOs serves as a model for the circular economy. These models integrate social, economic, and environmental aspects, recognizing the multidisciplinary and intricate nature of reducing food waste [65].

NGOs wield significant influence on sustainable development and food waste mitigation, contributing through various means such as advocacy, policy influence, awareness and education, food recovery and redistribution, support for sustainable agriculture and food systems, collaboration, partnerships, research, and innovation. Policymakers can strengthen these initiatives by providing funding, policy support, capacity building, collaboration, and recognition, fostering an enabling environment for NGOs to operate and amplify their impact. Collaborative efforts between policymakers and NGOs can pave the way for a more sustainable future [96].

The establishment of public policies aimed at mapping the value streams of food waste can empower supply chain actors to pinpoint critical waste points. This value stream mapping approach provides a means to increase food quantity without expanding production, thereby enhancing production efficiency. As production costs decrease, the prices of nutritious food may also reduce, benefiting vulnerable and hungry populations [29].

Despite their significant contributions, NGOs often need more recognition. The belief that public institutions should meet social needs rather than private initiatives hinders support for NGOs focused on preventing and reducing food waste [89]. Collaboration among different actors in the food supply chain is crucial to supporting NGOs to sustain their activities in both developed and developing countries [29, 75, 86].

Upcycling, generating new uses for raw materials or food parts that would otherwise be discarded, represents a win–win solution [18]. It aids in reducing the environmental impact of food waste, generates producer revenue, and meets consumer demand for differentiated and sustainable products. This model can be adopted by food supply chain actors globally, offering a means to reduce and valorize food loss and waste [5]. Upcycled goods will likely be cost-effective, increasing demand [63].

Upcycling involves redirecting food that would otherwise be wasted to more valuable uses, benefiting the environment and society. This approach underscores the economic value of discarded food, generating interest in circular economy practices. Upcycling excess food efficiently redistributes it, improving global health, the environment, and economies while reducing greenhouse gas emissions caused by food waste [18, 103].

Effective communication strategies are crucial for consumer acceptance of upcycling and biotechnology in food quality. Emphasizing the benefits of these approaches, showcasing tasty, pesticide-free ingredients, and ensuring a transparent supply chain can enhance acceptance. For example, presenting genetically edited tomatoes with a longer shelf life as personally and socially beneficial increased acceptance among participants in the UK and Switzerland [19, 97].

In many developing and developed countries, NGOs face substantial financial gaps. In this context, governments and international financial institutions should provide support [59, 70, 75]. Research in Sweden identified reluctance toward consuming upcycled food, with ethical concerns playing a significant role. It emphasizes the need for environmental education to promote sustainable consumption and achieve UN Sustainable Development Goal 12.3 by 2030 [97]. In developing countries like Brazil and Togo, awareness still needs improvement, complicating NGOs' efforts. Therefore, NGOs supporting environmental preservation should be transparent about their approaches to treating, transforming, and recovering food waste [79].

NGOs dedicated to activism can enhance food waste recovery by utilizing insects and their gut microbes. This method, involving selectively rearing insects on food waste and agricultural byproducts, transforms resulting biomass into protein-rich animal and human food ingredients. This approach surpasses traditional waste management methods, reducing greenhouse gas emissions and environmental impacts while enriching agricultural soils [90]. Practical implementation on a pilot scale is essential to confirm local feasibility and cost details, especially in developing nations [19] like Brazil and

Togo. This strategy can help NGOs produce upcycled food, promote insect-based products, and encourage stakeholders to adopt the technology, promoting a circular economy throughout the production chain [13].

4.6 Discussions on implications of the study

The study carries substantial implications for policymakers, NGOs, practitioners, and researchers, and its contributions can be categorized into key areas.

Firstly, regarding policymakers, the study offers valuable insights into NGOs' challenges and limitations when aligning with circular economy principles in food waste management. It underscores the potential for guiding the formulation of public and private policies that support and incentivize NGOs to play a more effective role in circular food waste initiatives. Given the vital role of NGOs in filling gaps related to government and private company actions, the study recommends specific policies about regulatory frameworks, financial incentives, and capacity-building programs.

For practitioners engaged in food waste management, the study provides practical insights into the ReSOLVE framework and its implementation in real-world situations. This knowledge can aid practitioners in adopting more effective waste management strategies aligned with circular economy principles. Additionally, the study introduces upcycling, inspiring practitioners to explore innovative approaches for repurposing food waste and fostering the development of novel products, processes, and business models.

In the academic realm, the study contributes to the discussion of harmonizing circular economy principles with food waste reduction, particularly in developing countries. This contribution may motivate researchers to delve deeper into challenges, analyzing cultural, economic, and logistical obstacles that hinder the full implementation of circular practices. The absence of circular economy national policies guiding strategies is also highlighted, paving the way for further investigation.

Theoretical advancement lies in introducing upcycling as a complement to the circular economy in food supply chains, suggesting opportunities for researchers to explore deeper theoretical underpinnings and practical implications.

The findings emphasize the significance of existing and future research and policy in circular economy and food waste management. They shed light on challenges and opportunities within the NGO sectors, especially in developing countries, providing valuable insights for existing research. The study also stresses the need for more consistent and comprehensive studies in the field, encouraging future research to address identified challenges, explore emerging themes, and fill research gaps.

In terms of policy, the study underscores the relevance of the findings for policymakers, advocating a holistic and systemic approach to managing food waste and promoting circular initiatives effectively. It highlights the importance of establishing robust institutions, increasing awareness, promoting collaboration, and supporting circular economy practices in food waste management, particularly in developing countries.

Overall, the study emphasizes the significance of the findings for advancing research, guiding future studies, and informing policy development in the realm of circular economy and food waste management, particularly in the context of developing countries.

5 Conclusions

NGO managers underscore the importance of converting food waste into compost despite the limited evidence of circular practices within the ReSOLVE framework. The convergence of upcycling and the circular economy emerges as a beacon of hope amid challenges like food security, equity, and sustainability. The literature envisions a future characterized by more resilient, equitable, and efficient food systems driven by creativity, collaboration, and innovation. This transformative approach curtails waste and redefines our relationship with natural resources, envisioning economic prosperity in harmony with a balanced and sustainable world.

However, the study grapples with inherent limitations in empirical research. The qualitative analysis presents challenges for broad generalizations, and while the findings suggest similar perceptions among actors from diverse regions, their applicability to other developing countries remains speculative. Centered on two nongovernmental organizations, the research offers a specific perspective rather than an exhaustive one, necessitating a more comprehensive approach. Primarily relying on the ReSOLVE framework, the study proposes future investigations to assess partnerships between

pro-waste NGOs and commercial establishments. These inquiries could explore various circular economy models and delve into the nuanced concept of upcycling, contributing to a more nuanced understanding of these dynamic processes.

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Declarations

Competing interests The authors declare no competing interests.

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