Municipal solid waste composition and food loss reduction in Kyoto City

Tetsuji Yamada¹ · Misuzu Asari² · Takahiro Miura¹ · Tomoyuki Nijima¹ · Junya Yano³ · Shin-ichi Sakai³

Received: 28 January 2017 / Accepted: 13 June 2017 / Published online: 28 June 2017
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Abstract For 35 years, Kyoto City has conducted detailed household waste composition surveys under the guidance of Kyoto University by dividing household waste into approximately 400 categories. In addition, the city has conducted detailed composition surveys of commercial waste generated by businesses. These surveys show that food loss accounts for approximately 40% of total waste, of which leftovers and untouched food account for about 40% in both households and business facilities. Consequently, the annual generation of household and commercial food loss is estimated at about 30,000 tons. Various efforts have been made to reduce waste, including food loss, but further reduction in environmental burden is needed. Thus, Kyoto City revised the ordinance for waste reduction, and in March 2015, formulated a new municipal waste management plan. The plan not only includes the 2Rs (reduce, reuse), but also, for the first time in Japan, sets quantitative targets for reducing food loss. Kyoto City must ensure that the necessary waste reduction measures are clearly explained to the residents and business operators. To ensure that this plan is successful, it is important to clarify concrete actions that residents and business operators should implement, along with their effects.

Keywords Food loss · Waste composition survey · 2Rs (reduce and reuse) · Separation/recycling

Introduction

Reduction of food loss is more relevant now than it has ever been before. The Food and Agriculture Organization (FAO) of the United Nations reported that 1.3 billion tons of food, representing one-third of global food production for human consumption, is discarded annually [1]. Ideally, developed countries should increase efforts to reduce food waste, since they usually generate more food waste at the consumption stage than the developing countries. Food waste is categorized according to whether it is inedible (e.g., cooking waste) or edible (e.g., leftovers). The latter can be salvaged and is commonly termed as food loss [1, 2].

When planning measures to reduce food loss, waste composition surveys are useful for ascertaining the actual conditions of waste disposal. The Waste and Resources Action Programme (WRAP) has conducted household food waste composition surveys in the United Kingdom, one of the most detailed surveys conducted in the EU [2]. Several studies have investigated the actual conditions of waste disposal, through composition or record surveys of municipal solid waste and food waste generated from households and business facilities [1–10].

In Japan, the Ministry of Agriculture, Forestry, and Fisheries (MAFF) initiated statistical research on food loss from households and business facilities in 2003. Kyoto City has conducted detailed household waste composition surveys since 1980. Based on the results of these surveys, Kyoto City formulated its “New Plan for Halving the Waste Generated by Kyoto City”, with the aim of reducing food loss by half compared to the peak level in 2000.

This study aims to determine the actual conditions of food waste and food loss in Kyoto City and considering the policies of local governments. Waste composition surveys

✉ Misuzu Asari
misuzuasari@eprc.kyoto-u.ac.jp

¹ Environment Policy Bureau, Kyoto, Japan

² Kyoto University Graduate School of Global Environmental Studies, Yoshida Honmachi, Sakyo-ku, Kyoto 606-8501, Japan

³ Kyoto University Environment Preservation Research Center, Kyoto, Japan

of household and commercial wastes were conducted. Measures to reduce food loss in Kyoto City are also discussed.

Policy trend on reducing food loss

International trend

The FAO established the Special Action Programme for the Prevention of Food Losses in 1976, aiming to halve post-harvest food loss. In 2015, as part of the 2030 Sustainable Development Goals, the UN adopted the target of halving per capita global food waste at the retail and consumer levels, and reducing food losses along production and supply chains, including post-harvest losses [11]. The European Union Directive on waste, revised in 2008 [12], required EU Member States to formulate plans for reducing food waste by December 2013. The European Environment Agency (EEA) reports annually on progress achieved toward preventing waste generation in each EU Member State as part of its formulated plans [13, 14]. According to these reports, 20 nations and regions of 31 countries in the EU had already formulated plans by the end of 2013, with seven more nations and regions joining by the end of 2014. Of these plans, 26 refer to food waste. Furthermore, six nations/regions (Brussels, England, Malta, the Netherlands, Poland, Sweden, and Scotland) have adopted quantitative targets. In December 2015, the European Commission (EC) adopted the Circular Economy Package [15], which commits the EU and its Member States to meeting the UN's above-mentioned target. The Package sets out the following timeline:

By 2016:

- to standardize food waste measurements in the EU,
- to define relevant indicators, and
- to take measures to clarify EU legislation relating to food waste.

By 2017:

- to examine ways to improve the use of the “best before” date and its understanding by consumers.

The EC has also proposed the following amendments to the Waste Directive:

- the EC establishes methodologies to measure food waste,
- by measuring food waste on the basis of the methodologies, Member States should monitor and assess progress on implementing measures to prevent waste generation, and
- the EC establishes common indicators in order to ensure uniform measurement of the overall progress in implementing waste prevention measures [16].

Furthermore, as part of the joint statement, the G7 reconfirmed the need to further advance its initiatives for resource efficiency and the 3Rs (reduce, reuse, and recycle) at the G7 Toyama Environment Minister's Meeting (held in May 2016). In addition, the Toyama Framework on Material Cycles was adopted in the annex. This ambitious framework commits G7 members to state-of-the-art domestic policies for resource efficiency and the 3Rs. These policy initiatives demonstrate a tangible commitment to share each country's knowledge on reducing food waste and to collaborate in the development of comparable methodologies for measuring the environmental benefits of food waste reduction. In doing so, they emphasize the importance of promoting reduction, particularly of food loss and food waste [17].

Trend in Japan

In Japan, the Fundamental Plan for Establishing a Sound Material-Cycle Society (based on the Fundamental Law for Establishing a Sound Material-Cycle Society) [18] aims at establishing social and economic systems in which reduction and reuse activities (the 2Rs) such as reducing food waste, containers, and packaging are practiced prior to recycling activities [19]. The ministerial ordinance of April 2012, concerning the Law for Promotion of Utilization of Recyclable Food Resources [20], was revised to focus specifically on food waste. The ordinance defines criteria such as a basic unit of food waste generation, classified by type of food industry. By August 2015, standard values had been established for 31 types of food industries, with plans to establish standard values for another 20 types [21, 22]. In July 2015, the Basic Policy for Promotion of Utilization of Recyclable Food Resources was revised. It required actors throughout the entire food chain (including national and local government, food business operators, and consumers) to promote food loss reduction. Furthermore, it stipulates that these efforts be implemented by every main constituent. It requires the Japanese Government to evaluate the scale and implications of food losses and encourage nationwide responses. It also requires local governments to adopt appropriate measures within their waste management programs, such as utilizing recyclable food resources [23].

A questionnaire survey of food businesses and local governments estimated food losses as 6.43 million tons in 2012 (3.31 million tons from households and 3.12 million tons from business facilities). Approximately 17 million tons total food waste was generated then [24–26]. In addition, the basic policy, which is based on the Waste Disposal Law (revised in January 2016), sets more stringent numerical targets for local governments with regard to investigating the proportion of food loss among food waste: the target was revised from 43 local governments in FY

2013 to 200 by FY 2018 [27]. It is hoped that this investigation and quantification of food losses by local governments will improve the estimates of food loss from households and promote efforts to reduce food loss.

Materials and methods

Since 1980, Kyoto City has conducted detailed household waste composition surveys. Thus, these surveys have been ongoing for 35 years, under the guidance of Kyoto University. The surveys were aimed at assessing waste composition, including the amounts of food waste generated [28, 29]. Food waste thus received particular attention and a more detailed survey is conducted every 5 years. Furthermore, the method for surveying household waste was applied to the detailed composition of commercial waste in FY 2007 and FY 2011. This study reports on the detailed composition of household waste (October 17 to November 7, 2012) and commercial waste (October 22 to November 18, 2011) [30, 31].

Figure 1 shows the detailed survey procedures adopted for assessing household waste composition. Kyoto City collects

combustible garbage for incineration (twice weekly); plastic containers and packages (once weekly); cans, glass bottles, and PET bottles (once weekly); and small metal objects and spray cans (once monthly); all of these are sorted at the household level. This study focuses on combustible garbage. The study sample comprised 268 waste bags collected from 216 households in three districts of Kyoto City (total weight, 888 kg; total volume, 3841 L). The three targeted districts were populated by traditional townhouses, stand-alone houses, and mid-to-high-rise residential buildings for over 35 years. They represented the typical socio-economic characteristics of areas in Kyoto. Waste was first roughly classified into 12 categories (e.g., food or paper waste), and then by materials and purposes of use. It was then further classified into 408 categories (food waste, 2; paper, 94; plastic, 109; fiber, 13; waste rubber, 4; leather, 4; glass, 74; metal, 86; vegetation, 2; wood, 8; ceramic, 5; and other classifications; 7). Untouched food was defined as discarded edible food that retains more than 50% of its original shape, whereas leftovers were defined as discarded edible food that retains less than 50% of its original shape. Cooking waste was classified as

Fig. 1 Outline of the methods used for the “detailed composition surveys of household waste (FY2012)”

Fig. 2 Outline of the methods used for the “detailed composition surveys of commercial waste collected by contractors (FY2011)”

Fig. 3 Detailed composition of **a** household waste and **b** commercial waste in Kyoto City

inedible food. Kyoto City identifies untouched food and leftovers as sources of food loss that could be reduced. We further classified food waste into 64 categories based on detailed surveys of food waste conducted for the first time in 5 years. We also examined possible relationships between “disposal date” and “best before date or use by date” for untouched food.

Figure 2 shows the procedure for conducting commercial waste surveys. The composition ratio was based on contact quantity according to the type of business, and this ratio was calculated for 137 cases. The sampled material had a total weight of 3907 kg and a volume of 30,231 L. Waste was first roughly classified into 12 categories, and then by material and purpose into 161 categories (food waste, 3; paper waste, 55; plastic, 34; fiber, 3; rubber, 2; leather, 2; glass, 18; metal, 30; vegetation, 2; wood, 4; ceramics, 3; and others, 5). Food waste in commercial waste requires more in-depth analysis as it is not classified with the same level of detail as household waste.

Results and discussions

Food waste as part of household waste

The survey of combustible household waste (see Fig. 3a) shows that 39.8% (437 g/per capita/per day) was food

waste, of which 39.4% was “Food Loss” (untouched food, 17.1%; leftovers, 22.3%). According to the area, the amount of generated waste and food waste were lowest in residential area (figures are not shown). A study in Sweden by Schott et al. reported that 35% of food waste was avoidable [8]. In addition, a study by Hansen et al. showed that edible food waste accounted for 57.7% of total food waste in Norway [4]. The waste composition in the present survey is obtained from detailed composition surveys of household waste, and hence exhibits the same ratio as that in Schott et al., but smaller than that in Hansen et al. These disparities are influenced by region and by differing definitions of avoidable food waste and edible food waste.

In summary, the estimated food loss from households in Kyoto City is approximately 30,000 tons annually. Food loss is avoidable and urgently needs to be addressed in order to reduce the amount of waste generated.

Vegetables account for the highest proportion of food loss, and included in untouched food and leftovers (Fig. 4). In questionnaire surveys regarding the potential causes of food loss arising at the time of food purchase, the majority of respondents have indicated that foodstuffs are sold in excessively large units [32]. Hence, the retail sales system is considered one of the causes for households discarding vegetables untouched.

Figure 5 shows the relationship between best before date and date of disposal (for untouched food that included

The sunburst chart displays the distribution of time intervals for two main categories: 'Before Best before date' and 'After best before date'.

Category	Sub-category	Percentage
Before Best before date (31.9%)	Over 6 months	8.7%
	Within 6 months	17.5%
After best before date (68.1%)	Within 2 weeks	20.3%
	Within a month	1.4%
	Within a week	1.4%
	Within a week after the date	8.7%
	Within a month	4.3%

Fig. 6 Food loss classified by type of business (composition of food loss in business facilities) (Source Survey of Kyoto City (FY 2011))

1) Retail

2) Restaurants

3) Service businesses

Fig. 7 Food loss by business category in industries with a high percentage of food loss (Source Survey of Kyoto City (FY 2011))

Table 1 Amount of food loss from supermarkets and restaurants

	Ratio (%)	Amount (t/year)	Number of offices	Basic unit (kg/office/day)
Supermarkets	13.7	4700	338	38.1
Restaurants	33.2	11,500	5272	6.0

the best before date on its container or packaging). On number basis, 31.9% of untouched food was discarded before the best before date, and an additional 29.0% was discarded within 1 or 2 weeks after the best before date, and these items could hence still be regarded as edible food. It is therefore necessary to focus on consumers' attitudes toward the importance of consuming food as intended (i.e., not wasting food) and to promote a better understanding of best before dates.

Food waste as part of commercial waste

The detailed composition of commercial waste is shown in Fig. 3b. Of the 32 kg of combustible commercial waste/office/day that is collected and transported by municipal solid waste contractors, 43.6% is food waste and of 19.1% constitutes food loss. Commercial food loss in Kyoto City

is therefore estimated to be approximately 34,000 tons per year.

As shown in Fig. 6, the majority of food loss occurs in the retail and restaurant businesses, followed by the service sector. Untouched food and the disposal of leftovers account for the largest fraction of food loss in the retail sector and the restaurant industry, respectively. Particular attention should therefore be given to reducing food losses in these two sectors.

Figure 7 provides further analysis of these three sectors that generate substantial food losses. A comparison of the distribution of food loss by type of business shows that supermarkets and retail food stores account for the largest proportion of food loss, followed by convenience stores and commercial buildings in the retail business sector (Fig. 7-1). In the restaurant sector, most food loss is generated restaurants, including taverns or Japanese pubs

Fig. 8 Changes in the amount of waste, number of incinerator plants, and waste targets for Kyoto City

(Fig. 7-2). In the service sector, nursing homes are responsible for the highest fraction of leftovers. Hotels and other organizations (e.g., event sites and amusement facilities) show roughly the same amount of food loss (Fig. 7-3).

Reviewing the list of contractors and comparing basic units of food loss (Table 1) shows a large gap between supermarkets, which account for the largest fraction in the retail business sector (38 kg/office/day), and restaurants, which account for the largest fraction in the restaurant sector (6 kg/office/day).

Kyoto City's measures to reduce food loss

Kyoto City is an ordinance-designated city that covers an area of 827.9 km² and has a population of approximately 1.47 million. The city is renowned as a tourist center for the 50 million tourists it receives annually (2014). As shown in Fig. 8, Kyoto City has also been engaged in various efforts to reduce waste with the cooperation and efforts of residents and business operators. Consequently, the amount of waste has been reduced by 46% (440,000 tons in FY 2015) from its peak level (820,000 tons in FY 2000). The amount of waste generated continues to decline, thereby reducing the burden on the environment and accounting for savings of 10.6 billion JPY.

Despite this progress, waste disposal still imposes a huge financial expense, which reached 26.1 billion JPY in FY 2014. Although the amount of waste generated

continues to decrease, the scale of reductions has remained low for the past few years. The city therefore needs to accelerate waste reduction efforts in order to promote effective use of resources and energy, and to lessen the burden on the environment.

The following initiatives constitute examples of Kyoto City's efforts to reduce food loss. Since FY 2012, the city has implemented the "3-KIRI Movement" for reducing food waste, including food loss. The movement refers to "Tsukai-KIRI" (using up), "Tabe-KIRI" (eating up), and "Mizu-KIRI" (draining), and is intended to raise public awareness about this issue and to encourage residents to take up the initiative. In FY 2014, the city introduced "Non-leftovers Promotion Premises" as a new system for reducing leftovers from restaurants. Restaurants and accommodations that practice food waste reduction methods, such as using up foodstuff and permitting customers to take their leftovers home, are recognized as "Non-leftover Promotion Premises" (152 premises were recognized by the end of November 2015).

In addition, the "Kyoto City Ordinance for Waste Reduction and Proper Disposal, etc." was drastically revised in March 2015 (effective October 1, 2015) to focus more strongly on promoting the twin pillars of the "2Rs", namely separation and recycling of waste. The ordinance has been termed the "Shimatsu no Kokoro Ordinance", and it aims at halving the amount of waste generated [33]. It was so named in the hope that residents would become motivated to treat their belongings carefully at the outset so

Table 2 (a) Duties related to reducing food loss and (b) examples of efforts toward food loss reduction

(a) Duties related to reducing food loss

	Duty to be implemented	Duty to make efforts
Restaurant	Conduct PR activities to eliminate food leftovers (introduction of small-sized dishes; displays and PR materials prepared by the city, etc.)	Respond to customers who wish to take their leftovers home (provision of containers (doggie bags), etc.) (Efforts of residents) Try to leave no leftovers when eating
Retail	Conduct PR activities to encourage consumers to buy products with less packaging or cooperate in collecting recyclable resources	Promote sales by measurement/weight, simplified packaging, and sales with less packaging Discount foodstuffs that are close to their best before date Inform consumers of sales policies for reducing food losses, including displaying the reasons why some foodstuffs are out of stock

(b) Examples of efforts toward food loss reduction

Type of business	Outline of efforts	
	Business operator (provider)	Citizen (guest)
Restaurant	Inform customers of activities to reduce the amount of garbage through internet reservation services, e-mail, or mail (ask customers for cooperation)	Reduce dishes, considering the volume and flavor, that the guest can complete to eliminate leftovers
	Provide a small or half-sized menu	Order dish after checking the amount of food to eliminate leftovers
	Inform customers of the volume of the dish by printing photographs on the menu and include information on the dish such as ingredients, allergens, or calories	Order the dish after checking the amount of food etc., to eliminate leftovers
	Frame rules carefully to eliminate food leftovers (e.g., “feel free to refill, but try to leave no leftovers when eating”)	Order precisely considering the amount and flavor to eliminate leftovers
	Manage raw materials minutely and ensure full cooperation of all employees (e.g., among stores and divisions, sharing food and stock information, reducing amount of food preparation to prevent overproduction)	Confirm with the shop assistant if the volume and size of dish is adjustable
	Advertise information on food for take-out, such as dried food that does not readily perish	Take leftovers home after confirming the shop assistant if the food is available for take-out
	Provide service and information for promoting use of personal bottles at cafes and convenience stores	Bring and use my bottle
Retail	Manage raw materials minutely and ensure full cooperation of all employees (e.g., among stores and divisions, handling of food-stuff, sharing stock information, reducing the amount of food preparation to prevent overproduction)	Shop systematically, including practices such as checking the stock at home before going shopping
	Sell food in reduced packaging and offer small portions or servings	Purchase only the food that you can consume

Waste reduction initiatives to be implemented by business operators are coupled with those aimed at residents

that they may last longer (e.g., enabling longer use by repairing), enrich their quality of life, and firmly embed the eco-friendly way of living in their personal and professional lives.

The ordinance refers to “Duty to implement/Duty to make efforts” and “Duty to Report”, as well as the “Civic monitoring system” in six key areas: Manufacturing, Food, Sales and Purchase, Events, Tourism, and Universities/Residential Complexes. These efforts consist of 29 important actions directed in particular at waste reduction. Toward food loss reduction, “Duty to implement” and

“Duty to make efforts” are shown in Table 2a. In addition, concrete examples for business operators and residents are shown in Table 2b. Neither of them can be executed without the cooperation of business operators and residents.

In March 2015, Kyoto City formulated its “New Plan for Halving the Amount of Kyoto City Waste”. This is a new municipal waste management plan based on the “Waste Management and Public Cleansing Law”. This plan not only imbibes the contents of the “Shimatsu no Kokoro Ordinance” as well as actions to be taken to

implement the 2Rs (e.g., food loss reduction), but also sets numerical targets. In addition to being the only city in Japan to have continually assessed the scale and characteristics of food loss and food waste, Kyoto is the first to set numerical targets for reducing food losses [34]. By FY 2020, the plan aims to reduce the amount of waste to 0.39 million tons (730 g/capita/day), and set fixed numerical targets to reduce food losses to 50,000 tons (94 g/capita/day), which is approximately half of the peak level of 96,000 tons in FY 2000.

Kyoto City has thus constructed a robust framework to monitor and assess progress toward reducing food losses, by setting numerical targets and conducting detailed surveys of waste composition. Regulations and campaigns based on the revised ordinance promote activities to reduce food losses. Nevertheless, in order to achieve the targets for reducing food losses, it is necessary to clarify tangible measures that will have maximum effect. Therefore, Kyoto City should focus on defining indicators, and on monitoring and assessment.

Conclusion

We report on surveys of household and commercial food waste in Kyoto City, as a means to evaluate the scale and composition of food waste, including food loss. Food losses from households and business facilities are estimated to be 30,000 tons/year and 34,000 tons/year, respectively, with overall food waste generation being 164,000 tons/year. In addition, 31.9% (number basis) of untouched food generated from households is discarded before its best before date. Thus, actions to target food loss reduction assume importance with regard to achieving the aim of halving the amount of food waste by FY 2020 from the peak level in FY 2000. Furthermore, detailed information is required to further categorize types of commercial food waste with the same level of detail as household food waste. We have already conducted detailed composition surveys of commercial combustible waste from January to February 2016. Similar to past reviews, the findings indicate that it is important to analyze the composition of commercial waste by the generation sources in offices, as well as by types of foodstuff.

Kyoto City has constructed a framework to monitor and assess progress on measures to reduce food loss by conducting detailed composition surveys of waste, in combination with setting numerical targets for reducing food loss. Similar to European policies, the City has devised the ordinance to promote measures to reduce food losses, such as introducing regulations and initiating campaigns. Nevertheless, future efforts to promote food losses should be

based on specific and tangible measures that are best suited to achieving the prescribed targets.

Acknowledgements This research was supported by the Environment Research and Technology Development Fund, Grant Number 3K153001, from the Ministry of the Environment, Japan.

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