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The management and prevention of food losses and waste in low- and middle-income countries: A mini-review in the Africa region

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Abstract

This mini-review analyses food losses and waste (FLW) management in low- and middle-income countries (LMICs) and identifies potential strategies to improve FLW management efficiency on the African continent. To achieve this aim, a search of grey and published scientific literature-case studies, feasibility studies, theses, peer-reviewed journals, governments and technical reports was performed. Food waste (FW) per capita in sub-Saharan Africa (SSA) was determined to be between 6 and 11 kg capita^{-1} year^{-1}. Factors militating against FLW management include a lack of infrastructure, waste reduction and mandatory waste management plans, financial support for food redistribution programmes, awareness and a lack of knowledge of FW management and effective approaches. Poor recovery systems, a lack of incentives in FW recycling programmes, a lack of a regulatory and policy framework and institutional weaknesses as well as a lack of sufficient and appropriate education programmes to improve FW source separation and collection rates are all significant challenges in the African region, with negative consequences for the environment and public health. Except for fuel conversion and food scraps for digestion to recover energy, there is a huge potential for composting and using FW as a digestate, which could eventually lead to a reduction in the amount of FW being landfilled or incinerated. The study explores potential interventions to reduce amount of FLW and form a basis for future research in this field and improving FW management efficiency in LMCs, especially on the continent of Africa. It also provides information that could assist researchers, policymakers and decision-makers reduce amount of FLW, aid in the utilization of FW for energy production, and reduce greenhouse gas emissions in the continent, as well as support the achievement of other sustainable development goals, such as 12.3, which is particularly important in the context of the African continent, which is dependent on food imports.

Keywords

Food losses and waste prevention, food losses and waste, composting, environmental sustainability, multi-stakeholder partnerships, policy reforms

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Introduction

In low- and middle-income countries (LMICs) in the African region, FLW management challenges may be exacerbated by inappropriate consumer behaviour and stockpiling of foodstuffs when lockdowns were implemented during pandemics, namely, COVID-19 (Jribi et al., 2020). This is because many African countries have not prioritized *sustainable management of food* waste (FW) (e.g. prevention of surplus, avoidance of FW), and FLW management systems are still in their infancy (e.g. lack of reuse, diversion of food scraps for production of animal feed and reduction of food surplus generated, and fuel conversion and food scarps for digestion for energy and creation of nutrient-rich soil) (Food and Agricultural Organization [FAO], 2011; Mmereki et al., 2016). Indeed, a lack of consistent FLW management regulations, a lack of clearly defined specific objectives for reducing FW, and insufficient implementation of thorough food regulations and a recycling culture result in many African countries having incomplete and insufficient FLW management systems (Thi et al., 2015). This is also exacerbated by inadequate administrative measures and weak institutional structures, and

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poor budget allocations to enhance recycling activities, environmental and sanitary problems that are caused by FW, which pose adverse impacts on the environment and public health (Chalak et al., 2016; Mmereki et al., 2016). This scenario is complicated by the fact that that FW segregation from municipal solid waste (MSW) is still not given priority in many African countries (e.g., weak source segregation systems). A lack of public–private partnerships in improving composting of FW and using it as a digestate in biogas technology, and investment in research and development of FW management to improve food distribution to reduce FLW, and also ameliorate challenges of FLW management. This leads to increased disposal of organics such as FW in landfills (Weghmann, 2019).

Food losses and waste (FLW) is considered a major threat to achieving sustainable development as outlined and detailed in Agenda 21 (Thi et al., 2015) (i.e. ensure sustainable consumption and production patterns), and Agenda 2030 under goal 12.3 in many of the LMICs (Jribi et al., 2020), and environmental sustainability. African countries are not an exception. Therefore, it is necessary to develop more sustainable approaches to ameliorate the challenges of FLW and improve FLW management efficiency in LMICs, and the African region in general.

Research has suggested that, in sub-Saharan Africa (SSA), post-harvest food losses are estimated to be worth over US$4 billion per year, which is estimated at roughly 37% or 120–170 kg year^{-1} capita^{-1} – or enough to feed at least 48 million people. It is further indicated that in many African countries, the post-harvest losses of food cereals are estimated at 25% of the total crop harvested (World Bank, 2011). In South Africa, the cost of post-consumer FW in South Africa is estimated to be approximately US$2.7 billion per annum (de Lange and Nahman, 2015; Nahman et al., 2012). The World Wildlife Fund (WWF) and the Council of Scientific and Industrial Research reported that South Africa wastes around 10.3 million tonnes of edible food in the agricultural value chain, costing the South African economy approximately US$700,000 a year. This further leads to a whopping 90% of this FW being disposed into landfills. This uncontrolled food degradation in landfills inevitably leads to the production of environmentally harmful greenhouse gases (GHGs), as methane (Bessa et al., 2021).

Past research has highlighted that SSA has high food wastage (estimated at roughly 37% or 120–170 kg year^{-1} capita^{-1}) (FAO, 2019; Sheahan and Barrett, 2017; World Bank, 2011), which is predominantly and primarily occurring at the farmer producer stage of the supply chain (Affognon et al., 2015). It is noted that FW differs from one culture to another irrespective of the country's development. Several environmental regulations have been developed and implemented to reduce waste in many African countries. Although these countries have the potential to use food resources or use them in other processes (e.g. composting or energy generation) (Vries et al., 2017), progress on these aspects has not been fully evaluated. Fewer studies have been conducted on FLW in the African region. Jribi et al. (2020) investigated the impact of the COVID-19 lockdown on Tunisian consumer awareness, attitudes and behaviours related to food wastage, and the most cited reasons given for discarding food were overcooking, inappropriate storage and overbuying. In South Africa, studies have investigated FW management, and cost related to FLW management (de Lange and Nahman, 2015; Nahman et al., 2012). Maduhu et al. (2019) identified opportunities and challenges militating against FW management in Tanzanian coastal hotels.

Abouabdillah et al. (2015) evaluated household FW in Morocco, and assessed the knowledge and relative importance of FW; attitudes towards FW; impacts of behaviours regarding FW management; quantity and value; as well as barriers and willingness to behavioural change towards FW management. The researchers found that household planning and shopping activities are important predictors of FW and that attitudes may change according to periods especially during Ramadan (with 87% declaring that FW is higher during this month) and the category of food (i.e. most wasted product groups being cereals and bakery products, fruits and vegetables). To the best of the authors' knowledge, no study has investigated the status of FLW management in the African continent and provided information on a shift in FLW management towards sustainable FW management, and potential strategies to prevent and reduce FLW. Although FW reduction offers multi-faceted wins for people and the planet, improving food security, addressing climate change, saving money and reducing pressures on land, water, biodiversity and waste management systems (United Nations Environment Programme [UNEP], 2021), there is somewhat limited data on the potential for FW digestion for energy recovery and diversion of food scraps to animal feed production. Information on the status of the FLW management in the African region is lacking. Therefore, the objectives of this study are to: (i) provide an overview of the status of FLW, sources and composition or characterization and management in African countries; (ii) identify the challenges affecting FLW management practices and (iii) provide recommendations to ameliorate challenges of and reduce the amount of FLW and improve diversion of food scraps to animal feed production and recovery for energy in the Africa countries. This study contributes to synthesizing evidence of the status of FLW management, insights into FLW management and the associated challenges, and building a foundation for future research on FLW management in Africa. Moreover, it also offers a reference to researchers, and environmental and waste managers to develop sustainable FLW management strategies of such as using FW substrate as compost, and production of heat or electricity through biogas and energy content derived from landfill gas (LFG) capturing technology, which could improve energy issues and the reduction of the environmental, social and economic impacts of FLW management in African countries, as well as as well as the potential to reduce waste.

Definitions of terms, concepts and scope

In this study, FLW is referred to as per the UNEP definition below. Weddings, funerals, parties, and other celebrations are examples of socio-cultural activities that contribute to FW. The

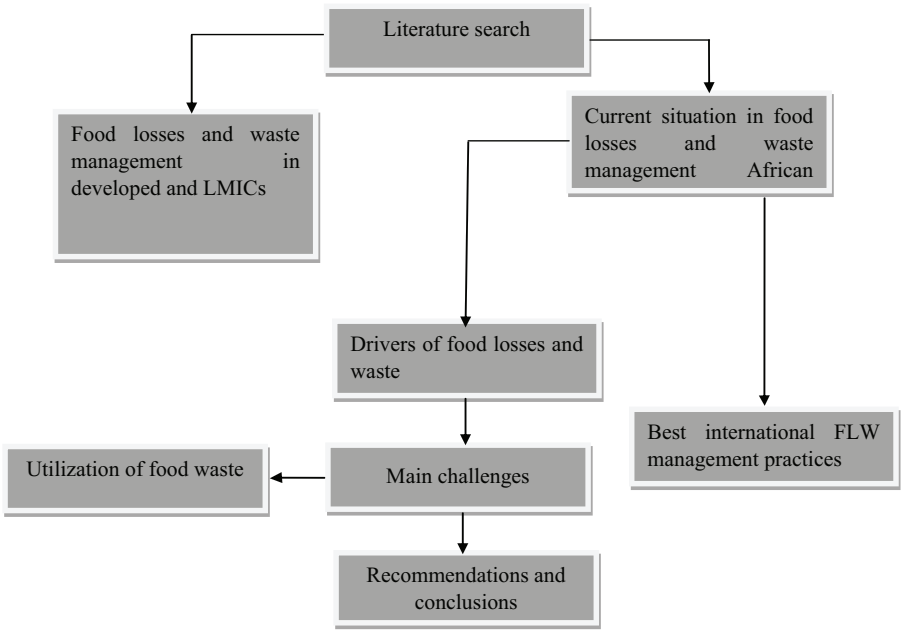

Figure 1. Context used in the study.

study covered FLW management in African countries. Therefore, FW is used throughout the study to refer to FLW, directly from human food consumption (Kummu et al., 2012).

Food losses are defined as:

> food that gets spilled, spoilt or otherwise lost, or incurs reduction of quality and value during its process in the food supply chain before it reaches its final product stage. Food losses typically take place at production, post-harvest, processing, and distribution stages in the food supply chain. (UNEP, 2021)

FW is defined as:

> food that completes the food supply chain up to a final product, of good quality and fit for consumption, but still does not get consumed because it is discarded, whether or not after it is left to spoil or expire. Food waste typically (but not exclusively) takes place at retail and consumption stages in the food supply chain. Overbuying, poor planning, and confusion over labels and safety contribute to food waste at stores and in homes. (UNEP, 2021)

Methods

This study followed some of the steps used in a systematic literature review (SLR), that is, defined strategy and eligibility criteria, but did not use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. Following some of the steps of the SLR, assisted in having a criterion-based literature selection from diverse sources. This technique is appropriately assisted in screening out unnecessary literature based on the search strategy due to the complexity and diversity of the topic, and synthesizing literature to develop knowledge in the field (Tranfield et al., 2003). Therefore, this method has the potential to be applied to explore FLW management, and potential initiatives to ameliorate the challenges of FLW in the waste management sector.

A thorough search of various scientific databases, including Web of Science, ScienceDirect, GoogleScholar, Sage Open, and Springer Link, was conducted in this study for case studies, feasibility studies, theses, peer-reviewed journals, reports by international agencies, official government publications, and technical reports on FLW management in African countries. Only peer-reviewed literature published in English was searched, as illustrated in framework shown in Figure 1. The literature was searched done using a combination of keywords and Boolean functions such as 'food losses and waste' OR 'food losses and waste management', OR 'food losses and waste management in African countries', AND 'food waste management hierarchy' OR 'food losses and waste management in low- and middle-income countries' AND 'food losses and waste in high-income countries' AND 'food losses and waste in African countries' AND 'best international practices for food losses and waste management'. Moreover, official government documents and reports from the United States Environmental Protection Agency (USEPA) for FW management and the FAO were used. Studies on the challenges of FLW management and COVID-19 were also consulted. The search was carried out from March to June 2022.

Studies that focused on FW management actions (FLW reduction), FLW definitions, and major findings on FLW management activities were included. In this study, peer-reviewed studies, review studies, feasibility studies, theses/dissertations and official documents considered relevant to policy formulation for the effective management of FLW were included. Studies focusing on relevant information regarding the protection of the environment and public health and/or potential initiatives or strategies to reduce FLW throughout the food supply chain were also considered. We did not impose any restrictions on the year of publication of the studies and study designs. Articles that described the production, benefits of food, and the use of various methods for food production without a primary focus on the generation of

FW, quantities, characterization of FW, and associated environmental and public health impacts, as well as potential strategies or practices to reduce FLW throughout the food supply chain in the waste management sector, were excluded.

The study starts by introducing FLW, followed by the status of the food supply chain in Africa, FLW as occurring in its different stages, and drivers of FLW and highlight approaches to its prevention and mitigation in Africa. Thereafter, the composition and characterization of FW are highlighted. It then elaborates on the status of FLW management in African countries. Then it focuses on the best international practices on FLW management in other countries such as the United States (US), France, Canada, Argentina, Asian countries and so on, to understand how/if the good practices in the prevention and mitigation of FLW could be adopted in African countries to improve food security, poverty and environmental health. It then highlighted the utilization of FW and its benefits followed by policy recommendations, barriers and implementation. Finally, the study discusses the study's limitations, conclusions and recommendations for future research and approaches that can be helpful to the decision-makers, policymakers and researchers in the waste management sector to strengthen institutional capacity to ameliorate the challenges of FLW management, and reduce amounts FLW being generated, and promote sustainable FLW management systems, and to promote the diversion of FW to animal feed production and compost, and for nutrient-rich soils in the African continent, and FW for digestion (e.g. digestate) to recover energy, and can be further processed to be utilized on soil enrichment in the African region.

Results and discussion

Based on the literature search from the selected databases, quantitative and qualitative studies were initially retrieved from each database-initially, by title and, then by abstract and full-text screening. From these, 488 were identified as potentially relevant, and 227 were included after a full-text review. Through the screening process, 109 studies were identified and found to be appropriate for the aim of this review and were assessed; the studies were from South Africa, Egypt, Morocco, Tunisia, India, Argentina, the USA, some European member states, China and Australia. These studies contained data on FLW management components, awareness of FW management and strategies or initiatives to potentially reduce FLW. Eight studies reported on the costs associated with FW management and assessed food wastage in the South African context. The remainder of the studies from other African countries reported on the reduction of FLW, the extent and causes of FLW, and the composition and characterization of FW scraps. Based on the retrieved studies from the different African countries, it was found that the research focus of most of the studies was on the reduction of food losses, that is, approaches to reduce food losses. Some of the studies of FLW management focused on organic FW, liquid FW, awareness on FLW management; costs related to FLW, the composition of FW and quantities of FW and described the potential strategies to reduce food scraps (e.g. composting of FW). In recent years, studies focused on systematic review and meta-analyses on FLW and PHL mitigation. Others focused on the comparison of FW management strategies between countries and sustainable management practices of FW. Most studies were exploratory studies, quantitative and qualitative studies. Most of the studies determined food losses using the FAO methodological designs.

The status of the food supply chain in Africa

Globally, around 1.4 billion hectares of land are used to grow food, accounting for roughly one-third of the world's total agricultural land area being used to grow food that is lost and wasted (FAO, 2013). Vorst (2015) distinguished two types of food supply chains, namely, supply chains for fresh agricultural products and supply chains for processed food products. He highlighted that 'supply chains for fresh agricultural products–entail growers, auctioneers, wholesalers, importers and exporters, retailers and specialty shops–deliver the original product from the production stage in the countryside to the customer'. Vorst (2015) also highlighted that supply chains for processed food products add considerable value to agricultural raw materials, thus extending the shelf life of these products.

In many African countries, the new international food security agenda prioritizes small farmers at the centre of its efforts to resolve the growing problem of food insecurity.

It is noted that crop supply chains typically consist of farmers whose produce is aggregated through formal or informal farmer groups

> to access some form of primary off-taker, for example, a local processor, retailer or multi-national cooperation. Established supply chains of this nature provide a good base to introduce post-harvest loss (PHL) reduction interventions as well as engage key stakeholders such as agro-dealers, farmer associations, and off-takers. (Crush and Frayne, 2010).

In most of the urban areas in the South African Development Community (SADC) countries, the informal sector plays an extremely important role in the food sector, whereas the private sector plays a significant role in urban agri-food chains (Crush and Frayne, 2010). It is suggested that in most of towns and cities in the Southern African region, the food supply chain rests on 'a very well developed, highly sophisticated food marketing [and production] system . . . and a well-organized informal food marketing system'. It has, however, been noted that, in Southern African context, the supply chains link sites of production to urban consumers. This might be because most urban households interact with the supply chain at the point of food purchase (from formal or informal retail outlets). Indeed, Crush and Frayne (2010) suggested that the major retailers, for example, Pick n Pay, Shoprite, Woolworths and so on, are only the public face of an integrated chain of distribution, wholesaling, processing, transportation and production. For instance, in the South African context, the major producers of foodstuffs for urban markets are large privately owned commercial farms and agribusiness estates and plantations, and supermarkets, which account for more than

55% of national food sales in the country. These findings regarding the food supply chain are corroborated by the results obtained in African countries, for example, Tunisia (Jribi et al., 2020), Algeria (Arous et al., 2018), Morocco (Abouabdillah et al., 2015) and Botswana, Malawi, Zambia and Namibia. This clearly demonstrates that the private sector is becoming increasingly significant in the urban food supply chain (Crush and Frayne, 2010).

Past research has suggested that in many African countries 'national governmental policies, the expansion and upgrading of infrastructure, primarily roads, rails, harbours, and communication networks, are of main concern'. 'Also, little or no collaboration among farmers, neither buyers nor suppliers are consumer-oriented, lack of reliability among food supply chain partners, government and society' (Ortmann and King, 2010). From governmental policy perspectives, 'at the producer stage, traditionally managed small-sized farms face technological, institutional and managerial innovations, while at the food processor stage innovations regarding the pre-treatment, preservation, handling, and packaging of food are major challenges in many African countries' (Gold et al., 2012). The United Nations Economic Commission for Africa recommends that African countries develop sustainable agriculture and increase food supply by reinforcing links between agriculture and other economic sectors, promoting sustainable agricultural production systems, and regionally integrating respective supply chains (FAO, 2018). FLW is predicted to increase due to a lack of policies on the management of FLW (Totobesola et al., 2022), exponential population expansion and consumption trends in African regions (African Development Bank [AFDB], 2020).

In the African region, it is suggested that food supply does not meet the required demand for the rapid population, with up to 650 million Africans-more than 50% of the continent's population lacking economic or physical access to sufficient food to meet their minimum daily needs. It has been noted that to satisfy the total food requirements of its population, most African countries depend heavily on food imports, spending over US$47 billion in 2018 to buy food on the world market. From 1998 to 2018, food imports shot up by over 1000% in Ethiopia and Ghana, by over 300% in Nigeria and Kenya and by 122% in Tanzania. It is noted that the average Kenyan still spends almost 50% of their income on food, and the average Nigerian almost 56% (Mitchelle et al., 2021). The growing reliance of most African countries on food imports is not only driven by population growth, but also a need to reach sustainable development goal (SDG) 2, which seeks sustainable solutions to end hunger in all its forms by 2030 and to achieve food security. The aim is to ensure that everyone everywhere has enough good-quality food to lead a healthy life. It is suggested that achieving this goal will require better access to food and the widespread promotion of sustainable agriculture (Gil et al., 2019; UNEP, 2021). It is, however, noted that food consumed has significantly increased, with increased food demand and changing consumption habits leading to rapidly rising net food imports, which are expected to grow from US$35 billion in 2015 to over US$110 billion by 2025. It has been estimated that the annual growth rates in consumption of livestock products up to 2050 in Africa – 3.3% for poultry and pork, 3.1% for eggs, 2.5% for beef and 2.2% for milk (FAO, 2019). However, this has also increased FW (e.g. in SSA, accounting for around 20% of cereals; 40–50% for root crops, fruits and vegetables; and 33% of fish). This has also increased FW, and threatened long-term food security in the African region. As such, African countries are experiencing FLW, posing a significant challenge to waste management infrastructure. Despite the fact that many African countries are experiencing significant FLW, there are limited initiatives, municipal budgets, limited composting facilities and policies to address FLW concerns and reduce FLW. This is accompanied by more reliance on disposal sites such as landfills, which impose environmental, social and economic costs. It has, however, been noted that studies that analyse the causes of FLW along the whole food supply chain in African countries are somewhat limited (Chalak et al., 2016).

Available data on FW amount in the different stages of the supply chain

Figure 2 depicts FLW at various stages of the food production process. In LMICs such as African countries, FLW are caused by: (i) lack of clear knowledge of the real magnitudes of losses and quantification of PHL in SSA; (ii) poor post-production infrastructure for handling perishable produce across SSA; (iii) poor handling during transportation; (iv) poor processing, preservation and storage technologies used in SSA (Affognon et al., 2015); (v) the fact that most of the existing PHL technologies remains meagre; (vi) inadequate storage technologies; (vii) inappropriate practices in harvest and post-harvest handling (e.g. poor sorting techniques); (viii) adoption of inappropriate PHL interventions; (ix) poor shelf-life technologies (e.g. first-expired-first-out); (x) poor infrastructure and lack of established PHL technologies; (xi) lack of rural financial market and credit access by farmers; (xii) slow technology uptake; (xiii) information constraints and bottlenecks within the rapidly evolving value chain; (xiv) inefficient markets and value chains with the benefit of reducing PHL; (xv) households over-purchasing in order to avoid stock-outs, resulting in greater PHL; (xvi) diversifying diets towards more perishable meat and fruits and vegetables; (xvii) use of poor varietals, on-field pest control and crop disease prevention; (xviii) unsafe food from the systems before it reaches consumers; (xix) not diverting inedible food towards safe composting or energy creation and (xx) poor institutional and physical marketing infrastructure (Sheahan and Barrett, 2017).

Meanwhile in high-income countries (HICs), FLW (i.e. FW from customer, logistics and farm) are caused by: (i) consumers preparing and serving more food than they can consume (e.g. at household levels, it is caused by excessive purchasing; the other is that the wrong packing methods have been used); (ii) logistics: processing, transportation and distribution constraints (i.e. limited timeframe and the high-standard storage environment, lack of unified processing standards are the reasons for FW in the logistics stage, caused by normal wastage in the processing, such as eliminating bones and root, and other waste during processing

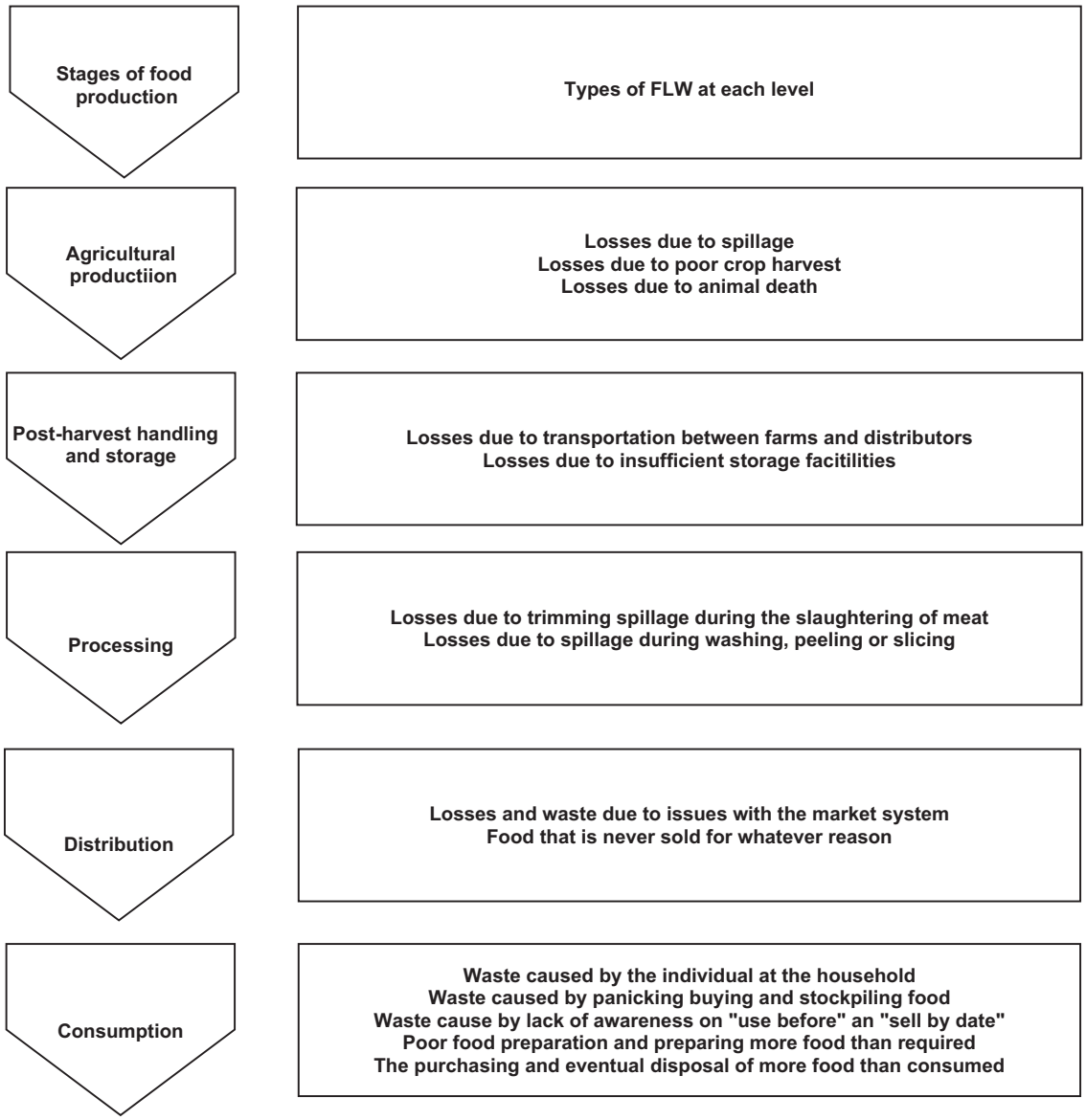

Figure 2. Food supply chain stages and examples of causes of food losses and waste.
Source: Revised by the authors from retrieved literature.

resulting from uncontrolled temperature); the cold-chain logistics system not meeting the market demand and extreme weather events, which reduce production, and inappropriate harvesting and post-harvesting storage methods in the field and (iii) farm level constraints (i.e. ignorance of the preservation tasks from the first step of production transportation, fresh food will lose the ability to keep fresh, even if these foods have support from advanced cold-chain logistics by the farmers, and overproduction in the production terminal is overproduction (i.e. fresh products' supply exceeds demands from the market due to wrong predictions) (Li and Pan, 2021).

Research has suggested that FLW occurs in each stage of the food supply chain: harvesting, transport, storage, packaging, processing, wholesale and retail trade, and where food is consumed (Arous et al., 2018; Gustavsson et al., 2011). Elmenofi et al. (2015) also highlighted that FLW is generated through the whole food supply chain. This finding was corroborated by Abouabdillah et al. (2015) who indicated that FLW is generated in significant quantities across the food supply chain, from production to consumption, posing a threat to the environmental, social and economic costs. A study by Kummu et al. (2012) in SSA, has reported that food losses at the consumption stage are very low compared to the industrialized regions. It is, however, been noted that more food wastage occurs at the consumption stage compared to other stages of the food supply chain such as production and harvesting, storage, transport and/or processing. For example, in SSA, it has been reported more than 90% of FW occurs before to the consumption phase (FAO, 2011; Reynolds et al., 2019). Meanwhile, in HICs such as in Europe, the largest single contribution is reported to come from the consumption stage – with much of that at the household level, with around 50% of wasted food estimated to come from households (Reynolds et al., 2019; Stenmarck et al., 2016).

The situation of food losses generated in farms has been reported in Asian countries such as China (e.g. the average production of meat, aquatic products, dairy products and eggs

adding up to 4.9 million tonnes 3.8 million tonnes 1.7 million tonnes and 1.1 million tonnes, respectively between 2015 and 2019) (Wang et al., 2023) and India, with over 50 kg of food wasted per person per year or 68,760,163 tonnes a year (UNEP, 2021). In these countries, this became challenging when lockdowns were implemented during the COVID-19 pandemic. As consequence, a huge amount of FW was generated from regular human activities. In the African region, this was especially a challenge in Tunisia, whereby online shopping had a strong relationship due to panic buying, which lead to increased FW (Jribi et al., 2020). This inevitably caused a significant increase in the amounts of food wasted unpredictably. The increasing amounts of FW generated, and its inappropriate means of disposal have continued to pose a negative threat to public health and the environment.

Food waste is generated throughout the manufacturing process in LMICs, whereas it is mostly driven by retailers and consumers in HICs (Arous et al., 2018; Parfitt et al., 2010). Consumer behaviours such as cooking portions have increased over time, and large meals often include more food than can be finished, and people often forget to eat leftovers and end up throwing them away. Personal, cultural and religious values and ideals are also viewed as a major contributor to increased FW generation during the consumption phase. Researchers (Arous et al., 2018; Lundqvist et al., 2008; Katajajuuri et al., 2014) have pointed out that the losses occur in the first part of the food chain due to poor harvesting, transport and storage and are more important. The majority of food losses in industrialized countries, HICs, and MICs occur at the retail and consumer level (Gustavsson et al., 2011). In the African context, exploratory studies in Egypt (Elmenofi et al., 2015), Morocco (Abouabdillah et al., 2015) and Algeria (Arous et al., 2018) found that food consumption patterns had implications on the amount of food lost and/or wasted, corresponding to 'at least 250 g of still consumable food thrown away weekly by households' (Elmenofi et al., 2015).

Meanwhile, research in many African countries suggested that food is mainly wasted at the consumer level particularly at restaurants, caterers, cafeterias and, especially, by households (Odalepo et al., 2015; Oelofse et al., 2021; Orhorhoro et al., 2017). In the Near East and North Africa region, it is projected that FW is approximately 250 kg year^{-1} individual^{-1} and mainly at the consumption stage, that is, household and/or food service sector or even retail corresponding to 34% (Institute of Mechanical Engineers [IME], 2015; Jribi et al., 2020). Research has reported that the annual per capita FW generation in North Africa, West and Central Asia region generated throughout production, handling, processing, distribution and during consumption, mostly in urban centres, accounting for approximately 68% of food wasted (Baig et al., 2019). Regarding the yearly percentage of FW per individual, studies (FAO, 2013; Jribi et al., 2020) reported that North Africa and Central Asia accounted for about 16%, whereas food wastage in Europe, Asia, North America and Latin America accounted for 34, 31, 39 and 11%, respectively (FAO, 2013). It has been reported that household FW corresponds to approximately 30% of total FW (Berjan et al., 2018). In SSA, 39 and 37% of FW occur at the handling and storage levels, respectively, adding up to 76% of average FW upstream of the supply chain (Sheahan and Barrett, 2017). More than two-thirds of food losses in LMICs, notably in African nations, occur at the postharvest and processing levels due to poor agricultural practices, technological and financial, and labour restrictions. This is also due to poor infrastructure for storage, processing and transportation (Chalak et al., 2016; Kosseva and Webb, 2013; Nellemann et al., 2009).

It has been observed in HICs that a significant fraction of food wastage rather happens at the level of consumption mainly driven by consumers' values, behaviours and attitudes (Schanes et al., 2018). Table 1 shows available information about the differences in FW generation between income groups in some African countries. The findings from Table 1 present a mixed image, which is to be expected, generally high-income households have higher FW than low-income households (UNEP, 2021). This information could be important to develop sustainable FLW management strategies. It has, however, noted that, in many African countries, even at the consumption level, studies on behavioural and attitudinal aspects relating to food wastage are lacking. Nearly all African countries have no FLW management policies at the local level. The retrieved literature also demonstrates that the local level, sorted waste collection and research are remarkably lower among the African countries, suggesting that most countries need significant room to improve FLW management efficiency.

The drivers of FLW and approaches to its prevention and mitigation

Research has indicated that FW generation is influenced by several factors, namely, in-store behaviour (related to over-shopping) and household management practices (poor planning/food management, storage problems, etc.). Psychosocial factors (i.e. personal choice and lifestyle, food habits and lack of cooking skills) are also viewed as drivers of FW (Aschemann-Witzel et al., 2016; Farr-Wharton et al., 2014; Jribi et al., 2020). Thi et al., (2015) suggested that people generally have a perception about the importance of not throwing away food. Interestingly, communities' awareness of source separation, collection, and utilization of FW is significantly lower in African countries like Tunisia and is influenced by wasteful consumption practices (Jribi et al., 2020), whereas in restaurants, markets or retail outlets, the unsold commodities and FW are directly turned into MSW. As noted by researchers and analysts (Nahman et al., 2012; Oelofse and Nahman, 2013; Schanes et al., 2018; Thi et al., 2015), food wastage activities are linked with social, practical and consumer behavioural trends. The main reason is that there are no well-established strategies or regulations for encouraging societies to save and recycle FW (Thi et al., 2015; Oelofse et al., 2021).

Studies highlighted that drivers of FLW differ between HICs and LMICs due to numerous factors (Oelofse et al., 2021; Rutten and Verma et al., 2014; Sharma et al., 2022). For instance, in HICs, the education level is often high in FW management-relate issues, whereas in LMICs, the education level is generally low

Table 1. Some of the studies undertaken on FW management in African countries.

Country	FW category	FW estimate (kg capita^{-1})	Year
Algeria	Cereals and bakery products, root, and tubers (potatoes), fruits and vegetables, meat and meat products, dried vegetables and oilseed, fish and seafood, milk and milk products	At least 0.25 kg week^{-1} of consumables	2018
Egypt	Fruits, vegetables, cereals and bakery products, pulses and oil seeds (e.g. peas, chickpeas, olives, sunflowers), meat and meat products, fish and seafood, milk and dairy products, roots and tubers (potatoes, etc.)	At least 0. 25 kg week^{-1} of consumables	2015
Tunisia	Fish and seafood, meat and meat products, pulses and oils, roots and tubers, cereals (e.g. pasta, couscous), milk and dairy products, fruits, vegetables, bread and baked goods	Unspecified	2020
Morocco	Fish and seafood, meat and meat products, pulses and oils, roots and tubers, cereals (e.g. pasta, couscous), milk and dairy products, fruits, vegetables, bread and baked goods	Unspecified	2015
Nigeria	Vegetables: Onions (green), tomatoes, chilli peppers	3148.8 kg production^{-1} day^{-1}	2015
Ethiopia	Unspecified	92 kg capita^{-1} year^{-1}	2017
South Africa	Unspecified	9.04 million tonnes per annum in 2007 (estimated at 177 kg capita^{-1} annum^{-1} and consumption waste at 7 kg capita^{-1} annum^{-1})	2013
	Unspecified	10.3 million tonnes per annum of food and beverages wastes (about one-third of food available)	2021
	Cereals, roots and tubers, oil seeds and pulses, fruits and vegetables, meat, fish and seafood, milk and eggs	Unspecified	2019
	Unspecified	0.48 kg (Ekurhuleni) and 0.69 kg (Johannesburg) of FW disposed of into the municipal bin per household per week	2018
Republic of Tanzania	Dairy products, vegetables, grain products, fruits, sugar/sweeteners, meat, poultry and fish, fats and oils, eggs	Unspecified	2019
Kenya	Fruit and vegetables, meat and fish	Unspecified	2019
Ghana	Cereals, tubers and suckers	Low 80, middle income 86 and high income 86 kg capita^{-1} year^{-1}	2015
	Paddy, fruits vegetables and nuts, maize, fish and oilseeds	0.23 kg person^{-1} day^{-1}	2015

Source: Reversed by authors from retrieved literature (2023).
FW: food waste.

(Schanes et al., 2018). In fact, lower education levels in LMICs, such as most African countries, lead to people not paying considerable attention to FW disposal (Maduhu et al., 2019).

In Africa, a study in Tunisia by Jribi et al. (2020) highlighted that social and religious occasions such as the holy month of Ramadan increase food wastage, which is ascribed to the preparation of meals that largely exceed families' needs. In terms of the association between Ramadan and food waste behavior, these findings were supported by research from other African nations, such as Algeria (Arous et al., 2018), Egypt (Elmenofi et al., 2015) and Morocco (Abouabdillah et al., 2015). It should be highlighted, however, that this is contrary to Islamic teachings, which prohibit wastage in every aspect of life. In the South African context, a review assessed the cultural practices and their influence on FW and found that cultural and social events, when food is prepared in large quantities, remain a primary driver of FW. It is noted that this food ends up not being wholly consumed, thus resulting in increased FW that gets disposed of at landfill sites. To curb food wastage or reduce the generation of FW food wastage challenge, the study advocated for the government of South Africa to institute awareness-raising measures to inform and disseminate information to communities about FW management. It has been found that this can assist in the reduction of the emission of GHGs from FW while also protecting the environment, and public health (Phasha et al., 2020).

It is increasingly acknowledged that cultural and social events, habits and a lack of knowledge can all contribute to FW (FAO, 2013). Other drivers that contribute to FW in African countries include a lack of awareness; insufficient and inappropriate planning when shopping. It has been found that in African countries, the instrumental factors include cultural practices or policy framework issues, which lead to food wastage. Post-harvest food losses in SSA are estimated to be around US$4 billion year^{-1} – or enough to feed at least 48 million people (WWF, 2017). It has been noted that FW in restaurants, celebrations, social events and occasions is enormous. For instance, during festivals and special events, the custom is to provide more food than required (World Bank, 2011). Researchers (Arous et al., 2018; Elmenofi et al., 2015) have found that the average share of household income used for food in Algeria (average national guaranteed wage) is US$133.3 month^{-1}, whereas their neighbours (Morocco) average household income used for food is approximately US$89.95 month^{-1}, and Egyptians spend about 37% of their income (i.e. approximately 630 Egyptian Pound (EGP) month^{-1}) on food (Abouabdillah et al., 2015; Elmenofi et al., 2015). Serving styles and time are seen to be the most important factors in FW generation in the hospitality industry (e.g., hotels or at seminars). Therefore, there is a need to focus on the development of FW reduction strategies to improve environmental health, food security and poverty and on raising the awareness of food providers.

It has also been suggested that in many African countries, consumers' poor understanding of the two date-markings on products, namely 'use by' (relating to food safety) and 'best before' (relating to food quality), may contribute to FW at the household level (Abouabdillah et al., 2015; Arous et al., 2018; Venter, 2017; Weber, 2020). In contrast, in the US, federal law mandates manufacturers of processed items to use three separate dates on the packaging: 'sell-by' or 'best if used by', with 'use-by' being the first expiration date for the product to remain on the supermarket shelf (National Institute of Standards and Technology [NIST], 2013; Newsome et al., 2014). This is a confusing approach in the context of African nations since some of the countries have adopted the expiry date of the items, which shows the point at which food would expire but does not suggest that food past the date will 'automatically become poison'. For instance, research indicated that 60% of Egyptian respondents (Elmenofi et al., 2015) and 70% of Algerian respondents (Arous et al., 2018) were confused between the two labels, that is, 'use by' (i.e. they the statement indicates to consume or throw food before this date) and 'best before' (i.e. they think it means that food must be consumed before or discarded after that date) (Elmenofi et al., 2015), which increases the amount of FW (Arous et al., 2018). In the case of Morocco, household planning and shopping activities are important predictors of FW (Abouabdillah et al., 2015).

Sources and composition of FW

The status of the household such as low-income, middle-class and affluent households elicit a stronger relationship on the composition of FW and correlates with demographic factors such as age and gender as well as the household income and the number of people residing in a household (Chalak et al., 2016; Jain et al., 2018; Schanes et al., 2018). The evidence further suggested that during rainy seasons, the wastes tend to be wetter (Papargyropoulou et al., 2016). Table 2 summarizes some of the studies on FW management in the African continent. The studies reported on exploratory data on various FW from households and retail services ranging from fruits, vegetables, cereals and bakery products, pulses and oil seeds (e.g. peas, chickpeas, olives and sunflowers), meat and meat products, fish and seafood, milk and dairy products and roots and tubers (potatoes, etc.). From Table 2, it can be noted that the concerns about FW management applications seem to be concentrated in South Africa (Table 2). For instance, South Africa accounted for 30.8% of the research (four studies); this was followed by Ghana with 15.4% (two studies) and Tunisia, Ethiopia, Morocco, Algeria, Kenya and the United Republic of Tanzania with 7.7% (one study each).

The centralization of research in South Africa is in line with the government's strategic priority to reduce FW by 50% by 2030 and improve renewable energy generation, as stated in the National Waste Management Strategy 2020, which is part of the government's strategic priority to reduce waste disposed of in landfill by 45% by 2025. This has identified FLW as a critical area requiring action (Department of Environment, Forestry & Fisheries [DEFF], 2020). This is also in line with the implementation of the extended producer responsibility scheme for packaging products, which was originally published in November 2020, under which producers are given significant responsibility – financial and/or physical – for the treatment or disposal of

Table 2. Studies providing results of FW by income groups in some African countries.

Author	Country	Area	Methodological notes	FW by income group (kg capita^{-1} year^{-1})		
				Low	Middle	High
Nahman et al. (2012)	South Africa	Nationwide	Income group waste rates derived from secondary literature observations, combined with national waste statistics	27	30	45
Oberlin (2013)	United Republic of Tanzania	Kinondoni municipality, Dar es Salaam	75 households sampled in total, only in middle- and low-income settlements, primarily high population density informal settlements. Three days' waste collected	98	142	
JICA (2010)	Kenya	Nairobi	150 households sampled in total. One week's waste collected	78	114	151
Takeuchi (2019)	Kenya	Nairobi	90 households sampled in total. One week's waste collected	40	176	125
Miezah et al. (2015)	Ghana	Nationwide	1014 households sampled in total across 10 districts nationwide, sampled for a period of 3–5weeks	80	86	86
Ramukhwatho (2016)	South Africa	City of Tshwane	210 households participated in the study that used a purposive sampling method	6 kg household^{-1} week^{-1}	6 kg household^{-1} week^{-1}	6 kg household^{-1} week^{-1}
Oelofse et al. (2018)	South Africa	Johannesburg	74 waste collection routes covering 44 927 households	0.69 kg week^{-1}	0.69 kg week^{-1}	0.69 kg week^{-1}
	South Africa	Ekurhuleni	41 routes covering 20 439 households	0.48 kg week^{-1}	0.48 kg week^{-1}	0.48 kg week^{-1}

FW: food waste.

post-consumer products, and the Food and Packaging Waste Prevention and Reduction Initiative, which seeks to address food security from the perspective of avoiding FW (DEFF, 2021). No studies were found reporting on FLW undertaken from other southern African countries such as Botswana, Malawi, Lesotho, Eswatini, Zimbabwe, etc. Notably, the majority of the studies focused on the awareness and costs of FW management.

Most FWs have been characterized as easily degradable, with high moisture content, low pH and high solubility, which gives it higher energy content per dry mass (Slopieck et al., 2022). FW has been characterized in numerous ways, including natural resources (Shurson, 2020), cooking food, human food chain level and physical state (Nath et al., 2023). Agriculture is the initial link in the food chain, followed by warehouses and businesses such as flour mills and food preservation factories (Bartali et al., 2022). In this human food chain, FW can be divided into the following categories: (i) agro FWs derived from farmers, (ii) industrial FWs derived from wholesalers, (iii) market FWs derived from secondary distributors, (iv) hotel and restaurants FWs derived from secondary distributors in the form of cooked products and (v) domestic FWs derived from customers (Nath et al., 2023). Figure 3 depicts an overview of categorization of FW.

A survey conducted in the selected areas of the City of Tshwane Metropolitan in South Africa, 35% of households threw away pap (referred to as maize porridge), 26% wasted rice, 25% bread and 14% fruit and vegetables (Ramukhwatho, 2016). Another study by Ramukhwatho et al. (2014) in Mamelodi, South Africa, found that most of the food wasted included porridge (58%), referred to as 'pap' as a staple food, followed by rice (26%) and bread (16%). These studies demonstrated that the majority of food that is wasted is cooked rather than uncooked. Available regional estimates by food products suggested that at the consumption level in North Africa, West and Central Asia, wasted food comprises 45% fruits and vegetables, 28% fish and seafood, 26% roots and tubers, 18% dairy products, 14–19% grains, 16% oilseeds and pulses and 13% meat (Berjan et al., 2018). This scenario translates to fruits and vegetables among the highly discarded food category, which is common internationally given their perishability. These food categories are easily degradable, have higher energy content per dry mass and compostable and are rich in organic carbon and other elements, including nitrogen, phosphorus and potassium, which cannot be wasted (Slopiecka et al., 2022). It has been noted that FW has a moisture content of 74–90%, a high percentage of volatile solids (around $85 \pm 5\%$), and a pH of about 5.1 ± 0.7 (Fisgativa et al., 2016).

Most household waste food categories include perishables like fresh fruits and vegetables, bread, and so on (Fanelli and Di Florio, 2016; Schanes et al., 2018 Szabó-Bódi et al., 2018). For instance, in Tunisia, it has been often noted that bread is the most wasted food product. A survey in Algeria found that cereals and bakery products are the most wasted products in households, corresponding to more than 20% of purchased cereals and bakery products followed by vegetables and dairy products. Actually, Algerian cuisine is mainly based on bakery products (e.g. couscous, chakhchoukha, etc.) and bread (Arous et al., 2018).

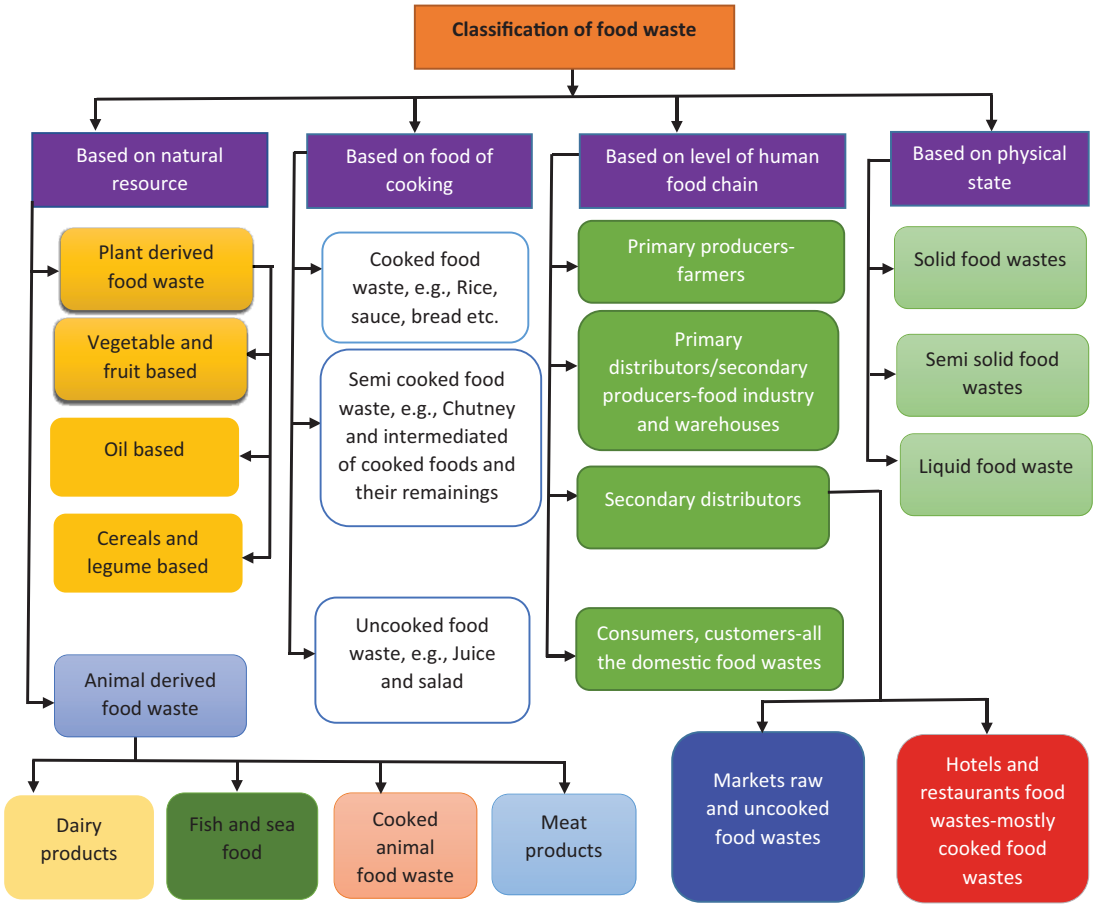

Figure 3. Overview of classification of FW.
Source: Adopted from Nath et al. (2023).

In the Tanzanian context, research has noted that hotels are the main sources of FW compared to other institutions within the food service sector. Quick-service restaurants, fast food services, and residential and industrial settings are among the other sources for FW. The findings showed that vegetables have a significant percentage of FW compared to other institutions within the food service sector. It has also been reported that dairy products, grain products, fruits, sugar/sweeteners and meat, poultry and fish are other constituents of FW (Maduhu et al., 2019). This demonstrates that the proportion of this FW can be utilized for composting and digestate in waste-to-energy (WtE) projects (e.g. production of biogas) because of higher energy content per dry mass. However, the study did not provide information on the characterization of FW from these sectors. Understanding the characteristics of FW is important to assist in the development of sustainable FW management initiatives.

Status of FLW management in African countries

In many African countries, different approaches have been adopted to prevent and mitigate FLW (Schanes et al., 2018). In most African countries, FW is currently utilized in compost mixtures for soil fertilization. It is, however, been noted that some of these are indiscriminately disposed of in open space which causes unpleasant odours and leads to harming natural resources (FAO, 2011). Although landfilling is not considered a sustainable option in the long term (Sinha and Tripathi, 2021), most FW is predominantly landfilled, which corresponds to approximately 90% of total FW. When organics such as FW are disposed of in landfills, considerable volumes of LFG are produced, posing a threat to the environment and public health. LFG comprises methane (50–60%), carbon dioxide (CO_2, 40–50%), less than 1% ammonia, oxygen, non-methane organic compounds (e.g. acrylonitrile, benzene, 1,1-dichloroethane, CO_2 and nitrogen (2–5%), a powerful GHG, from the decomposition of organic (Paritosh et al., 2017)). Figure 4 summarizes the situation of FW management and valorization. Please joins this sentence with the preceding sentence.

Research has indicated that valorization of FW through integrated biorefinery conversion to valuable chemicals, energy and consumer products might be viable alternatives both in terms of economics, sustainability and social and environmental impacts (Isah and Ozbay, 2020). It is further noted that valorization using FW has a multitude of benefits such as the generation of renewable energy, reduced emission of GH, decreased dependency on fossil fuel and improved food and energy security, health and sanitation, water bodies protection, self-sufficient and resilient communities (Sinha and Tripathi, 2021).

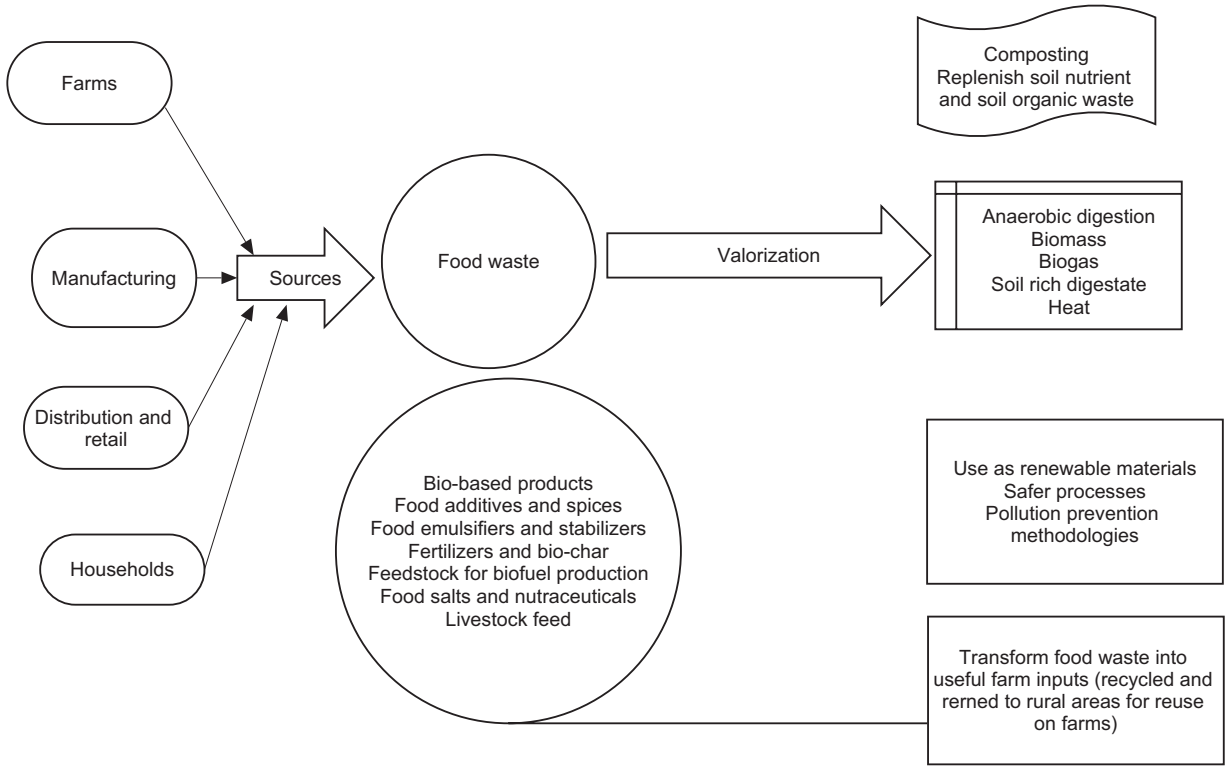

Figure 4. Food waste sources, their valorization methods and reported products from studies related to Africa.
Source: Revised by authors from retrieved literature.

The use of FW as substrate in compost is also adopted (with a rate ranging from 1 to 6%), followed by anaerobic digestion (AD) (with a use rate of under 0.6%) (Paritosh et al., 2017). It has, however, been noted that food wastage's carbon footprint is estimated at 3.3 billion tonnes of CO_2, which is the equivalent to GHG released into the atmosphere per year (FAO, 2013). Recent research has also noted that the utilization of food resources through AD are not yet being adequately utilized in some African countries (Maduhu et al., 2019; Thi et al., 2015). The utilization of FW for soil nutrient enrichment is lacking (Mmereki et al., 2016). This may be due to inadequate diversion of FW and food scraps for energy recovery. This might be a primary concern in waste management systems because of waste separation issues (Haile and Abiye, 2012).

While some African countries, such as Botswana (Charis et al., 2019), South Africa (Mukumba et al., 2016), and Nigeria (Itodo et al., 2021), have implemented technologies such as biogas technology, the majority of them are ineffective due to a lack of a maintenance culture. Similarly, compost of FW does exist in African countries, but most of these activities are on a small scale, whereas usage of FW for animal feed production remains largely lower or non-existent. It has been noted that there remain some inadequacies of compost production in most African countries, which is triggered by unpurified waste feedstock, resulting from the piecemeal source-segregated FW systems (Paritosh et al., 2017).

In most African countries, FW incineration and food scrap diversion for animal feed production are uncommon (Thi et al., 2015). In African countries, namely, Liberia, Nigeria and so on, FW management is nascent, that is, FW management strategies or guidelines remain in infancy. For instance, in the Liberian context, it has been reported that the country seems behind in terms of the legislative framework for the utilization of FW as a digestate for compost and energy recovery. This is accompanied by limited strategies for prevention and sustainability and no incentives for waste reduction. Actually, in Liberia, to a lesser extent, there is limited and/or non-existent research in the field of FW. It is, therefore, noted that recycling operations are mainly undertaken by the informal sectors, and only 8% of total FW generation is recycled and used to produce compost (David et al., 2020). In the cases of the two states of Southwestern Nigeria (Lagos and Oyo States), it was found that the food processing firms generate a huge amount of solid (e.g. fruits, vegetables, meats, bread, grains, egg shells, etc.) and liquid wastes, such as oils, milk used oil, fats and grease, are not appropriately managed. This scenario is explained by the possibility of a lack of reuse and composting of their FW that litters the street. It has also been noted that there are little or no available statistics on the actual quantity of FW produced. This is exacerbated by inadequate, and inconsistent Nigerian government policy, technology and facility for separation of wastes at source, finance and a lack of involvement of the public or limited concern about FW generated by their products outside the firm (Soethoudt et al., 2021). From the research and development perspective, there are limited published works on the current recycling activities. For African countries to compete in the 21st global economy, there is a need to strengthen their systemic and institutional level capacity and utilize FW as a resource for energy generation and FW composting.

African countries, such as Tunisia, have launched the SDG 12.3, through the participation of national institutions and non-governmental organizations. The main objective is to halve per-capita FW at the consumer level by 2030 (e.g. covering private households as well as food services). However, there is often limited impact. This is because approximately 900,000 baguettes of bread are thrown daily produced from over 3170 classified bakeries (Jribi et al., 2020).

A survey in Algeria has reported that there is a high level of awareness among Algerian households about the adverse economic and environmental impacts of FW in short and long time. The results study showed that there is a readiness of more than 90% of Algerians to change their behaviour to reduce food wastage (Arous et al., 2018). However, in other African countries such as Morocco, more attention is paid to food losses while FW is generally overlooked, with fewer research activities on this problem (Abouabdillah et al., 2015). With these factors such as a lack of accurate statistics and data on food waste in African countries, there is an urgent need to provide relevant information on the magnitude and extent of FLW in the African region and strengthen policies and financial support for the utilization of FW fractions that can be exploited for fuel conversion and food scraps for digestion to energy recovery and creation of nutrient-rich soil. Therefore, this should be an obligation for African countries to report food losses to FAO, and to report FW to UNEP in the future according to the published methodologies from both UN organizations.

Best international practices in FLW management

The integration of source reduction mechanisms, that is, reducing the volume of surplus food generated and feeding the hungry and diverting food scraps to animal feed production, fuel conversion and food scrap for digestion to recover energy and creation of a nutrient-rich soil amendment are viewed as critical components throughout the FLW management cycle. An integrated and systemic level approach is required to achieve a significant and sustainable reduction in FLW. This includes reducing the volume of surplus food generated to improve environmental health and food security, as well as providing financial support for long-term operations for sustainable FW management. These are viewed as the best international practices to prevent and divert wasted food because they create the most benefits for the environment, society, and the economy (Eriksson et al., 2014). From the recovery of nutrients and energy production perspective, a well-functioning source segregation system of organic waste such as FW is a vital component in improving of FW management system efficiency (Chaboud and Daviron, 2017). There are, however, differences in the collection systems in various municipalities in LMICs: some cities have separate collections of FW, whereas others collect a wider range of organic material, that is, comingled disposal of FW with other waste streams.

Recently, best international practices in FLW management have been characterized by sustainable development practices (i.e. digestion of FW to recover energy, and strategies ranging from FW prevention to food surplus redistribution and FW reuse) (El Bilali and Hassen, 2020) and use of innovative technologies (rendering, transesterification, pyrolysis and refuse-derived fuel, and recycling of FW waste into products such as biofuels, biochar or compost). In a study by Rehan et al., (2018), the authors highlighted that biodiesel production from FW sources such as fats, oils and grease in Saudi Arabia could between 1.08 and1.41 million tonnes, with an energy potential of 43,423−56,493 TJ by 2030. This is an important aspect of reduction of FW to promote environmental health.

One of the best mechanisms to follow in the FW management sector can be the reduction of FLW to improve food security and protect the environment. This also involves the adoption of activities as illustrated in Figure 5 that stakeholders may use to prevent and convert FW into biogas and compost. Based on these activities, the prevention and diversion of wasted food are the best ways to reduce FLW because they create the most benefits for environmental sustainability, society and the economy. It has been suggested that this is because growing food requires resources, such as land, water, fertilizer and pesticides (High Level Panel of Experts [HLPE], 2014).

In other instances, mandatory regulatory strategies, diversion of FW from landfills and the prevention of FW have been implemented and adopted in HICs (mainly the US and European Union (EU) member states) in response to the reduction of the volume of surplus food generated (HLPE, 2014). For instance, in the USA, there is a growing national, regional and international impetus to address FLW. This includes FW-related policies and programmes, the 2030 Development Agenda and the food recovery hierarchy, which is very important to prevent waste at the source before it is created, and then fresh food which is still consumable may be donated to feed those in need. It has been noted that the food hierarchy encourages feeding pets with fresh food scraps and turning fats, oils and grease into useful products such as biofuel, and using FW to nourish the soil. Based on the food recovery hierarchy, the disposal of food scraps in landfills should be considered the last resort (USEPA, 2014). Other HICs have implemented economic incentives, such as fees, taxes and subsidies, to reduce FW (Edjabou et al. 2016). Accordingly, these are considered effective tools to shift consumption patterns towards more sustainable FW management practices (Reisch et al., 2013).

Countries such as Canada, Sweden, Japan, Taiwan, Korea, Thailand, Vietnam, China and the USA have implemented the volume-or-mass-based ‘Pay-As-You-Throw’, an effective scheme to reduce FW by charging households for personally generated waste (Schanes et al., 2018). Some of the EU member states such as France, Italy, Belgium and the Netherlands have adopted regulatory approaches such as waste reduction targets, laws and standards, mandatory management plans, restrictions or covenants aimed at inducing waste reduction and prevention behaviour through the introduction of penalties for actors who do not comply with regulatory provisions. In France, the National Pact against Food Waste outlines 11 measures as detailed in Mourad (2015) and Schanes et al. (2018), which offer a rich set

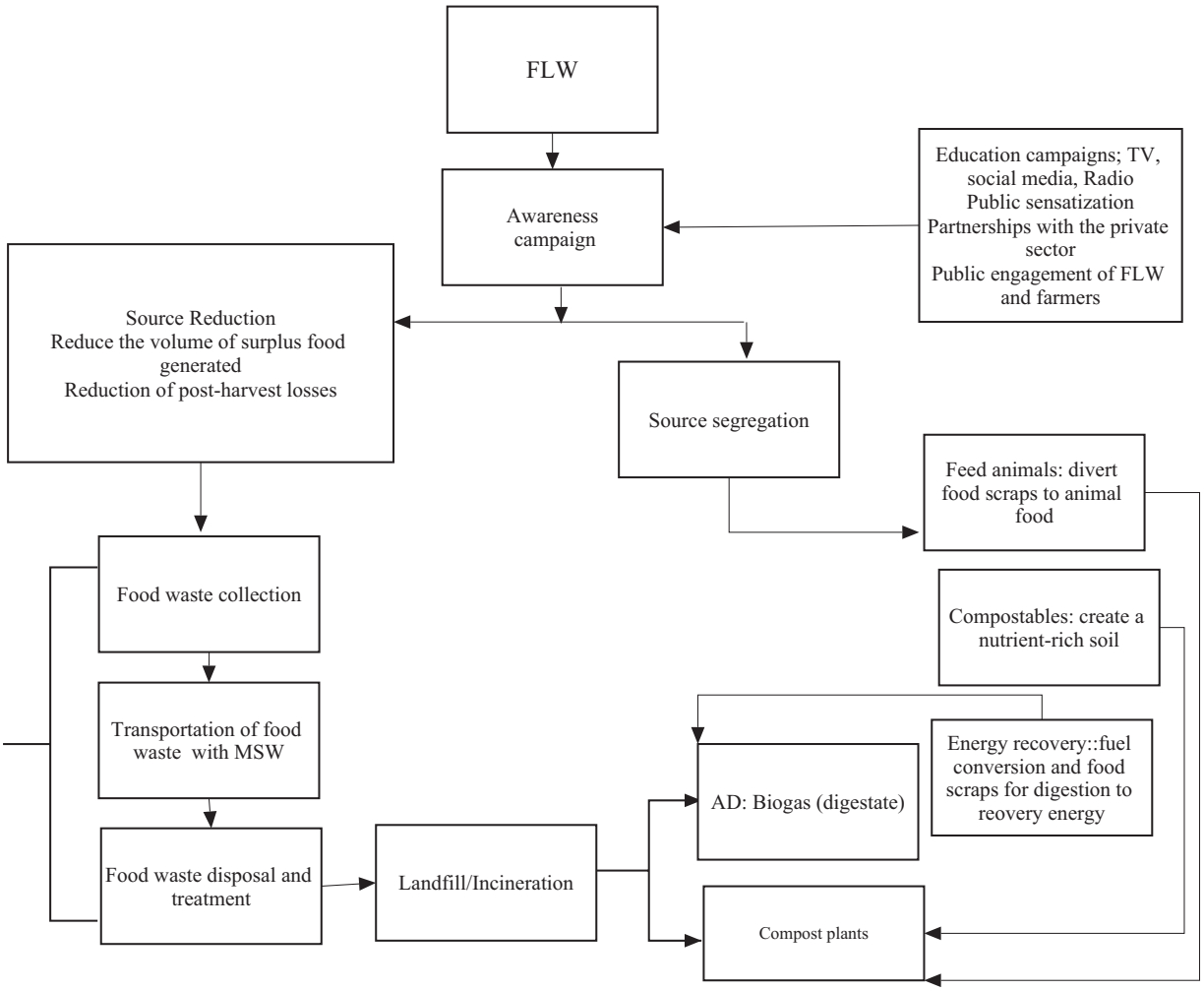

Figure 5. Proposed regulatory approaches for prevention of FLW.
Source: Revised by the authors from retrieved literature.
FLW: food losses and waste.

of ideas for prevention, recovery and recycling such as a ban on supermarket FW and to achieve FW reduction by 50% by 2025 (IME, 2015). This is based on per-person estimates of the level of FW, about 300 pounds per person per year in France, which reflects a crisis in food production and consumption systems (Mourad, 2015).

Other approaches implemented in Europe are the improvement of consumers' knowledge to raise awareness about FW prevention, recycling and recovery through the dissemination of information and education campaigns (Schanes et al., 2018). These approaches demonstrate that the EU member states have given priority to achieving sustainable FW management systems. Especially, these efforts are geared towards meeting the SDG (12.3), which includes the target to halve per-capita FW at the consumer levels and retail by 2030 (Baig et al., 2019; Jribi et al., 2020; Schanes et al., 2018).

In Latin America and the Caribbean (LAC) countries, there is a growing interest in the research, promotion and implementation of various waste management alternatives, such as sorted waste collection, recycling and WtE approaches. Research and policy initiatives on sustainable and circular production models (SCPMs) prioritize bioenergy and biofuels as leading possibilities for the valorization of the organic fraction of municipal solid waste (OFMSW) such as FW (Ulloa-Murillo et al., 2022). One of the major priorities in LAC was reflected in the circular economy (CE) and bioeconomy as the primary drivers of waste recovery and/or valorization. Policy strategies in LAC have undergone a significant transformation, shifting away from traditional collection and final disposal systems in landfills to achieve the goals of the 2030 Agenda (Savino et al., 2018). In Argentina, co-digestion of sewage sludge and OFMSW could result in a unified WtE process, amplifying economic benefits and minimizing environmental impacts (Morero et al., 2017).

Garcia-Peña et al. (2011) studied the practicality of hydrogen (H_2) generation under batch circumstances using fruit and vegetable waste (FVW) supplied from local markets in the Mexican context and discovered that H_2 production from FVW is a novel and feasible energy technology. Research has noted that these countries have made progress in implementing public policies for integrated MSW management based on SCPMs (Duque-Acevedo et al., 2020a; Duque-Acevedo et al., 2020b; Ulloa-Murillo et al., 2022). LAC countries have considerably

enhanced the conversion of waste into valuable goods (organic amendments, animal feed, bioenergy and biofuels), contributing to the establishment of new markets (Schröder et al., 2020; Ulloa-Murillo et al., 2022). In Mexico, a study by Garca-Pea et al. (2011) focused on the feasibility of using FVW from a food distribution market as a substrate for AD and discovered that pH control and nitrogen addition improved AD performance and co-digestion with meat residues allowed for better results (Garca-Pea et al., 2011). In the case of SCPMs, it is noted that the organic percentage of MSW is a crucial raw resource (Pavolová et al., 2020).

In Asia countries, the existing FW management policies emphasized FW segregation and treatment instead of prevention at the source itself. It has, however, been noted that animal feed production, incineration and landfilling are unsustainable since they pose various health and environmental hazard risks (Joshi and Visvanathan, 2019). To promote energy recovery, it is noted that AD is the preferred option over aerobic digestion (composting) considering the characteristics of the available FW in Asia and the underlying environmental and economic benefits (Sinha and Tripathi, 2021). As such, decentralized, community-scale and AD systems have been gaining traction over the centralized and large-scale systems because of their lower energy footprint, ease of operation and need for lesser resources. This was also due to lower operation and maintenance costs, and higher chances of public acceptance (Joshi and Visvanathan, 2019). The authors concluded that the policy to gain energy from segregated FW is a larger driving force for the efforts to promote AD, thereby managing FW sustainably (Joshi and Visvanathan, 2019). As for France, subsidies have been made to support similar investments (Mourad, 2016).

A systematic review in the Gulf Cooperation Council countries argued that regulations and policies are key to reducing FW alongside the effective participation of all relevant actors, new ways of organization and governance of food supply chains and the concept of CE and sustainability (El Bilali and Hassen, 2020). Likewise, Mourad (2015) addressed FW management concerning the food recovery hierarchy, in which existing incineration and landfill diversion targets for businesses and institutions generating large quantities of food and organic waste are outlined. Concerning FW generation at households and workplaces, and FW reduction targets, Mourad (2015) indicated that awareness campaigns would be implemented by a new national entity in charge of waste prevention, with an estimated budget equivalent to US$33 million to US$43 million for research, expertise and communication. This also includes setting up policies for efficient quantification of FW at both national and local levels, and encouragement of innovation for FW management. Especially among researchers and municipalities, ‘zero food waste’ is critical to enable companies and communities to document and communicate their actions to reduce and recycle FW. The French government has adopted the ‘circular’ or ‘sharing economy’ (Mourad, 2016). These cases from other LMICs, such as Latin American countries (Argentina) and Asian countries, as well as HICs such as the United States and France, showed that African cities can learn from their experiences. These African cities can use strategies like ‘zero waste’ and ‘circular economy’ to use food as a digestate for compost (e.g., home composting can potentially divert up to 150 kg of FW per household per year from local collection authorities) (FAO, 2013), and to effectively manage FW sustainably. Altogether this can have positive implications for environmental sustainability and the adoption of international best practices to prevent food wastage.

It has been found that in most African countries segregation and collection of FW are not yet adequately practiced. Therefore, almost all of the generated FW is mixed with MSW and disposed of together in landfills (Chalak et al., 2016; Hodges et al., 2011; Maduhu et al., 2019). The absence of source segregation is one of the major challenges in following sustainable disposal and treatment of FW in LMIC landfills in Africa. Furthermore, in many African countries, the inadequacy of basic waste infrastructure and inadequate waste collection systems are likely to remain the major influencing factors in the increased generation and inappropriate management of FW. Overall, the lack of well-functioning collection systems and regulatory framework affect the efficiency of FW management systems. This can be further exacerbated by a lack of political interest and will, commitment of the national government, private sector and limited investment to support FW management strategies. In some African countries such as Tunisia, the deficiency of national selective sorting and the recycling system, at the household level presents major challenges to FW management (Jribi et al., 2020).

To ameliorate the challenges faced by African countries on FW, the adoption of best international practices in FLW management could be extrapolated for application across the African continent taking into consideration the socioeconomic and cultural differences between the countries. Past research has suggested these strategies can bring about significant environmental and economic benefits (El Bilali and Hassen, 2020). Concerted efforts by governments of African countries is urgently needed to shift towards engineered landfill operations such as LFG capturing technology to reduce GHG released into the atmosphere per year. It is also necessary to adopt the digestion of food scraps to recover energy and as a digestate in compost. As such, the conversion of FW to biofuels or food sent to an anaerobic digester for household energy supply is critical in reducing FLW. For instance, fats, oils and grease can be collected and converted to biodiesel by local manufacturers into environmentally friendly biodiesel fuel. The same products can be added to an anaerobic digester at the household level to generate renewable energy in the form of biogas. Furthermore, African countries need to adopt globally sound environmental sound practices to measure and reduce FLW and shift consumer behaviour to urgently cut FW. This requires the development and implementation of national strategies, policies and partnerships to accelerate action to reduce FLW as enshrined by UNEP. For instance, South Africa has committed itself to reducing FW by 50% by the year 2030 following the United Nations SDG (UN SDG 12.3) summit (ReSource,

2022). Indeed, this is expected to reduce methane emissions from landfills, which represent one of the largest sources of GHG emissions from the waste sector (FAO, 2013).

From the retrieved literature, it was found that FLW management issues were researched by different scholars globally. The status of the food supply chain in Africa was mentioned in this section as available data on FW composition. Food is wasted at all phases of the supply chain, from production to consumption and the causes of FW differ at each stage of the food supply chain (Sinha and Tripathi, 2021), as seen in Figure 2. In LMICs, a large amount of food wasted is from households (Ramukhwatho et al., 2014). Researchers have noted that when food is wasted, the resources used during the production of those foods are wasted (Totobesola et al., 2022). Drivers of FLW were identified, namely social events, attitudes, stockpiling of foodstuffs, cooking too much, buying too much, fruit and vegetables going off, poor storage, handling and processing, store behaviour (related to overshopping) and household management practices. This is also due to psychosocial factors, social, practical and consumer behavioural trends, lack of awareness of communities on source separation, collection and utilization of FW and well-established strategies or regulations towards encouraging societies to save and recycle FW. These drivers of FW are similar to those found in other LMICs like China, where FW is a major challenge, especially at the household level (Wang et al., 2023). FLW differs between LMICs and HICs. The retrieved literature in this section showed the challenges to FLW management are a global issue that is being experienced by both HICs and LMICs. The conclusion is that if FW is not managed appropriately, segregated and reduced at source, the amount of FW that ends up at landfills cannot be minimized and be utilized as a digestate for biogas and compost. As noted, using FW as a substrate is an alternative way to divert FW for compost and generation of energy that can be a feasible substitute for African countries, because of its higher energy content per dry mass.

Utilization of FW and its benefits

FLW management plays a significant role in achieving sustainable environmental, socioeconomic and public health benefits. The utilization of FW might reduce waste, which ultimately reduces GHG emissions, and can enhance environmental sustainability and air quality (Al-Rumaihi et al., 2020). The generation of energy from FW can reduce the constraints on fossil fuel sources and disposal of FW in landfills, which can reduce CO_2 emissions and other pollutants from microorganism degradation that contribute to poor air quality and climate change (Paolini et al., 2018). FW has been proven to be a reliable resource for compost. It has been noted that utilizing FW as a source of energy through WtE projects can also be a source of job creation and revenue, thus alleviating poverty (Pour and Makkawi, 2021). For example, in Malaysia, LFG was used to generate up to 1.9 billion kWh of electricity worth US$190 million and received over US$85 million in revenue (Johari et al., 2012). Therefore, the implementation and utilization of FW for landfill gas for energy (LFGE), and as a digestate for biogas and compost should conform to the UN SDGs one, two, seven and eight.

Stakeholders including the public, decision-makers and policymakers must understand the benefits of the utilization of FW to produce and compost, and the government can utilize FW to generate biomethane that can be feasibly collected and used in a cost-effective way (Pour and Makkawi, 2021). Public awareness and sensitization and technically skilled human resources are critical components in maximizing the intended benefits of the utilization of FW for both energy generation and compost. Other critical factors in the utilization of FW include the compilation of numerous technical considerations, such as FW composition, characterization, quality and quantity of FW and the location of a suitable end user (HLPE, 2014). Thereafter, a holistic assessment of the feedstock capacity requirements, costs and benefits associated with various WtE alternatives in African countries should be evaluated. How well these options fit the social, technical and economic status of the countries should also be evaluated. As a result, proven and emerging technologies and the food recovery hierarchy offer practical solutions that could effectively assist in implementing the recovery of FW for compost and WtE projects, including the treatment of FW to remove moisture (HLPE, 2014). In the context of the African region, however, FW for energy production is not yet prioritized by most African governments, and many governments are holding out on fossil fuels because of inadequate public acceptance.

Many African countries lack regulatory policy frameworks aimed at promoting compost, energy production from FW, and the provision of financial incentives to encourage the utilization of FW. FW as a substrate for energy is not yet prioritized because of the need for treatment systems for WtE projects, which could increase the costs (Al-Rumaihi et al., 2020). Other reasons why FW is not utilized as a substrate and compost include the lack of detailed final feasibility assessments by qualified professionals before preparing the design, initiating construction and purchasing materials for biogas and compost plants. It is found that in many African countries, the public is still unaware and lacks knowledge of the benefits it offers in terms of energy production, reducing landfill disposal and its environmental benefits as compost. However, the benefits of a circular, resource-efficient economy are vast including reduction of GHG emissions, increased employment creation and reduction of waste generation (Pour and Makkawi, 2021). For African countries to reduce FW generation in the 21st global economy, there is a need to strengthen their institutional capacity and utilize the FW for improved energy generation and composting.

This section presented the findings on the utilization and benefits of FW. It was discovered that there is a limited utilization of FW in African countries. Though the benefits of the utilization of food have been well-documented, there is not much in the African region. Fewer countries utilize FW as a digestate for compost and biogas technology, animal feed production, and for soil nutrient enrichment; this may be because African countries lack FLW management policies and initiatives compared to HCIs where food is given a higher priority. Another reason for African

countries not utilizing FW was that at household, people relied on household garbage bins, that is, municipal waste collection services, to dispose of FW, without source segregation, and this may be an indication that consumers do not have awareness about FW as a resource for compost and biogas, and its impacts on the environment which they live in. The study concludes that regardless of the African countries having policies (e.g. South Africa halving FW by 50% by 2030), there is slow progress in doing so.

Possible policy recommendations, barriers and implementation

In many African countries, the management and reduction of FLW are still largely linear from collection to disposal compared to countries such as the USA, Canada, Saudi Arabia, Brazil, Australia and China. The lack of reduction FLW mechanisms to promote food security, poverty and environmental health, source reduction strategies, lack of available data on FLW inventory, policies promoting the utilization of FW and inadequate market systems lead to this linear system of FW disposal, which cannot be changed into a circular one. Furthermore, insufficient usage of FW as a digestate for compost and in biogas technology, as well as a lack of environmentally sound management strategies, are key contributors to the slower progress in the management of FW in many African countries (Gold et al., 2012). On the other hand, implemented biogas and composting projects are not meeting their objectives, and there is limited data on their efficiency and contribution (Parawira, 2009).

Despite the promising potential of FW as digestate for compost and in biogas technology, FW is disfavoured by legislative obstacles and factors militating against its management. Among these, one of the major challenges is the lack of policies on FW management in many African countries. When compared to conventional methods of FW treatment, the utilization of FW as compost and digestate in biogas technology is regarded expensive due to the components, which many households may not be able to afford. Past research has highlighted in many African countries the uncertainties related to the utilization of FW in biogas technology have exacerbated household participation in the technology. Funding is the main bottleneck militating against the utilization of biogas technology among households in many African countries; many projects are obsolete or nonfunctional because households, governments and municipalities do not have enough resources, that is, technically skilled personnel, and capital to maintain, implement and sustain the biogas technology.

FLW management in African countries are still largely linear from collection to disposal, and happening at a slow rate compared to HCIs such as EU member states and the USA, Canada and Australia. The recommendations could assist to improve environmental health and enhance the adoption of effective strategies for FLW management, and the utilization of FW as a digestate for energy production and compost in African countries are as follows:

- FLW can only be reduced through well-developed policies and FLW management systems from production to consumption levels. Therefore, policy should be reformed that will allow the development of effective and efficient waste segregation at the source and separate collection, and monitoring of FW. Designing target-oriented policies and time frames for the attainment of goals and quantifiable targets and operational plans, and integrating the existing guidelines considering the experiences learned from frontrunners such as the USA and the EU member states is essential. African countries should not directly adopt the approaches used by others; however, they must learn from the frontrunners and develop appropriate FLW management strategies considering their socio-economic context and own limitations. The African Union adopted the UN SDG 12.3 related to food losses (qualitative goal) for African countries, which specifically seeks to ‘halve per capita global FW at the retail and consumption levels and reduce food loss along production and supply chains (including postharvest losses) by 2030’ (Totobesola et al., 2022). Similar policies within African countries, for example, related to the plastic bag ban are available, which could be used as blueprints or models for additional strategies to ameliorate challenges of FLW, especially in the context of SDG 2, which addresses hunger. Therefore, for successful implementation and delivery of a well-functioning FLW management system, it is critical to consider strengthening systemic and institutional level capacity and reforming waste management practices and policies considering the scientific, social, political, technological, technical and economic aspects (Mmereki, 2018).
- National governmental policies should be reformed through a multi-stakeholder collaboration between the government and private sector to fund the expansion and upgrading of infrastructure for FW management such as basic infrastructure, collection system and disposal system. The legislation should include:
  - Extensive collaboration mechanisms among farmers and buyers, and suppliers by ensuring that these stakeholders are consumer-oriented, and can enhance reliability among food supply chain partners and government and society.
  - At the producer stage, there should be the development of technological (for storage, handling and processing), institutional and managerial innovations to improve traditionally managed small-sized farms whereas at the food processor stage pretreatment, preservation, handling and packaging of food, initiatives should be developed in many African countries.
  - Extensive public involvement in the development of FLW management projects such as biogas technology and composting. Therefore, the public and environmental groups should be made aware of the advantages of the utilization of FW as a digestate for energy generation and compost.
  - Development of action plans for society to realize public participation and involvement of everyone in FLW management practices.

- Current policies and legislative frameworks regulating solid waste management in most African countries must be reviewed to ensure that the benefits of FW are fully maximized. The promulgation of policies and regulations should establish policy targets and comprehensive policy assessments, technology assessment and the development of best international practices such as the food recovery hierarchy (USEPA, 2014).
- FLW management strategies must be developed promptly in order to address FLW concerns in many African countries. The strategies should address specifically suitable aspects for each country's context, and this can be achieved through feasibility studies that consider the technical, economic, environmental and social aspects of each country.
- In many African countries, information on the extent of FLW, and strategies taking area-specific measures taken according to waste characteristics like regional-specific waste and their varied composition is a challenge. These can be solved through capacity building, research and developing an FLW information system. In-depth data studies on the inventory of FLW in many African countries must be conducted.

Limitations of the study

The retrieved studies were primarily from fewer countries in the African region, namely, Egypt, Algeria, Morocco, Tunisia, Nigeria, Kenya, Tanzania and South Africa. Fewer studies provided quantitative data on the extent of FLW, composition or characterization and related FLW management activities. Because most of the studies focused on the awareness of FLW, which is only the source part of the potential FW generation, little is known about quantities in most of the economic sectors, and the actual FLW management issues. In addition, it remains unclear how FLW may affect the environment and public health. The limited number of studies could be due to the language criterion, and the deployed search strategy that could have limited the scope. However, it could also reflect that in many African countries, FLW management is not widely studied in the waste management sector. An SLR was not attempted due to logistic constraints and limited quantitative data. This is because SLR is an important line of approach to remove subjectivity in the selection of relevant studies regarding the subject matter, this could have reduced biased in the results, and the conclusion of the review. However, a certain degree of expertise-based subjectivity can also be considered a strength if used, for example, using PRISMA. This study is valuable due to the methodological approach of accumulating findings from a range of studies. The results of this study provide a foundation for future research in this field. Moreover, it offers a reference for researchers, waste management professionals, decision-makers and policymakers.

Conclusion

The present study contributes to a better understanding of the status of FW management and waste management sectors in the African region. It suggests the development of effective FLW management systems and WtE policy to convert WtE, particularly FW into a resource sector. At the policy level, solutions of the three interlinked sectors should be well-coordinated to ensure proper targets and results. FLW management practices must provide effective solutions to create an adequate waste collection and segregation system for the FW stream through a combination of approaches and financial incentives. The FLW management sector is faced with several major challenges that militate against its development: legal, human, institutional, financial and technical challenges. In the case of biogas technology, financial challenges arise from the high capital and operational costs associated with the construction and maintenance of biodigesters.

The study proposes a techno-economic analysis of biodigesters to understand the sustainability of biogas and compost projects and attract private-sector investment opportunities. Technical challenges arise from the inadequate compilation of FW composition, and viability in terms of WtE and composting projects, where FW can be used as a feedstock. African research needs to speed up the pace in developing and optimizing FLW management systems and initiatives tailored to the African context. Research directions on this important topic should focus on the valorization of FW within the sustainable paradigm of the CE.

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Appendix

Nomenclature

AD: Algerian dinar
AD: anaerobic digestion
CH_4: methane
CO_2: carbon dioxide
EPA: environmental protection agency
EU: European Union
FAO: food and agricultural organization
FL: food losses
FLW: food losses and waste
FVW: fruit and vegetable waste
FW: food waste
FWM: food waste management
FSC: food supply chain
HICs: high-income countries
GCC: Gulf Cooperation Council
LFG: landfill gas
LMICs: low- and middle-income countries
MAD: Moroccan dirham
MSW: municipal solid waste
MSWM: municipal solid waste management
NGOs: non-governmental organizations
PHL: post-harvest loss
SDG: sustainable development goals
SSA: sub-Saharan Africa
SHF: smallholder farmer
SFWM: sustainable food waste management
UK: United Kingdom
USA: United States of America
USEPA: United States Environmental Protection Agency