Synthèses

SUSTAINABLE FOOD SYSTEMS FOR FOOD SECURITY

Need for combination of local and global approaches

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Chapter 13

Urban food waste: a resource for circular economy between cities and agriculture

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Until recently, urban food waste was considered a minor issue within the global food system. As cities grow, especially in Asia and Africa, this concern is receiving more attention from policymakers and scientists in terms of food system efficiency and food security (Guilbert et al., 2016). Estimates predict that by 2050, half of all food waste, i.e., that which comes from both retail and consumers, will be generated by urban systems (Parfitt et al., 2010). In particular, the mass of urban food waste is directly correlated to the urban population and constitutes 20% to 80% of municipal solid waste throughout the world (Adhikari et al., 2009). In response, major investments have been made in the last 20 years to boost treatment of food waste either on site or in landfills. However, to deal with the rapid growth of cities, the management of food waste requires additional technical and organizational innovations, in particular due to the environmental and sanitary risks related to those by-products (Westerman and Bicudo, 2005).

According to the FAO, 'food loss and waste refer to the decrease in mass (quantitative) or nutritional value (qualitative) of food – edible parts – throughout the supply chain that was intended for human consumption. Food loss is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain (producers, processors). Food waste refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers.' (FAO, 2011) This chapter focuses on urban food waste and the value of this organic waste for a formal or informal circular economy.

Food waste management can be addressed through three main levers: 1) more efficient agrifood value chain distribution, 2) human day-to-day consumption practices, and 3) the new circular economy. There is obviously a paradox in promoting the recovery and recycling of 'waste'. However, since a large part of this waste is essentially due to consumption patterns, this major component of food systems must be tackled. From a circular economy perspective, and given the need to make better use of organic biomass, urban waste must be viewed as a resource, especially for urban and peri-urban agriculture (Westerman and Bicudo, 2005).

Is it better to deal with the problem at its source by reducing waste from distribution and consumption, or should the transformation of waste recovery and recycling systems be initiated, through the circular economy, at the urban system level? Should solutions be designed globally, or adapted to each local context? This chapter gives some examples on how to address the issue of food waste in cities at different scales. We consider in particular the peri-urban fields, economic channels, school canteen networks, waste channels and experimental urban farms.

With examples from various cities such as Montpellier, France; Chicago, Ill., USA; Antananarivo, Madagascar; Dakar, Senegal; and Hanoi, Vietnam; this chapter follows food waste production and recycling at different steps of the food system: in wholesale and retail markets, stores, restaurants and households. A first case study deals with food waste in various cities with a common approach, while another project, 'Bidons Bleus' [blue barrels], focuses on a particular type of waste in a single city. Our study shows that coping with food waste using solutions to limit emissions or recycle materials involves numerous stakeholders, and especially small-scale recyclers, specialized in waste recovery and valorization. Some stakeholders try to innovate in order to reduce waste production or to improve the collection and transformation of this waste into an important resource for agriculture. Our results highlight that a circular economy based on food waste valorization already exists around the world, with some constraints related to sanitary regulations. Synergies between agriculture and cities are possible within the food system in order to manage food waste more efficiently. Actions to develop such synergies should be considered from multi-partner and multi-sector perspectives, taking into account the system's upstream and downstream sectors and the corresponding stakeholders, including retailers and consumers. Agriculture could be a solution for managing urban food waste if consumers and policymakers increase their awareness and support it.

▸▸ How to reduce urban food waste by considering the circular economy?

Because of limited resources and energy sources, human activity should limit extraction from nature and promote economic efficiency. Waste is considered 'efficient' if the by-products generated from the consumption of extracted resources can be re-used or recycled instead of being lost for the community or for the environment. Re-using waste to produce new goods in a sustainable manner has two main interests: 1) environmentally, recycling may limit resource extraction for producing a new good and may benefit nutrient flows; and 2) economically, recycling can reduce costs and generate greater accumulation of wealth within the local and global economies.

The circular economy as a means to handle waste production

Closing the loop of the linear economy is a challenge for many countries that are in different development stages. Growing consumption in emerging and developing

countries needs to be considered as the strongest trend in the twenty-first century within urbanization trends, energy transition and climate change. The circular economy is linked to the industrial ecology of material flows. Material flows between actors should be mapped to understand the system organization (such as in agrifood systems, industrial systems or service-based economies). When waste emissions are identified, experts can assess the value of waste and find new options to re-use and recycle it. The objective of the circular economy is to reduce the amount of material extracted from nature per unit of produced good or service.

From that perspective, we recognize the bioeconomy as a social project based on allocating the use of biomass towards more sustainable development pathways. In that sense, the bioeconomy refers to a particular model of managing physical flows through loops and recycling. In practice, our economies are already more circular than what experts may claim. Many stakeholders around the world, from both formal and informal sectors, earn their living from recycling various organic wastes. Depending on how circularity is defined (re-using and/or recycling), the global economy was even more circular during the nineteenth and twentieth centuries (Daviron, 2019). The tradition of waste pickers still represents an important side of urban food systems in developing countries. In more developed countries, waste management shifts from individuals to state services and private enterprises. The circular economy involves both technical dimensions (material flows, biomass and derived energy, etc.) and socioeconomic dimensions (management organization, diversity of stakeholders, social choices).

The circular economy for urban food waste management: a growing challenge

Since 2007, cities across the world are now home to more than half of the planet's inhabitants and play an important role within the global agrifood system. The growth of the urban population has highlighted the emergence of food waste as an environmental and economic issue (Guilbert et al., 2016). Food waste production is directly related to the concentration of a population, but it is also highly dependent on household living standards. Nearly 20% of the global population lives in large metropolises, yet these cities produce 40% of food waste. With 65% of the world's population estimated to be urban residents by 2050, food waste management will certainly become a major goal of the global food system, along with food and nutritional security (Adhikari et al., 2009).

When applied to food waste, the circular economy aims to prevent waste going to landfills and to promote innovation in re-use and recycling. Recycling food waste through the circular economy is particularly promising for urban and peri-urban agriculture, since waste constitutes a potential resource. Food waste can have value for agriculture, feed and energy production. The challenge is to find the recycling method that is most suited to each context. The circular economy can then contribute to the relocation of production by developing farms in peri-urban zones, reshoring jobs and decreasing the agrifood system's footprint. The links between city, food waste and agriculture often rely on formal and informal networks of the circular

economy within the urban and peri-urban agriculture sectors (Borrello et al., 2017). Urban and peri-urban agriculture are globally important drivers for managing solid urban organic waste. They could be among the future central players for increasing the sustainability of cities.

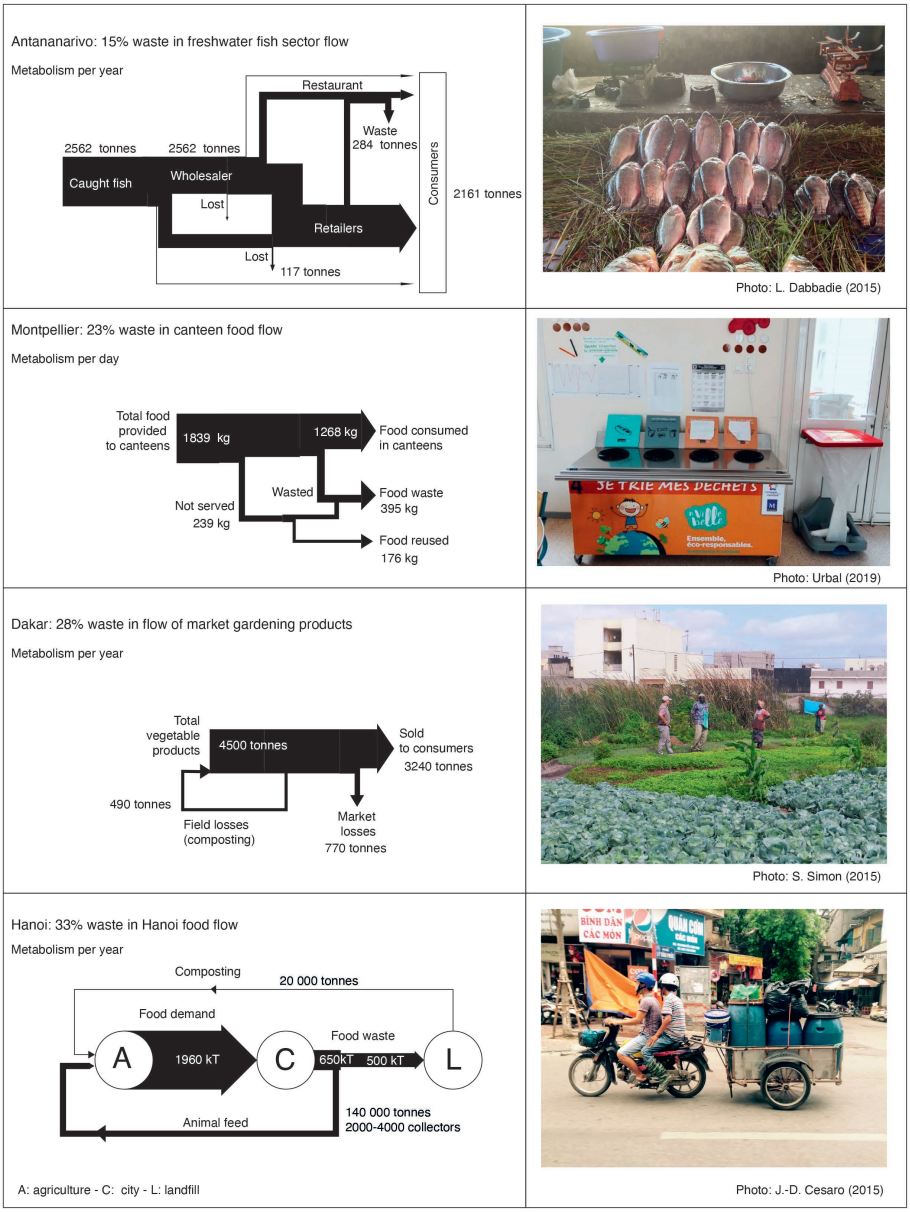

Figure 13.1. Flows of food and food waste in four cities around the world.

⏩ Territorial metabolism: a method to quantify and qualify urban waste

We have attempted to quantify the flows of food materials and food waste in different systems: 1) urban agriculture in Dakar (Senegal), 2) freshwater fish marketing channels in Antananarivo (Madagascar), 3) school canteens in Montpellier (France), 4) an industrial ecology centre founded in Chicago (USA) to maximize flows within the various agrifood activities, and 5) the urban food waste landfills in Hanoi (Vietnam). These very diverse case studies present contrasting situations of variable regulations, different masses of waste and disparate solutions to manage it.

Visualization and systemic analysis of food and food waste flows

The flow analysis findings from the five case studies are presented in Figure 13.1. The figure shows the evolution of proportional flows between agriculture (Antananarivo, Dakar, Hanoi) or food processing (canteens in Montpellier, a company in Chicago) and the purpose of the system, namely the final consumer for sector approaches (Montpellier, Antananarivo, Dakar) or landfill for circular economy analysis (Hanoi, Chicago). Two of the cases have a rather linear economy (Montpellier, Antananarivo). In three cases, material loops are highlighted (Dakar, Hanoi, Chicago). Only two cases (Hanoi, Chicago) are clearly targeted at the circular economy, in the sense of exchange between economic actors. In Madagascar and Dakar, the circular economy seems to be implicit within the waste trade but has not been studied. Food waste represents about 20% of the volume in each case and appears at different levels depending on the studied system.

Food waste in cities in the Global North: from public regulation to collective innovations

The Montpellier and Chicago case studies focused on the analysis of two organizations:
– school canteens in Montpellier (France);
– an experimental industrial ecology centre called ‘The Plant’ in Chicago (USA).

In Montpellier, the survey included 18 school canteens supplying 3200 meals per day to nursery and elementary schools. Two central kitchens prepared the meals that were then delivered by a catering company. Two types of food delivery systems were in place: hot or cold, depending on the equipment available in the canteens for reheating. In order to assess the level of waste, the method consisted in weighing the food arriving at the canteen (input) for two weeks. Two major food categories were considered: food served to children and food not served. All food waste was weighed at the end of the day.

These results showed that a significant volume of food was wasted. The total food received by the canteens was 1839 kg per day. Children consumed 69% of food delivered and produced 15% of food waste. Some 14% of food delivered was not served. The staff recovered almost half of the food not served, either for the children's snacks or for themselves, and the rest was thrown away. The total food waste was 422 kg per day, which represented 77 tonnes per year (182 school days). The catering company was well aware of the economic impact of food waste, since it had to pay twice for this waste: the purchasing price of the food supply that was not consumed, and taxes for urban waste collection services. French regulations encourage catering companies to donate unconsumed food in accordance with hygiene and cold chain standards. The staff can take home some of the unserved products. For food waste, local composting is preferred if there has been no contact with food of animal origin. Staff collect some waste for pets or household livestock production for their own use.

In Chicago, The Plant is an urban project to support industrial symbiosis between different production start-ups (mushrooms, algae, insects, honey, aquaponics, anaerobic digestion, among others) and marketing of products (direct sales) (Chance et al., 2018). The Plant hosts and collaborates with various companies to promote an inter-company operation in the framework of industrial symbiosis.

The work focused on studying the flows and exchanges of materials and energy between the partners of this industrial symbiosis and then monitoring the fate of two or three selected productions until consumption. It consisted in:
– developing a global vision of the whole system and the flows and exchanges between the different projects hosted in the industrial symbiosis;
– analysing more specifically a type of product and measuring local food waste at the distribution level. Material flows were monitored for three weeks, through three bread productions, and thus three deliveries per week. Losses were monitored both at the bakery and various points of sale (The Plant's site, the local market and four retailers in Chicago).

The three largest material outflows were the materials directly re-used on site (21 tonnes), those used at the landfill (19 tonnes) and those sold off-site as goods (15 tonnes). Although the quantities of waste going to landfill and sold goods were composed of small and multiple streams, nearly 98% of the materials tracked through the system were composed of brewery co-products. The anaerobic digester was not yet operational at the time of the survey. When it is operational, it should be able to process 12 tonnes per day of biowaste, which will be an important source of compost for urban agriculture and natural gas for energy.

The application of the material flow analysis methodology to The Plant provided both global and targeted views of certain streams (Mulrow et al., 2017). The data collected on material flows and their materialization is useful to improve the symbioses between the site actors, but also to reduce losses and waste and to better plan the future (Figure 13.2). Some specific authorizations were issued for the first time to respond to the need for innovation, such as the authorization to breed animals for human consumption indoors, within the aquaponics system (Nogueira et al., 2020).

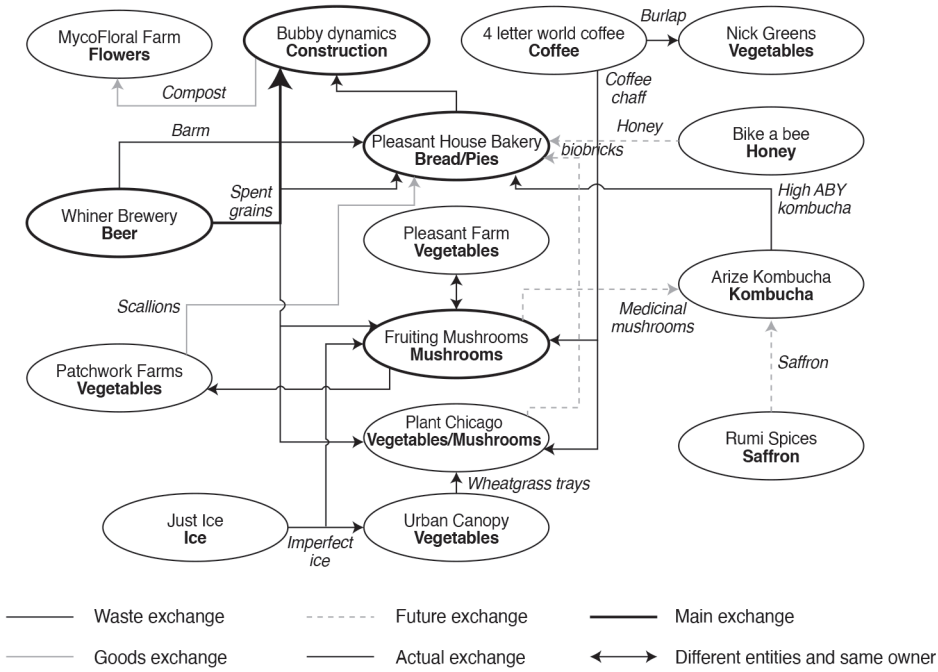

Figure 13.2. Material flow between the different projects and activities within 'The Plant'.

Food waste in cities in the Global South: the importance of informal practices

The case studies of Antananarivo (Madagascar) and Dakar (Senegal) focused on analysing two parts of the food system:
– the lake fish value chain providing fish to Antananarivo market;
– urban agriculture and marketing around Dakar.

In Madagascar, the study involved identifying the actors and stages of the freshwater (lake) fish distribution chain and quantifying, for each type of actor, the volumes purchased, sold and stored, as well as the volumes of waste. The study also aimed to extrapolate these volumes to the urban system of the capital city and map the flows and materials.

Using official data, we estimated that 2562 tonnes of lake fish were sold in Antananarivo annually. According to a survey downstream of the value chain, the waste resulting from the marketing and consumption of this fish was produced mainly by restaurants (284 tonnes), and by retailers and wholesalers (117 tonnes). These figures only took into account fish that had not been consumed. Direct food waste accounted for 16% of fish weight and was due to downgrading of fish for quality reasons. However, the study concluded that 50% of the weight of consumed fish was wasted. The waste biomass resulting from fish was partially recovered. The lake fish value chain produced

400 tonnes of direct food waste (fish not consumed) and 1,000 tonnes of by-products. Most of the waste ended up in landfills while the rest was re-used. It was difficult to precisely assess the use of fish carcasses in animal feed. Restaurants and traders gave this waste to itinerant collectors or sold it as animal feed.

In Dakar, nearly 62,000 households, i.e., about 14% of the population, work in urban agriculture. In the early 2000s, peri-urban horticultural production occupied more than 34% of the land area and accounted for nearly 40% of the production of horticultural products for the national market (Smith, 1999). To our knowledge, the current contribution of urban agriculture to the urban supply has not yet been studied in the literature. The food distribution network was particularly dense, with neighbourhood stores, daily markets and kiosks that allowed Dakar residents to purchase food without travelling long distances. This system has not been studied in detail and post-harvest losses and food waste have never been quantified. The study focused on two sites:

– Pikine Ouest, with 42 ha and 384 farmers. The productions monitored by the project were lettuce (about 3500–4000 tonnes/year, spread over the whole year), bitter eggplant, tomato, bell pepper and cabbage. Irrigation was carried out with a mixture of wastewater and underground water.

– Patte d'Oie, with 7 to 12 ha actually farmed and 280 farmers. The productions followed were lettuce (about 500 tonnes/year, distributed all year long), bitter eggplant and tomato. Irrigation was practised with a mixture of 'treated' wastewater from the sewage plant and underground water.

Post-harvest losses from gardening and product losses at market were estimated at around 10% with a marked seasonal effect, especially in the hot season. An average of 18% of bell peppers were lost in the field or at market. The total losses exceeded 28% in the hot season. On average, the production of losses and waste exceeded 400 tonnes in the Pikine area, which was relatively high. All post-harvest losses at gardening stage were returned to the soil in the form of compost. For losses at market, the landfill rate was very high: recycling of materials was rare, and the return for agriculture was virtually non-existent. A few livestock breeders located near landfills recycle vegetable losses into animal feed.

The production of food waste at the consumer level and losses throughout the value chain were quantified in the four case studies analysed. Territorial metabolism proved to be a very useful method to quantify and qualify urban waste. The volumes disposed of as waste varied among the horticulture, fresh fish and canteen value chains.

In a complementary approach, the practices of food waste re-use and recycling for livestock husbandry were reviewed in Hanoi, Vietnam. The purpose was to document an informal food waste recycling practice through animal feeding in Hanoi, and to assess its potential for sustainable development of urban food systems.

Recycling urban food waste through animal husbandry

The use of food waste in Hanoi, Vietnam, by pig breeders was reviewed to assess its potential for the sustainable development of the Hanoi food system. Technical and sanitary problems related to this informal business were also reported.

In Vietnam, urban food waste is part of a traditional relationship between city and intra-urban livestock systems. Farmers living on the outskirts of cities are used to coming every day to collect organic materials to feed to their livestock. Individual households and collective catering institutions also contribute to these recycling practices by giving away or trading their food waste with their neighbours who raise pigs. However, in the current context of urban growth and livestock sector industrialization, this type of traditional food waste management seems to be in decline. Today, food waste is transported in blue barrels over longer distances to livestock farms that were pushed out of the city by sanitary regulations.

Urban food waste recycling through pig feeding: a traditional activity

In Vietnam, since the beginning of the 1970s, many peasants living on the outskirts of large metropolises like Hanoi and Saigon used to buy urban kitchen scraps, also called swill, for pig feeding (Tran The Tong, 1973). This informal organization was seen as useful in the post-war subsistence economy. After the Đổi Mới economic reforms that started in 1986, the administration set up formal management of urban waste which contributed to the marginalizing of these small-scale collectors (Dao Ngo, 2001).

With urban sprawl and demographic growth, peri-urban agricultural and livestock activities have been decreasing. Agricultural belts are becoming unstructured and moving away from the city centre (Sautier et al., 2014). Livestock breeders using food waste try to maintain some proximity to city centres, although they are located in the city outskirts or in interstice areas.

Dao Ngo (2001) estimated that at the end of the 1990s, informal recycling of municipal solid waste carried out by farmers reached around 14% of total Hanoi municipal solid waste. However, he pointed out that farmers would also recover other materials, such as human waste. He believed that the maximum recycling rate likely reached 30%. Farmers could recycle between 65,000 and 140,000 tonnes of food waste per year at that time.

Takaaki et al. (2012) estimated that the recycling rate of food waste in 2009 was around 6.5% in Hanoi. We consider this rate to be the lowest estimate. For the high estimate of 2015, we have retained the rate of 22% provided by the planning department of Hanoi province. Livestock farmers could recycle between 40,000 and 140,000 tonnes of food waste in 2015.

The new business of urban food waste recycling

Despite the decrease of peri-urban livestock activities, the number of breeders interested in waste was high, leading to competition among them. The resource has been gradually transformed into commodity. ‘In the past, food waste was often free, now it’s becoming a business’ (interview with a breeder by Gia Lâm, 2016). Because this management became a ‘business’, the requirements of breeders were more demanding regarding the quantity and quality of urban waste.

According to the survey conducted between 2015 and 2016 (Cesaro et al., 2019), the collectors harvested food waste from restaurants (75%), corporate and school canteens (22%), households (11%), hotels (8%) and markets (4%). On average, the waste producers (mostly restaurants) produced 30 kg of food waste per day. Households produced much lower volumes. The average composition of food waste was rice and noodles (58%), vegetables (18%), meat (8%), fish (6%), bones (5%) and other (4%). To transport this food waste, 85% of the collectors drove a motorcycle, 10% a truck and 5% a bicycle. Those who collected waste by truck were more organized and able to collect larger quantities. Those on bicycles logically looked for proximity with urban pig breeders. Collectors used several types of blue barrels, ranging from small barrels of 20 litres to very large barrels of more than 200 litres.

Based on data from the 2001 and 2011 agricultural censuses, the rapid decrease in the number of peri-urban farmers raising at least one pig per household in a radius of 30 km around Hanoi was confirmed. We estimated that there were around 4,000 blue-barrel collectors in 2016, accounting for around 40% of breeders within a 10 km radius, but only 4% within a 30 km radius. At 30 km from Hanoi, there were other large cities and industrial areas providing food waste to surrounding breeders (Cesaro et al., 2019).

Health and epidemiological risks related to the informal sector

Raising animals in cities, especially in densely populated areas, leads to severe constraints and high risks in terms of environmental pollution and impact on the population health. The conditions of pig farming by peri-urban breeders vary greatly. We identified three types of livestock farms in the Hanoi suburbs.

– Farms in a constrained urban environment. These were areas where agricultural plots were non-existent. The health and environmental risks associated with management of livestock manure were high. This kind of breeding was common in the middle of outlying urban districts.

– Farms in agro-urban interstice areas. These farms benefited from the preservation of certain agricultural areas in urban space, particularly along the banks of the Red River or in flood-prone areas left for market gardening or arboriculture. The health and environmental risks were lower on these farms.

– Farms in rural areas on the edges of towns/villages. The location of these pig farms gave the farmers an advantage for managing pig effluents thanks to the direct access to agricultural plots or lakes.

The pressure of livestock farming on urban environmental resources led the authorities to develop programmes for the relocation of livestock from town to villages, within intensive farming areas (Cesaro et al., 2018).

The epidemiological study identified three types of sanitary hazards for pigs: physical, chemical and biological. The typical sign that was mentioned for pigs affected with a physical hazard was fever caused by swallowing toothpicks. The risk of chemical hazards was higher due to food waste contaminated with dishwashing liquid.

Regarding biological hazards, the risk was low because all farmers used cooked food waste (Duong et al., 2017).

The recycling system has been recently dealing with new epidemiological and health constraints. The first constraint (epidemiological) is linked to the spread of African Swine Fever (ASF) in China and later in Vietnam in 2018 and 2019. According to the FAO, 'local government authorities have been implementing strict movement control of pigs and pig products from infected communes, mobilising their resources for pig culling and disposal, small pig farming models with low biosecurity and swill feeding still continue to facilitate ASF spread.' (FAO, 2019). Unlike China, Vietnam opted for a less restrictive approach and let breeders operate with good practices and the limitation on marketing of pigs outside production regions for small producers. The second constraint (health-related) was the COVID-19 pandemic and the implementation of containment measures. Because restaurants were closed, collectors no longer had access to their main resource. Breeders then sold their pigs in massive numbers. Some turned to more conventional farming systems. With the re-opening of businesses, the breeders and collectors resumed their activity, but with the worry of being vectors of disease.

Conclusion

Urban food waste represents an interesting resource for agriculture. It is used for energy generation in fermenters and as organic fertilizer, industrial materials or animal feed. Some recycling practices exist in many cities in the Global North and Global South and offer interesting alternatives to promote the circular economy between cities and agriculture. However, these practices are still limited and measures encouraging the recycling of urban food waste may conflict with the main stated objective of current public policy, i.e., preventing food waste by reducing it at the source. It remains difficult to industrialize urban food waste collection without impacting the organic quality and agricultural potential of this material. Moreover, regulations often limit recycling flows because of sanitary risks. As a result, only a small fraction of landfilled quantities is recycled, especially in the Global North where informal practices are strongly regulated.

Expanding the application of the circular economy to urban food waste will require financial investments, technical innovations and organizational solutions. The sustainable development of urban food systems is heavily dependent on being profitable. But addressing the issue of food waste in cities is not just a matter of investment, organization and technological innovation. It is mainly a multidimensional issue that requires specific solutions to respond to specific problems and contexts, notably to urban morphologies and sociologies. Efforts to reduce food waste at the source on the one hand, or recycling on the other, must be considered in conjunction with the diversification of food systems, the development of the circular economy and the growth of participatory economies based on informal systems. Multi-stakeholder platforms are needed to identify the appropriate collective choices to be made in each context. Recycling urban food waste remains a major challenge for

the common future of cities and agriculture. Due to the world's rapid urban growth, this challenge will become increasingly important in the coming years.

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